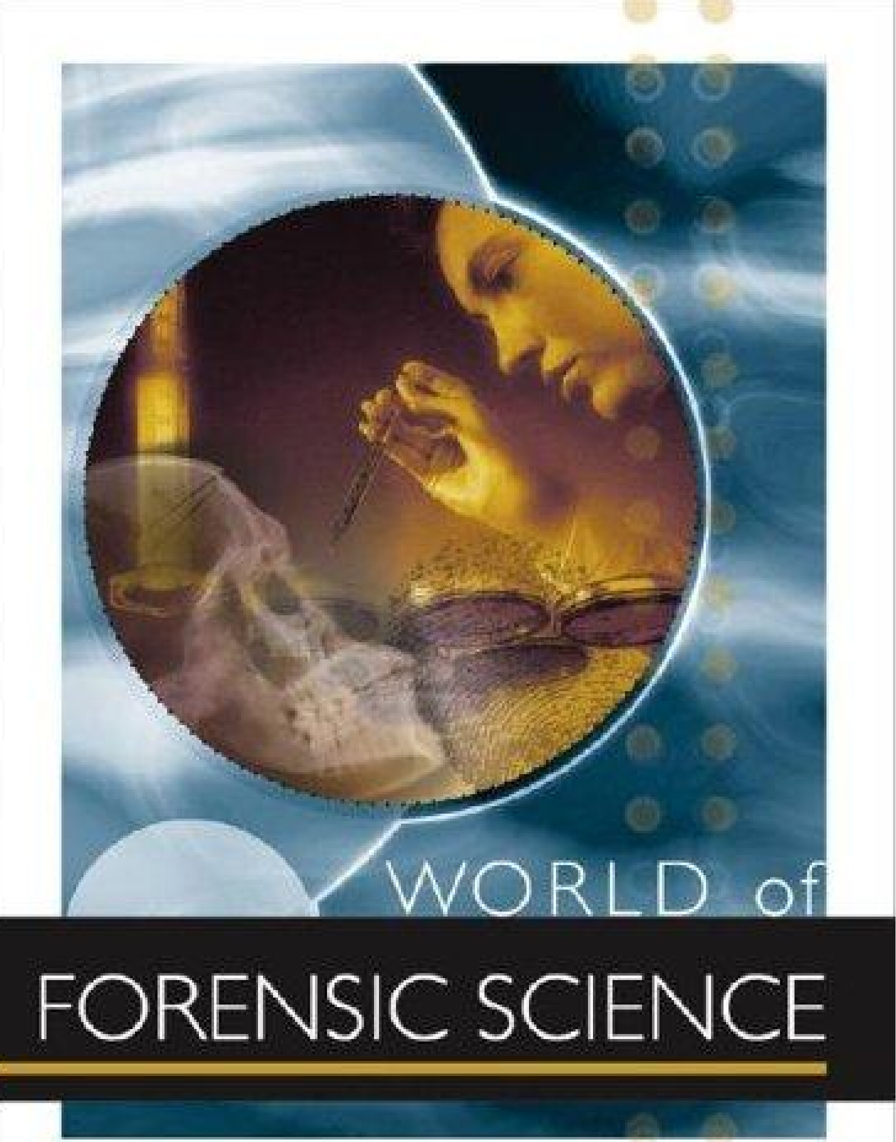

Volumes 1 & 2

WORLD of FORENSIC SCIENCE

WORLD of FORENSIC SCIENCE

VOLUME 1

A-L

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INTRODUCTION

World of Forensic Science portrays the vast scope and influence of modern forensic science. From its origins in pre-scientific human fascination with the causes, manner, and circumstances of death, to the increasingly vital role of forensic science in law, security, and global economic and health issues, *World of Forensic Science* contains articles dedicated to providing insight into the science, applications, and importance of forensics.

To cover a topic of such scope and impact as forensic science is a daunting task. Interest in forensics spans human history, impacts philosophical and religious thoughts about death, and now, fueled by television and movies, is reflected in popular culture. Human interest in forensics dates to our earliest recorded histories. Egyptian Pharaohs first appointed officials to make inquiries into questionable deaths as early as ca. 3000 B.C., and accounts of ancient Roman law include references to the use of forensic experts in legal proceedings. Medieval English Common law, upon which portions of modern United States law is based, called for forensic determinations in the handling of estates.

Forensic science also has played—and in some cases continues to play—an important part in philosophical and religious thoughts about death. In some religions, for example, the determination of the manner of death may impact whether a body is fit for burial in certain grounds. Religious beliefs can also impact forensics, as there are still areas of the world and groups that consider autopsies as desecration.

As a formal science, forensics grew lockstep with advances in many branches of science during the nineteenth and twentieth centuries. The interval from scientific invention to forensic application narrowed as forensic scientists borrowed from the latest innovations of virtually every field of science to solve mysteries. However, just as advances in microscopes and atomic science allowed forensic applications to aid in the investigation of crimes at the most minute molecular and cellular level, the breadth of applications of forensic science underwent exponential expansion. In modern times, in addition to solving local crime, the next global pandemic or bioterrorist attack might well be first detected by a forensic scientist initially investigating a mysterious death.

World of Forensic Science is a collection of nearly 600 entries that evidence the wide diversity of forensic science. Articles on topics such as art forgery and wine authenticity indicate the far-reaching economic impact of forensic science. Heart-wrenching applications of forensic science, from uncovering the mindsets, methods, and motives of modern terrorists to discovering the far-reaching extent of natural disasters, are discussed in articles ranging from the "Identification of Beslan victims in Russia" to "Identification of tsunami victims"

Articles on a number of topics related to genetics, DNA fingerprinting, and microbiology show how recent advances in research quickly find their way into forensic application. A range of articles related to basic science reflects the fact that modern forensic investigators must be able to understand and properly apply tools from virtually every scientific discipline.

Nature is often innately tricky enough to confound scientists seeking to uncover its mysteries, but forensic scientists must also pit their skills against those deliberately trying to conceal or mislead. The importance of skill and experience to the forensic investigator is evidenced in the authoritative writing of many articles, including Ed Friedlander's article on autopsy procedures and Nancy Master's article on latent fingerprint analysis. (Friedlander serves as chairman, Dept. of Pathology, Kansas City University of Medicine and Biosciences, is board-certified in anatomic and clinical pathology, and has conducted an estimated 700 autopsies. Masters is the 2004 Dondero Award winner for identification in forensics.)

While selected topics acknowledge the relationship of forensic science to history and culture, and others describe the brutal realities of sensational crimes involving serial murders, ritual killers, or bombers, it was our intent to keep *World of Forensic Science* focused on science. The editors hope that *World of Forensic Science* serves to inspire a new generation of forensic scientists and investigators. It is also our modest wish that this book provide valuable information to students and readers regarding topics often in the news or the subject of civic debate.

K. Lee Lerner & Brenda Wilmoth Lerner
Editors
Santa Rosa Island, Pensacola, FL, and London, U.K.
April 2005

How to Use This Book

The articles in the book are meant to be understandable by anyone with a curiosity about topics in forensic science. Cross-references to related articles, definitions, and biographies in this collection are indicated by **bold-faced type**, and these cross-references will help explain and expand the individual entries. *World of Forensic Science* carries specifically selected fundamental topics in genetics, anatomy, physiology, microbiology, and immunology that provide a basis for understanding forensic science applications.

This first edition of *World of Forensic Science* has been designed with ready reference in mind:

- **Entries are arranged alphabetically**, rather than by chronology or scientific field.
- **Bold-faced terms** direct the reader to related entries.
- **"See also" references** at the end of entries alert the reader to related entries not specifically mentioned in the body of the text.
- A **sources consulted** section lists the most worthwhile print material and web sites we encountered in the compilation of this volume. It is there for the inspired reader who wants more information on the people and discoveries covered in this volume.
- The **historical chronology** includes many of the significant events in the advancement of forensic science.
- A **comprehensive general index** guides the reader to topics and persons mentioned in the book. Bolded page references refer the reader to the term's full entry.

Although there is an important and fundamental link between the composition and shape of biological molecules and their detection by forensic testing, a detailed understanding of chemistry is neither assumed or required for *World of Forensic Science*. Accordingly, students and other readers should not be intimidated or deterred by the complex names of chemical molecules. Where necessary, sufficient information regarding chemical structure is provided. If desired, more information can easily be obtained from any basic chemistry or biochemistry reference.

A

Accelerant

An accelerant is a substance that is used to cause the rapid spread of a fire. An example of a commonly used accelerant is petroleum distillate, the liquid that is collected from the vaporization of petroleum-containing liquids. This fire-starting fluid is sold in hardware stores and is utilized to rapidly ignite coals in a barbeque.

The accelerant used in a barbeque is deliberately applied. So it is with the accelerants that are of forensic concern. A fire in a building, vehicle, or other location can be deliberately set. This is known as **arson**. In an investigation of a fire whose origin is suspicious, a forensic investigator will be interested to find out how the fire started. As part of this investigation, the investigator will look for **evidence** of the presence or use of an accelerant.

During a fire, the fuel available for burning combines with the oxygen in the air in a reaction that is called combustion. Often, a fire will start in one location and subsequently spread. However, if an accelerant has been spread in an area, the pattern of the fire's origin can be different. The origin can be spread out more than is the case naturally. As well, the fire may start more explosively than would occur naturally. These differences can yield patterns that are distinctive to the trained eyes of the forensic investigator.

Once the origin of a fire has been determined, the area can be probed for the presence of residual amounts of the accelerant. This can be done using specially trained dogs that literally sniff out the chemical. In addition, samples of the scene can be collected and taken to a laboratory for analysis with specialized instruments.

For liquid samples, an instrument called a gas chromatograph is typically used. The liquid is heated to convert it to a mixture of gases. The identity of each of the gas components can be determined and this pattern will tell the investigators whether or not the liquid was an accelerant.

Similar analyses can be done on articles of clothing and even the skin of a suspect. Detection of traces of the accelerant on a person or their clothing can be powerful evidence linking them to the arson site.

SEE ALSO Accident reconstruction; Arson; Canine substance detection; Childers hostel blaze; Fire investigation.

Accident investigations at sea

Accidents can occur anywhere that there are people operating machinery. The world's oceans are no exception. Sea-going accidents have been a consequence of maritime tradition ever since boats put out to sea thousands of years ago.

Even in the early days of seafaring, there was interest in determining how an accident occurred and in seeking ways of preventing similar occurrences. These investigations eventually became official duties of the government, for example, in Britain formal marine accident inquiries were established approximately 150 years ago. Today, the investigations of sea accidents can reply on the skills of forensic scientists and the various technologies they can bring to bear.

When a seagoing accident involves an injury or fatality, an investigation can be very similar to that conducted on land. The object is to determine the cause of injury or death. Photographs of all the areas of the ship that are relevant in the investigation will be taken. The accident scene will be carefully scrutinized to recover any **evidence** and witnesses will be interviewed. All these steps help to piece together what occurred.

But an accident investigation conducted at sea presents some unique challenges. If the ship is still at sea, then the rapid transport of the samples to a laboratory for analysis may not be possible. In that case, the samples need to be stored so as to prevent tampering and deterioration. In the case of biological samples like tissues and **blood**, storage on ice at refrigerator or freezer temperatures can be options.

Other facets of an accident investigation are not concerned with injuries, but with the damage caused to the vessel. By analyzing the pattern of a fractured hull, for example, inspectors can gain an understanding of the cause of the damage. A gashed hull caused by a collision with an iceberg will be different than the damage caused by an impact with another vessel. A skilled forensic naval architect is able to examine a damaged vessel (a bent propeller shaft, for example) and determine the cause of the damage.

An accident investigation can involve the recovery of materials that have been dislodged from the vessel into the surrounding water, or of an entire sunken vessel. Some material may be floating on the surface. Then, recovery of the flotsam involves a surface search, usually by means of a search boat. Divers or submersible craft may also be used to locate debris that has sunk to the bottom of the ocean. In deep water, this process can be a very complex and dangerous activity.

In the investigation of an accident or crime on land, the investigative team often consists of more than one person. But, in the depth of the sea, only a single diver may be present. The diver must handle an object to identify it and determine its position on the sea floor. Once back at the surface, the diver must report on what was seen. The smallest detail can be important in guiding further recovery efforts and in piecing together the course of events. So, an investigative diver must be meticulous and attentive to detail.

Subsequent efforts can utilize sonar. This underwater version of radar sends out pulses of energy and displays the pattern of returning echoes to obtain images of underwater objects.

A critical facet of a marine accident investigation is collecting information on the weather patterns around the time of the accident. The value of this approach is exemplified by the investigation of the November 10, 1975, sinking of the freighter SS *Edmund Fitzgerald* in Lake Superior. The tragedy, which killed 29 mariners, formed the basis of a song by the Canadian singer/songwriter Gordon Lightfoot. By analyzing the ship's course and wind patterns, investigators determined that a shift of wind during a fierce mid-winter storm took the ship away from the protection of nearby land and put the vessel directly in the path of huge waves.

That investigation also exemplified the value of collecting and analyzing all communications that occur between the affected vessel and other vessels, aircraft, and the shore. In the case of the *Edmund Fitzgerald*, it was established that the captain was not aware of the severity of the threat until the ship became swamped with water and sank.

Simulations of the accident can be a useful way to reveal potential causes of an incident. Computer programs can be used to carry out simulations. As well, models of the affected vessel can be constructed and positioned in a specially constructed pool that can generate waves. The National Centre for Inland Waterways, located in Burlington, Ontario, Canada, has a pool where such testing can be carried out.

Another technology that has been advocated and is becoming more popular is the voyage data recorder. Akin to the flight recorders that are a standard on aircraft, a voyage data recorder provides information on various aspects of the ship during the voyage. A meeting of the International Marine Organization held in December 2004 was expected to pass amendments to the 1974 International Convention for the Safety of Life at Sea (SOLAS) requiring the presence of voyage data recorders on cargo ships.

SEE ALSO Accident reconstruction; Chemical and biological detection technologies; Drowning (signs of).

Accident reconstruction

Deaths from vehicle accidents declined in the years of the late twentieth century, thanks to the widespread use of seat belts and a decrease in persons driving while intoxicated. Cars are now manufactured to higher safety standards, with design features such as airbags and crumple zones to help reduce the impact of a collision. Airplanes and trains are equipped with numerous safety features and have established emergency procedures that protect passengers in case of a mishap. When an accident does occur, it is important to investigate it thoroughly, especially if someone has been injured or killed or if a crime has been committed. Reconstructing an accident is a key element of such investigations.

The police clear vehicular accidents away as soon as possible to stop blocking the highway. Investigators, therefore, may not have the chance to visit the accident site. Instead, they use **evidence** to create a reconstruction of the accident from which they can try to work out the cause. Investigators require access to: photographs of the accident site; the police accident report, including eyewitness reports; and the wreckage of the vehicles. These sources provide information on velocities and positions of the vehicles; skid marks; impact damage to the vehicles; condition of the vehicle, especially the tires; the weather conditions; and the condition of the drivers.

The investigators first put together a general reconstruction scenario and then fill in the details from the facts available. Because the final positions of the vehicles are usually well established, they might work backwards from this point. If there is also hard information on the initial velocities and conditions, perhaps from a speed camera or a reliable eyewitness, a beginning and end point of the collision might be established. Then the task is to work out what happened between these two points.

The majority of vehicle accidents involve collisions—with another vehicle, a stationary object like a wall or tree, or a pedestrian. Therefore, the focus of the investigation is usually to analyze the collision itself from the reconstruction so the cause of the accident can be determined. There are two physical laws that guide this analysis, the law of conservation of energy and the law of conservation of momentum. Used together, these can often provide a detailed analysis of a collision.

The law of conservation of energy states that energy can neither be created nor destroyed, but it can be converted into different forms. A moving object, such as a vehicle, has kinetic energy. When it comes to a stop, it has zero kinetic energy. Under normal conditions, this energy is converted into heat through the friction between the brakes and the road. In a collision, the kinetic energy is dissipated in two main ways, via a skid, and in deforming the vehicles and their occupants on impact. A skid is an out-of-control type of braking and the analysis of any skid marks is a very important part of the accident reconstruction. Deformation of a metal object like a car involves work, the energy for which is the kinetic energy of the moving vehicle. Injuries to individuals are also brought about by transfer of kinetic energy.

Momentum is the product of the vehicle's mass and its velocity. A car traveling at 30 miles an hour has less momentum than one going at 40 miles an hour, and a truck generally has higher momentum than a car at the same velocity. When a collision occurs, the total momentum of the vehicles remains the same, but their individual momenta will change. If a car hits a stationary vehicle in a traffic queue (line), it will lose momentum, but the other vehicle will gain it. Overall, there is no alteration in momentum. The investigator can use the conservation of energy and momentum equations to try to establish facts such as initial velocity of the vehicles and so build a detailed picture of the collision.

The point of impact of the collision is an important factor and one that may be difficult to determine exactly. Tire marks, such as skids that suddenly change direction, however, can act as important clues. A head on collision might flatten the front tires, giving rise to a skid mark that suddenly terminates.

Examination of the vehicle wreckage, generally done off road, can also provide valuable information. For instance, under-inflated tires blowing out are an important cause of accidents. The blow point is often marked by a characteristic discoloration in the surrounding area. The hardness of the tire can also be measured using an instrument called a durometer. Its hardness profile shows if the tire has been run under-inflated. Metallurgic analysis of any fractures or dents in the car wreckage can give information on issues such as faulty welding or inferior repair work.

Accident reconstruction is particularly important in the case of large-scale accidents that involve many people, such as plane crashes, train wrecks, and even space shuttle disasters. The National Transportation Safety Board takes the lead in plane crashes and train collisions or derailings. Recovery of an airplane's black box, recording crew voices and instrument readings, is an important way to recover pertinent information about a plane crash. Conversations with air traffic controllers may provide information on what was happening on the plane at the time of impact. Witnesses may be asked to verify sounds or smoke coming from an airplane in trouble. These

A view of the floor of the Kennedy Space Center RLV Hangar showing a grid with outline of an orbiter and much of the space shuttle *Columbia* debris collected as of March 11, 2003, by the Columbia Reconstruction Project Team. Reconstruction of the orbiter helped to determine the cause of the *Columbia's* destruction. © NASA/CORBIS

investigations can be quite complex, and can take a year or more to complete, especially in high-profile cases.

The National Aeronautics and Space Administration (NASA), and sometimes an independent review board, investigates space shuttle accidents, such as the explosions of the *Challenger* in 1986 and *Columbia* in 2003. Although space shuttles are not equipped with black boxes, the crew members are in constant communication with NASA crews on the ground, and information from the shuttles' computers is constantly fed to ground control and recorded. This information becomes vital to an accident investigation and reconstruction process, should it become necessary.

Accident reconstruction is a complex matter. Not only does information from many sources have to be integrated, gathering this information is sometimes difficult, even traumatic. And however well the reconstruction has been put together, it is still only a model, and will often be subject to challenge from experts acting for parties to the accident.

SEE ALSO Airbag residues.

Adipocere

Also known as "grave wax," adipocere (from the Latin, *adipo* for fat and *cera* for wax) is a grayish-white postmortem (after death) matter caused by fat **decomposition**, which results from hydrolysis and hydrogenation of the lipids (fatty cells) that compose subcutaneous (under the skin) fat tissues.

Although decomposition of fatty tissues starts almost immediately after death, adipocere formation time may vary from two weeks to one or two months, on average, due to several factors, such as temperature, embalming and burial conditions, and materials surrounding the corpse. For instance, the subcutaneous adipose (fatty) tissue of corpses immersed in cold water or kept in plastic bags may undergo a uniform adipocere formation with the superficial layers of skin slipping off.

Several studies have been conducted in the last ten years to understand and determine the rate of adipocere formation under different conditions. Other studies also investigated the influence of some bacteria and chemicals, present in grave **soils**, in adipocere decomposition. Although this issue remains a challenging one, the purpose of such studies is to establish standard parameters for possible application in forensic analysis, such as the estimation of time elapsed since death when insect activity is not present. In forensics, adipocere is also important because preserved body remains may offer other clues associated either with the circumstances surrounding or the **cause of death**. The ability of adipocere to preserve a body has been well illustrated in exhumed corpses, even after a century.

Adipose cells are rich in glycerol molecules and are formed by triglycerols (or triglycerides). Bacterial activity releases enzymes that break these triglycerides into a mixture of saturated and unsaturated free fatty acids, a process known as hydrolysis. In the presence of enough water and enzymes, triglycerol hydrolysis will proceed until all molecules are reduced to free fatty acids. Unsaturated free fatty acids, such as palmitoleic and linoleic acids, react with hydrogen to form hydroxystearic, hydroxypalmitic acids and other stearic compounds, a process known as saponification, or turning into soap.

This final product of fat decomposition, or adipocere, can be stable for long periods of time due to its considerable resistance to bacterial action. This resistance allows for slower decomposition of those areas of a corpse where adipose tissues are present, such as cheeks, thighs, and buttocks. When a corpse is exposed to insects, however, adipocere probably will not be formed, as body decomposition will be much faster because of the insects' action. Animal scavenging of a dead body will also prevent adipocere formation.

SEE ALSO Decomposition; Entomology; Forensic science.

AFIS SEE Automated Fingerprint Identification System (AFIS)

Aflatoxin

A forensic investigation can often involve determining whether the victim was poisoned. Many different kinds of poisons exist. While some are synthetic, others are manufactured by living organisms. One example of the latter are aflatoxins.

Aflatoxins belong to a group of **toxins** called mycotoxins, which are derived from fungi. In particular, aflatoxins are produced by the soil-born molds *Aspergillus flavus* and *Aspergillus parasiticus* that grow on the seeds and plants. At least 13 aflatoxins have been identified, including B1, B2, G1, G2, M1, and M2. The B aflatoxins fluoresce blue and the G aflatoxins fluoresce green in the presence of ultraviolet light. The M aflatoxins are present in milk products. Aflatoxin B1 is the most ubiquitous, most toxic, and most well studied of the aflatoxins.

Afatoxins are so powerful that access to them is restricted and possession or handling of them by certain individuals constitutes a crime. The USA Patriot Act enacted on October 25, 2001 and signed into law (P.L. 107-56) by President George W. Bush is in effect as of January 2005 and contains a provision prohibiting possession or access to, shipment or receipt of, a "Select Agent" by "Restricted Persons" punishable by fines or imprisonment. Aflatoxins are considered select agents.

A restricted person is defined as someone who: (1) Is under indictment for a crime punishable by imprisonment for a term exceeding 1 year; or (2) Has been convicted in any court of a crime punishable for a term exceeding 1 year; or (3) Is a fugitive from justice; or (4) Is an unlawful user of any controlled substance (as defined in section 102 of the Controlled Substances Act (21 U.S.C. 802); or (5) Is an alien illegally or unlawfully in the United States; or (6) Has been adjudicated as a mental defective or has been committed to any mental institution; or (7) Is an alien (other than an alien lawfully admitted for permanent residence) who is a national of a country as to which the Secretary of State, has made a determination (that remains in effect) that such country has repeatedly provided support for acts of international terrorism (as of January 2005 these countries included Cuba, Iran, Iraq, Libya, North Korea, Sudan, and Syria); or (8) Has been discharged from the Armed Service of the United States under dishonorable conditions.

Aspergillus spp. contamination occurs as a result of environmental stresses on plants such as heat, dryness, humidity, or insect infestation. It can also occur if plants are harvested and stored in hot, humid environments. As a result, people who live in the regions of the world most prone to these conditions, such as sub-Saharan Africa and southeast Asia, are at highest risk for aflatoxin poisoning.

Aflatoxins were first identified in England in 1960 when more than 10,000 turkeys and ducks died within a few months. The disease contracted by these animals was called Turkey X disease and its cause was traced to *Aspergillus flavus* contamination of peanut meal that had originated in Brazil. The toxin was named for the shorthand of its causative agent: *A. fla*.

Aflatoxins are the most toxic naturally occurring carcinogens known. Aflatoxin B1 is an extremely hepatocarcinogenic compound, causing cancer of the liver in humans. Aflatoxin B1 exposure results in both steatosis (an accumulation of fat) and necrosis (cell death) of liver cells. Symptoms of aflatoxicosis are gastrointestinal, including vomiting and abdominal pain. Other symptoms can include convulsions, pulmonary edema, coma, and eventually death. Aflatoxins also pose a threat to developing fetuses and they are transferred from mother to infant in breast milk. Aflatoxins B1, G1, and M1 are carcinogenic in animals.

Poisoning due to aflatoxin occurs from ingestion of crops that have been infested with *Aspergillus* spp. or from eating animal products from animals that have ingested these crops. High concentrations of aflatoxins are most often found in plants with very nutritive seeds such as maize, nuts, and cereal grains in Africa and rice in China and Southeast Asia. In the United States, peanuts are routinely tested for aflatoxin concentrations, and contamination has also occurred in corn, rice, and cereal grains.

Most consider aflatoxins extremely dangerous and suggest that in human food they should have no detectable concentration. The maximum allowable concentration of aflatoxins set by the United States **FDA** is 20 parts per billion (ppb). Foreign markets usually reject grains with concentrations of 4 to 15 ppb. Acceptable levels of aflatoxins for animal consumption are up to 100 ppb. Because of the strict regulations regarding the permissible concentration of aflatoxin, exporting countries often reserve contaminated grains for consumption within their own country. Because *Aspergillus* spp. is usually colorless and does not break down during cooking, it is difficult to know whether or not people are consuming contaminated food.

SEE ALSO Biological weapons, genetic identification; Poison and antidote actions; Toxicology.

African Lemba tribe

The Lemba are a tribe of about 50,000 people living in South Africa and Zimbabwe who practice a religion that is strikingly similar to that of the Jews during Biblical times. Molecular genetics have provided the technology to compare genetic material of the Lemba people with that of modern Jewish people. The results show that the Lemba share several genetic characteristics with Jews including a particular marker on the Y-chromosome called the Cohen Modal Haplotype.

The Hebrew Bible tells the story of Jacob, the grandson of Abraham, who had 12 sons. Each of these sons became the leader of a tribe, collectively known as the twelve tribes of Israel. Historians date the origin of the twelve tribes to about 2,700 years ago. Over time, the twelve tribes became divided politically and geographically. The tribes of Judah and Benjamin lived in the southern part of Israel, while the other ten lived in the north. During the years 722–721 B.C.E, the Assyrians conquered Israel and exiled the ten northern tribes. Historians agree that the ten tribes were likely scattered and assimilated into local cultures to the east. Many groups from locations as disparate as Japan, China, India, and Ethiopia have claimed to be ancestors of the lost tribes, however the actual fate of these people is largely a mystery.

The Lemba of South Africa follow religious traditions that share many similarities with that of the Jews. They practice circumcision and ritual slaughter, scorn intermarriage, and have many similar food taboos, such as not eating meat from pigs. They follow a lunar calendar and celebrate holidays timed with the phases of the moon. Though they speak Bantu, their traditions vary greatly from that of other Bantu people. In addition, their oral tradition states that they came from the Middle East: "We came from the north, from a place called Senna. We left Senna, we crossed Pusela, we came to Africa and there we rebuilt Senna." Although many different lines of evidence point to a connection between the Lemba and the Jews, validating the relationship was never possible until the development of genetic testing.

The modern Jews are traditionally divided into three groups, essentially based on the oral traditions of their families. The Cohanim are thought to be descended from Moses' brother Aaron, who was the high priest of the Hebrew temple. Because Jewish tradition follows a paternal line of inheritance, all modern Cohanim share a paternally inherited priestly ancestor. The other groups are the Leviim, descended from the ancient tribe of Levi, and the Israelites, all non-Cohen and non-Levite Jews. In 1997, genetic researchers found that there is a specific marker on the Y-chromosome, which paternally passes through the genome, called the Cohen Modal Haplotype. This set of genetic markers is found in nearly 50% of all Jewish men who identify themselves as Cohanim. It is found with nearly the same frequency in both the Ashkenazic and Sephardic Cohanim, even though these two major groups of Jews have been geographically separated for hundreds of years. The Cohen Modal Haplotype is only found in about 10% of the Levites and Israelites. It is nearly non-existent in non-Jewish populations.

In 1999 genetic data on the Lemba was collected by Tudor Parfitt, director of the Center for Jewish Studies at the School of Oriental and African Studies in London. He and his collaborators took genetic samples from men of six Lemba clans whose geographic range was from South Africa to Zimbabwe. Of these six clans, the Buba are notable as being the priestly clan. The genetic material was analyzed for the genetic markers that have been found in the Jews. Similar to the general Jewish population, the Cohen Modal Haplotype was found in nearly 10% of all Lemba men. In addition, the Cohen Modal Haplotype was found in nearly half of the men in the Buba tribe.

Additional research by Parfitt identified a location in the Hadramaut region of Yemen as the Senna of the Lemba's oral history. In the past, Jewish communities thrived in Yemen. Parfitt found a town called Sena, which had been a vibrant community but had been almost completely abandoned nearly 1,000 years ago. The Lemba oral history stated that Senna was an extremely fertile place and that was irrigated as the result of a great dam. Parfitt found the remains of a dam in Sena and documented the rich history of the town. In addition, a valley called Wadi-al-Masila leads from Sena to a port city called Sayhut. Parfitt asserts that the Pusela of the Lemba oral tradition is the Masila valley near Sena. Under the right meteorological conditions, the winds could take a boat from Sayhut to South Africa in just over a week. Finally, the family names of the Lemba sound strikingly similar to names from the Hadramaut area.

While the Lemba cannot yet prove that they are one of the ten lost tribes of Israel, the scientific and ethnographic evidence shows that the Lemba of South Africa share a common ancestor with the Jewish people, and more specifically with an ancient priest. This has important implications, both historical and legal. Israeli law upholds the "right of return" that guarantees citizenship for any Jew. Jewish law, however, establishes Jewish identity maternally. Given that the Lemba have established their genetic heritage paternally, and that they practice a form of Judaism that is quite different from that practiced in Israel, there may still be controversy over the status of the Lemba in Israeli courts.

The ruins of Great Zimbabwe, discovered in 1867. Some scholars claim that the modern Zimbabwean Lemba tribe shares key genetic and cultural characteristics with descendents of an ancient Jewish people, and could be the creators of ancient Zimbabwe. © MARTIN HARVEY; GALLO IMAGES/CORBIS.

SEE ALSO DNA fingerprint; DNA sequences, unique; Genetic code; Y chromosome analysis.

Air and water purity

Humans are susceptible to contaminated air and water. Breathing in air that is laden with a noxious substance can cause illness or even death. Similarly, drinking water that contains an inorganic or organic poison, or an infectious microorganism can be debilitating or lethal.

Both water and air are particularly vulnerable to contamination by some bacteria and protozoa, and by their toxic products. While the contamination of air and water can be inadvertent, the noxious substances can also be introduced deliberately. Chemicals can also be dispersed in water and by air. A recent example occurred in 1995, when the Japanese cult Aum Shinrikyo released **sarin gas** into the Tokyo subway system. The poisonous gas attack killed 12 people and sickened 5,000.

As another example, in the months following September 11, 2001, there were several deliberate releases of **anthrax** spores into the air following the opening of contaminated letters. As well, the vulnerability of water supplies to contamination with a variety of infectious organisms has been recognized.

An amount as small as a glass of water can be contaminated with a quantity of organic or inorganic poison or microbe sufficient to cause harm. Even if the water has been chlorinated, disease causing microorganisms such as *Giardia* and *Cryptosporidium* are resistant to chlorine, as are bacterial **toxins**.

Technologies exist to kill the microorganisms that might be present (disinfection) or to completely remove the microbes and chemicals from the air or water (purification). These technologies, however, are usually designed to remove naturally occurring or polluting contaminants.

Groundwater or surface water treatment focuses on providing water that is fit to drink. Typically, the water is filtered to remove large debris. Some jurisdictions also pass the water through microfilters that remove objects as small as viruses from the treated water. Most drinking water is treated with chlorine or chlorine-containing compounds to kill any bacteria. Other treatments that are gaining widespread acceptance include the use of ultraviolet light, ozone, and other chemicals such as bromine. Water can also be purified by techniques involving reverse osmosis and steam distillation, although these techniques are not typically used, as they are expensive and purify relatively small volumes of water at one time.

Treatment and monitoring ensure that the water emerging from the treatment plant is safe to drink and that it remains that way all the way to the consumer's tap. However, these measures are not intended to thwart a deliberate contamination.

Yet for large surface water supplies, the volume of water alone makes the possibility of deliberate contamination remote. For example, it has been estimated that the contamination of the Crystal Springs Reservoir, which supplies some of the water for San Francisco, California, with enough hydrogen cyanide to harm anyone who drinks a glass of water would require over 400,000 metric tons of the poison. Similarly, huge amounts of bacteria or viruses would be required.

Technician taking a water sample. © JOHN ZOINER/CORBIS.

Air is vulnerable to contamination with a variety of bacteria, viruses, and fungi that are light enough to become dispersed in air currents. When inhaled, the microbes can cause infections. Chemicals and toxins can also float in the air, to be inhaled or settle onto exposed skin.

Air purification has long been possible using filters. Bacteria, viruses, and even some inorganic chemicals can be retained on specialized filters. These filters are mainly suitable for laboratories or relatively small, specifically designed ventilation systems. In large indoor environments such as malls or sizeable office buildings, and in the open air, air purification is virtually impossible.

Contamination of the open air poses a similar problem as the contamination of a large volume of water, namely the amount of poisonous agent that is required. For example, estimates are that hundreds of pounds of anthrax **spores** would be needed to achieve a massive contamination of the population of a large city.

The release of toxic agents into a more limited area such as an office building or a home is more plausible.

SEE ALSO Air plume and chemical analysis; Bioterrorism; Organic compounds; Toxins.

Air and water purity, forensic tests

Consumption of contaminated water or breathing in air that contains a noxious compound can be debilitating or lethal. Thus, forensic testing can include the testing of water or air to assess purity or impurity.

Many noxious gases can be transported in the air. For example, people are cautioned against leaving an automobile engine running in an enclosed space. This is because the tasteless, odorless, and colorless carbon monoxide (CO) emitted in the exhaust can cause illness or death, depending upon the concentration of the gas in the air. For example, at a concentration of 200 parts per million (ppm), CO produces a slight headache within hours. A concentration of 800 ppm causes nausea and convulsions (seizures) within 45 minutes of exposure, and can lead to unconsciousness, coma, and ultimately, death.

CO replaces oxygen in the bloodstream, by competing with oxygen molecules for the binding site in the transport compound of the blood called **hemoglobin**. As a result, the body becomes starved for oxygen.

As with gases, particulate material such as soot and asbestos can also be light enough to drift on currents of air. Microorganisms such as bacteria, viruses, and molds (and the **spores** produced by some strains) that dislodge from a surface can also drift on air currents.

The presence of these various agents in the air can be accidental. For example, the growth of molds and fungi in a damp wall of a house can lead to the aerial dissemination of spores. Of particular note, the fungus designated *Stachybotrys chartarum* produces spores that are toxic if inhaled. The fungus was implicated in the illness of 27 infants, nine of whom died, in Cleveland, Ohio, in 1993. All the infants lived in homes that sustained flood damage.

Besides *S. chartarum*, *Aspergillus versicolor* and several species of *Penicillium* are potentially toxic, and also thrive in damp environments.

Noxious agents have also been deliberately introduced into the air. For example, on March 20, 1995, the Japanese cult Aum Shinrikyo released sarin **nerve gas** in the Tokyo subway system, killing 10 people. And, at various times during the 1990s, the cult attempted to aerially disperse *Clostridium botulinum* spores.

Another form of spore is produced by the bacterium called *Bacillus anthracis;* the cause of **anthrax**. In the fall of 2001, a series of incidents occurred in the United States, in which letters containing a powdery form of anthrax spores were mailed to public figures including Senators Patrick Leahy and Tom Daschle and NBC news-anchor Tom Brokaw. Five people died after inhaling the spores released from tainted letters.

Water has been described as "the universal solvent." A huge number of **inorganic compounds** can dissolve in water. As well, microorganisms can be maintained in suspension and can survive for varying periods of time. The result if the water is used for drinking, washing food, bathing, and even recreation, can be illness or worse.

A particularly graphic example of the hazard posed by impure water occurred in the Canadian town of Walkerton, Ontario, in the summer of 2000. Contamination of one of the municipality's wells by a disease-causing (pathogenic) bacterium called ***Escherichia coli*** O157:H7 sickened over 2,000 people and killed seven. A number of those who recovered have been left with permanent kidney damage. Contamination of water and food by *E. coli* O157:H7 causes an estimated 73,000 illnesses and over 60 deaths in the United States each year, according to the **Centers for Disease Control and Prevention**.

Other bacteria including species of Salmonella, Vibrio and Shigella, which, like E. coli, normally dwell in the intestinal tract, can enter water when the water is contaminated by feces, as can intestinal viruses and protozoans. Contamination of drinking water by a protozoan called *Cryptosporidium* in 1993 produced a diarrhea-like illness in over 400,000 people in Milwaukee, Wisconsin.

Forensic testing of air and water is accomplished using the standard analytical procedures employed in other sectors. With air, for example, a device can be used that draws a defined amount of air through a filter. The size of the holes (pores) in the filter is big enough to allow the air molecules to pass, but restricts the passage of particulate material. Even viruses can be retained, if the filter's pore size is in the nanometer (10^{-9} meter) range.

The Simpson Tacoma Kraft Pulp Mill spews air pollution over the city of Tacoma, Washington, from its site on Commencement Bay in the shadow of Mount Rainier. © JOEL W. ROGERS/CORBIS.

The particles are subsequently recovered from the filters and analyzed. Analysis techniques include **spectroscopy**, electron microscopy, and the examination of genetic material. The latter can involve the use of a technique called **polymerase chain reaction** (**PCR**), which greatly increases the number of copies of a selected target region of the deoxyribonucleic acid (**DNA**). The sequence of nucleotide building blocks that comprise the DNA can then be determined.

Water samples can also be filtered to recover particulates and suspended microorganisms. The above techniques can then be used to examine a sample. As well, particularly for bacteria, assays that rely on the growth of the organisms on an appropriate food source, first developed hundreds of years ago, are still an important means of identifying the bacterial cause of an illness.

The types of forensic air and water analyses that are performed rely on the skill of the forensic examiner. Knowledge of the circumstances surrounding an illness or death, appearance of the scene, and the symptoms or behavior of the victim can provide clues suggestive of the involvement of a particular noxious agent.

SEE ALSO Aflatoxin; Air plume and chemical analysis; Biosensor technologies; DNA typing systems; *Escherichia coli*; Nerve gas; Pathogens; Sarin gas; Toxicological analysis; Water contamination.

Air Force criminal and forensic investigations

Forensic investigations are a part of the military as much as civilian life. Military investigations can take on added importance, since the use of **firearms**, **explosives**, and other high-risk tools are more prevalent than in civilian life. A military forensic investigation, such as in the U.S. Air Force, can help root out an anomaly, criminal or otherwise, that would otherwise threaten other service personnel.

A branch of the U.S. Air Force that is concerned with **forensic science** is the Air Force Office of Special Investigations. The AFOSI is the principal investigative service of the United States Air Force. Its ranks, which numbered over 2,500 in 2005, include active-duty Air Force personnel, reservists, and civilians.

Established in 1948 by then United States Secretary of the Air Force W. Stuart Symington, AFOSI is charged with investigating and preventing criminal activities by United States Air Force personnel, as well as by individuals outside the Air Force whose actions threaten the service's equipment, personnel, activities, or security.

Symington patterned the new office after the Federal Bureau of Investigation (**FBI**), and appointed Special Agent Joseph Carroll, assistant to FBI director **J. Edgar Hoover**, as the first AFOSI chief. Symington and Carroll developed an investigative service designed to provide unbiased information and operate independent of top air force command. To this end, the AFOSI included civilian personnel from the beginning.

Among the crimes addressed by AFOSI investigators are **murder**, robbery, rape, drug use and trafficking, black-market activities, and other unlawful acts committed by or against U.S. Air Force personnel. Economic crime, or fraud, is an area of investigation that places particularly large demands on AFOSI resources. AFOSI includes personnel with specialized missions and skills who fulfill functions ranging from that of polygrapher to computer expert to behavioral scientist.

SEE ALSO Aircraft accident investigations; Flight data recorders.

Air plume and chemical analysis

An air plume is a layer of warm air that immediately surrounds a person's body. It has also been referred to as a human thermal plume. An air plume carries chemical signatures that can be used to detect the presence of various compounds on a person.

While the security implications of this are immediately evident, for example if residue from **explosives** is in the air surrounding a person, an air plume can also be used in an investigation into a person's death. If an examination is conducted soon after death, the presence of a chemical residue may still be detectable in the air surrounding the body.

The skin's surface temperature is typically 33° Celsius, which is approximately nine degrees warmer than the surrounding air at a typical room temperature. The temperature difference causes heat to be lost from the entire surface of the skin to the surrounding air.

Because warm air rises, the plume rises up the body and flows off the top of the head and shoulders, instead of radiating outward to the surrounding air from all parts of the body. As the air moves up and away from a person, tiny bits of the skin and chemicals that were present on the skin's surface can also be carried upward. The presence of clothing has no effect on the upward movement of the air.

The presence of clothing also does not block the migration of chemicals from items being carried in the clothing. Particles of an explosive in a pocket, for example, will be able to pass through the pores of the fabric to the immediate vicinity of the skin. There, they will encounter the air plume and migrate upward with the airflow.

The chemicals that are carried in the air plume can be detected using sophisticated detection equipment. The chemical analysis of an air plume can detect explosives and even the aromas emitted by microorganisms.

The analysis of an air plume has grown out of studies that relied on the use of what is termed a *schlieren* system. The word schlieren is German for streaks, and describes the appearance of air in a special optical system. Schlieren optics measure air flow based on the scattering of light due to differences in density at the interface between moving air and relatively motionless air.

Scientists interested in imaging the schlieren patterns produced by people modified the small optical system so that it could be accommodated in a larger device. The device is similar in appearance to the walk through x-ray machines that are now commonplace in airport security areas.

When someone walks through the portal, the air plume is drawn into an analysis chamber positioned in the portal's archway. Any particles present are collected in a trap. As well, the vapors in the air plume can be condensed onto the trap. Chemical analysis is performed using a machine called an ion trap mobility spectrometer.

The trapping of particles and condensation of the vaporous air plume concentrates any compounds that are present. The trapped sample is delivered to a chamber that converts the sample molecules to ions. Typically, bombarding the sample atoms with electrons accomplishes this conversion. When an electron collides with a sample ion, an electron is dislodged from the sample atom, producing a more positively charged ion. As voltage is applied along the length of the chamber, the positively charged sample ions move toward the negatively charged cathode. Separation of the ions occurs based upon their different sizes and masses. For example, smaller ions move down the chamber faster than larger ions. As ions arrive at the cathode, a current is produced. The current can be amplified to produce a detectable signal. The different signals can be plotted to produce a spectrum. The different peaks in the spectrum can be related to known ions to determine the ionic composition of the sample.

The spectrometer is extremely sensitive and fast. Chemicals that are present in only a few parts per billion will be detected in about 10 seconds.

SEE ALSO Analytical instrumentation; Biodetectors; Gas chromatograph-mass spectrometer.

Airbag residues

Various residues (small particles) can attach to a person's body or clothing. These can be detected and analyzed to provide clues as to the person's involvement in a particular incident. **Evidence** of

A researcher examines a crash dummy and deployed airbag after a test crash. A powdery substance helps many air bags deploy without sticking, and often leaves a residue that can be collected for evidence in a crash. © TIM WRIGHT/CORBIS.

involvement in a motor vehicle crash can be provided by the detection of the residue released when an airbag is deployed.

An airbag is essentially a pillow (albeit a specialized one) that is normally concealed. It is triggered to expand by the force of a collision.

Airbags first appeared commercially in automobiles in the 1980s. At that time, they were located only on the driver's side, and were concealed in a compartment in the middle portion of the steering wheel. Airbags have been standard equipment on the front passenger side of cars since the 1998 model year and on the trucks since the following year. Some cars now additionally offer side-mounted airbags that offer protection in the event of a side collision.

The deployment of airbags depends on momentum, which is the product of the mass and velocity of an object. When a car is moving forward, both the vehicle and all the objects inside the car, including the passengers, will tend to keep moving forward.

When the vehicle is rapidly stopped, as occurs in a collision, the passengers' momentum will continue to carry them forward. Typically, passengers are restrained by seatbelts. But, in a high-speed accident, or when a passenger is not buckled in, the forward movement can be so great that the passenger is propelled forward at great speed. The result can be catastrophic injury.

It is this injury that airbags are designed to prevent. The airbag inflates when an accelerometer detects a force equal to running into a brick wall at 10–15 miles per hour. This force causes a switch in the accelerometer to close, allowing the flow of electricity. This current activates the sensor, which in turn activates the airbag's inflation system.

It is the inflation system that proves to be of forensic significance. A gas generator inside the airbag contains sodium azide (NaN_3), potassium nitrate (KNO_3) and silica (SiO_2). Upon the signal from the sensor, heat is supplied, which is necessary to decompose NaN_3. A series of three chemical reactions occurs. In the first reaction, the breakdown of NaN_3 produces nitrogen gas (N_2) and sodium (Na). The sodium then reacts with KNO_3 to generate potassium oxide (K_2O), sodium oxide (Na_2O) and yet more nitrogen gas. Finally, the potassium and sodium oxides react with SiO_2 to produce alkaline silicate (glass).

The latter reaction is a safety measure. Potassium oxide and sodium oxide are very reactive substances and it is dangerous to have them as the end products of the airbag inflation.

Prior to inflation, the NaN_3 and KNO_3 are solids, typically pellets. Their subsequent reactions produce a large amount of nitrogen gas, which bursts the nylon or polyamide airbag from its storage compartment at upwards of 200 miles per hour to approximately the size of a couch decorative pillow.

The entire process, from detection of an impact to the deflation of the airbag, is approximately 170 milliseconds; literally, in the blink of an eye. The inflation of the airbag coincides with the forward movement of the driver or passenger, so by the time a person contacts the airbag, deflation has begun. In this way, the bag acts as a cushion and dissipates the passenger's forward momentum. Without this exquisite timing, a person would contact a rock-hard bag that could cause as much injury as a high-speed collision with the car's windshield.

During deflation, the nitrogen gas vents through very small holes in the bag. It is during this deflation that other contents of the bag can also be released. This residue contains alkaline silicate, but most typically consists of cornstarch or talcum powder. The latter two compounds are included to keep the airbag soft and lubricated while stored.

The deflation can produce a fine powdery cloud of residue that will settle on clothing, vehicle surfaces, hair, and exposed skin. The residue is dissipated very quickly from the airbag. Once the bag has deflated, no more residue is released.

The airbag residue is slightly corrosive and so can be a mild respiratory and skin irritant. The red skin that can result from surface contact with the residue or the mild airway and lung irritation produced upon breathing in the residue can be other forensic clues of a person's involvement in a vehicle collision.

Because of this irritation, forensic investigators wear gloves and goggles when near a deployed airbag and wash with soap and water afterwards.

SEE ALSO Accident reconstruction; Automobile accidents; Death, cause of; Trace evidence.

Aircraft accident investigations

Although flying is generally a safe method of transportation, accidents occasionally happen—whether through human error, mechanical failure, or criminal activity. Over the last two decades (1985–2005), there have been between 30 and 65 fatal aircraft accidents per year worldwide. These, and lesser accidents, have to be investigated scientifically in order to gain important lessons about aircraft performance and safety.

The International Civil Aviation Organization (ICAO) requires that a civil aircraft accident be investigated by an independent body belonging to the country where the accident took place. Each country has its own organization taking responsibility for this: in the United States, it is the **National Transportation Safety Board** (**NTSB**); in the United Kingdom, it is the Air Accidents Investigation Branch (AAIB). The NTSB investigates around 2,000 accidents and incidents a year. The purpose of the investigation is to find out why the accident happened and how similar events might be avoided in the future, rather than to apportion blame. The police will be involved in the investigation if sabotage or some other form of criminal activity is suspected, and the military generally looks into accidents involving service aircraft.

The ICAO sets guidelines on how an aircraft investigation is to be carried out. The first step is to report the aircraft accident or incident. An accident is an event involving death or serious injury, or severe damage to an aircraft. Missing or out-of-contact aircraft must also be reported. Incidents are not as serious; they are events best described as "near misses" involving problems such as forced landings, near collisions, or fires.

The investigation team consists of a permanent core group and outside scientific experts who are called on when needed. They respond immediately to the accident and go to the accident site. Each member will carry flashlights, tape recorders, camera and film, as well as any specialist tools. The investigation of the accident site and the wreck itself may take from several hours to a few days. During this time, the team works in small groups and gathers a wide range of data which may be relevant to the inquiry.

The history of the flight and the crewmembers' duties leading up to the accident are noted. Careful documentation is made of the wreckage and accident scene, with calculation of the impact angles so that the pre-accident flight path can be determined. The experts will also examine the engines and propellers,

Forensic experts inspect some of the wreckage on July 26, 2000, after the crash of an Air France Concorde which ditched in a field outside Paris shortly after takeoff, killing its 109 passengers and crew. © REUTERS/CORBIS.

together with all details of the electrical, hydraulic, and pneumatic systems of the craft and the flight control instrumentation. The investigation is extended beyond the aircraft itself, to the weather prevailing at the time of the accident and the air traffic control instructions given to the plane. Crewmembers are interviewed to look at possible human error factors, such as medical history, fatigue, **training**, workload, working environment, and drug and alcohol abuse. If survivors are involved, the team will document injuries, offer support, and arrange evacuation and rescue efforts.

A vital part of the aircraft accident investigation in the case of larger planes is recovery and examination of the flight recorder, also known as the black box. Airplanes usually have two types of flight recorders, the flight data recorder (FDR) and cockpit voice recorder (CVR).

The FDR is a digital recorder which may use magnetic tape to record, although solid-state devices are now available which can store data on memory chips. The flight data recorder records various flight parameters; the basic ones include: altitude, airspeed, direction, acceleration, and microphone keying, that is, the timing of radio transmissions made by the crew. Modern jet aircraft can record far more data than this with the most advanced logging up to a thousand different parameters, covering every aspect of the flight. The FDR records on an endless loop principle and contains data from the last 24 hours of the flight.

The cockpit voice recorder (CVR) records not only the voices of the crew in conversation or making radio transmissions, but any noise within the cockpit such as alarms, control movements, switch activations, and engine noise. Data from the CVR is correlated with that from the FDR by the microphone keying mentioned above. The CVR may be an analogue recorder using magnetic tape, although, as with FDRs, there are now solid-state devices that store the audio data in digitized form on memory chips. The CVR also operates on an endless loop principle and carries the last 30 minutes of audio information.

Analysis of data from the flight recorders may be the only way of establishing what happened in some aircraft accidents, particularly if they occur at night or where there is little recoverable wreckage. They are also very useful when a sudden event, such as a change in wind speed or direction, is the prime cause of an accident.

Photographs such as this, showing the Concorde's left wing bursting into flame upon takeoff, helped experts determine the probable cause of the 2000 crash–engine contamination from a blown tire caused by a small piece of metal on the runway. © BUZZ PICTURES/CORBIS SYGMA.

Flight recorders are built to protect the data from both high-speed impact and any fire that may occur after impact. They are usually located near the aircraft's tail, because past experience has shown that this is the area that generally suffers least damage in an accident.

Recovering the flight recorders after an accident can, however, be challenging. In the VH-IWJ Westwind 1124 accident, which occurred on October 10, 1985, an aircraft crashed into the sea off Sydney, Australia, shortly after takeoff. The pilot and co-pilot, who were the plane's only occupants, were killed. Three months passed before the flight recorders were discovered on the seabed. Analysis of the CVR at the Australian Transport Safety Bureau (ATSB) labs showed that the pilot was testing the co-pilot and simulating emergency instrument flight conditions. The FDR revealed a loss of control at 5,000 feet which caused the plane to crash.

The flight recorders are analyzed in specialized audio laboratories. The black box data can be integrated with that from other sources, including ground-based radar recorders, wreckage analysis, and eye-witness reports. Advanced computer graphics can be applied to create a graphical reconstruction or video of the sequence of events leading up to the accident or incident.

The mission of the investigative team is to produce an interim report within four to eight weeks that will be sent to all the interested parties for their comments. Safety recommendations are always given priority, so that any changes can be put into place as soon as possible. A final report will appear some time after the investigation and will be published on the website of the investigative organization. This final report includes all the factual information collected in the course of the investigation, an analysis of the information, and a conclusion which gives the cause of the accident or incident and any safety recommendations arising.

Aircraft accident investigations cover events from the crash of light aircraft flown by one person to major disasters such as the terrorist attacks of September 11, 2001. One example, which illustrates many of the aspects of accident investigations described above, is the investigation into the loss of Pam Am Flight 103 over Lockerbie, Scotland, on December 21, 1988. None of the 259 crew members and passengers on board the Boeing 747 survived and eleven people on the ground were also killed. The US-based plane was bound for New York, but it was the United Kingdom's AAIB which carried out the investigation—starting on the day of the crash and reporting in 1990. The plane was brought down by a bomb that had been placed in one of the overhead luggage lockers. The criminal aspects of the event were investigated separately, as were issues of airport security.

The flight recorders were found just east of Lockerbie, about 15 hours after the accident. These showed nothing unusual, stopping suddenly at the moment when the bomb exploded. Investigation of the crew and the aircraft's technical history ruled out human error or technical failure. Weather conditions were unremarkable and the air traffic control records were consistent with the sudden loss of the plane as shown by the flight recorders.

The plane disintegrated in mid-air, creating 1,200 significant items of debris requiring investigation.

Larger items, such as the engines and the aircraft wings, fell on the town of Lockerbie, producing a fireball. Lighter debris was scattered for many miles.

Forensic scientists discovered traces of explosive material in the debris and were able to reconstruct the explosion and the impact it had on the plane. Post-mortem examination of the victims revealed they died of multiple injuries consistent with a mid-air explosion followed by impact on the ground.

The loss of Pam Am Flight 103 was a tragedy with far reaching legal and political implications. But for AAIB, the priority was aircraft safety. The report recommends developing the facility for a flight data recorder to record the pressure changes associated with explosions. It also suggests that aircraft should be designed to better withstand the impact of an explosion.

SEE ALSO Explosives; Flight data recorders.

Alcohol testing SEE Breathalyzer®

Alternate light source analysis

A forensic examination that is conducted only using the visible light wavelengths that are emitted from conventional bulbs may not reveal all the **evidence** present. Depending on the composition of the evidence or the material it is in contact with, its presence may be poorly revealed, if at all, by conventional light. The use of what has been termed alternate light sources can reveal otherwise hidden evidence.

The use of alternate light sources in forensic investigations was pioneered by the Royal Canadian Mounted Police in the 1970s. Then, the units were typically water-cooled argon-ion lasers. These large and expensive machines could not be transported to the scene. Rather, samples needed to be brought to a laboratory equipped with the **laser**.

Portable lasers capable of delivering a single wavelength of light were developed in the late 1980s. In the 1990s, the development of a high-intensity incandescent bulb allowed a wider range of wavelengths to be generated, from the ultraviolet range of the light spectrum to the near infrared. Modern alternate light sources can be less than 20 pounds and are easy to operate.

In general, an alternate light source consists of the light itself (such as a laser or incandescent bulb), a filter or combination of filters that enable all but the selected wavelengths of light to be screened out, a device to deliver the light to the area being examined and appropriate viewing accessories (such as protective goggles, if the wavelengths of light being used are potentially harmful, or goggles equipped with a filter to further screen the incoming light).

Since alternative light source examinations are typically done at the scene of the accident or crime, the light-delivering device needs to be rugged and portable. Typically the light will be equipped with a wheel containing a half dozen or so filters, which can be rotated to bring a different filter into the light path. Another alternate light source design utilizes a flexible fiber-optic cable, which is advantageous in examining confined spaces.

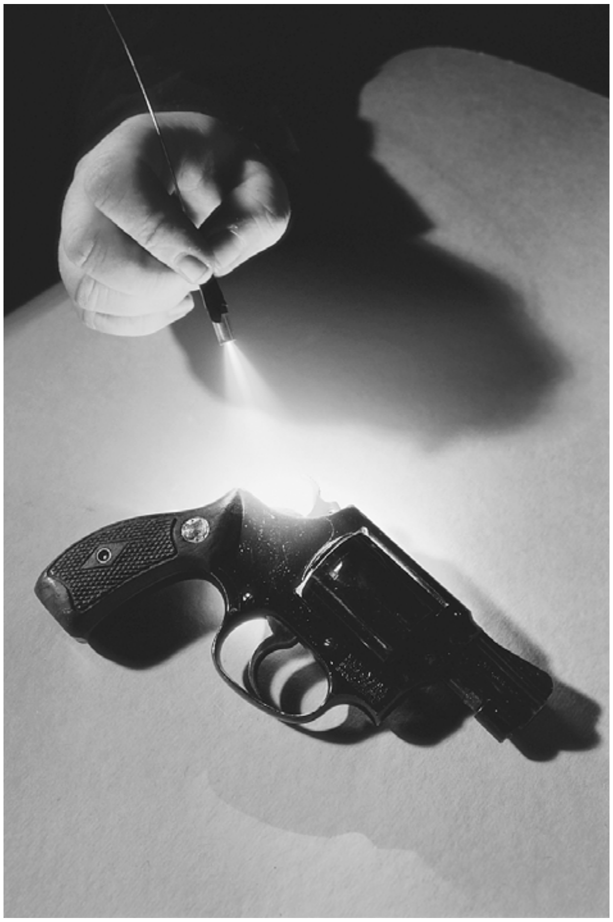
The key to the use of alternate light sources is **fluorescence**; the absorption of light at one wavelength and the emission of light at a longer wavelength. The emitted light can be detected by use of the screening filters, which block out the other wavelengths of light.

Most organic materials can be made to fluoresce. As an example, a **fingerprint** can be invisible to the naked eye. But, when illuminated using an intense blue-green light from a laser or incandescent source, the organic materials in the fingerprint will fluoresce yellow. The fluorescence is visible without the addition or powders or dyes.

The same principle applies to other organic samples including **semen**, **saliva**, **fibers** from materials, and ink. Furthermore, different organic materials will absorb light and fluoresce at different wavelengths. This means that evidence such as a fingerprint or a bite mark can be detected on materials as diverse as skin, paper, rubber, and cloth fabric.

This sort of differentiation requires a skilled operator, since the color of the illuminating light is critical to elicit the maximum fluorescence from the evidence while minimizing the background fluorescence from the supporting material. As well, the selection of the filter(s) is important, since it will block all but the desired wavelengths of the illuminating light while not blocking the wavelengths of the emitted fluorescent light (which is generally much less intense).

One use for alternate light sources is the examination of a weapon such as a gun or knife. Finger and palm prints are nearly invisible on such metal surfaces when examined under room light. But, when viewed under a green light and observed through an orange filter, the prints can easily be seen. Similar



Testing for fingerprints using a laser lightsource. © CHARLES O'REAR/CORBIS.

lighting conditions and special film can be used to photograph prints.

Body **fluids** can be detected using alternate light sources. For example, the use of near-ultraviolet light can readily reveal the presence of semen stains. Other body fluids that can be detected include saliva, **blood**, urine, and vaginal secretions.

Gunshot residue can also be readily observed using the appropriate illumination. Small bits of paint, fiber, hair, **glass**, crystals, and other "trace evidence," which can be physically difficult to find at a crime or accident scene, can be located using alternate light. Moreover, the differing chemistries and shapes of the objects can produce different patterns of fluorescence, allowing different objects to be coincidentally detected.

As a final example, **document forgery** can be detected using alternate forensic light sources, since differences in ink composition and the differing periods of time that the ink was in contact with the paper will produce detectable changes.

SEE ALSO Crime scene investigation; Document forgery; Fingerprint; Fluorescence; Luminol; Polarized light microscopy; Trace evidence.

American Academy of Forensic Sciences

The American Academy of Forensic Sciences (AAFS) is a non-profit, professional organization founded in 1948 in an effort to improve the effectiveness of justice through the application of scientific expertise to the legal process, **evidence** gathering, and crime investigation. AAFS is also dedicated to educating the law enforcement, legal, and scientific communities about the many scientific disciplines that have given rise to modern **forensic science**, and the application of scientific forensic techniques. The term forensic means "pertaining to the forum" (e.g., to a legal public court of justice). The forensic sciences, therefore, apply the knowledge of a variety of scientific disciplines to achieve optimum accuracy in legal investigations and the establishment of sound evidence to be used in civil legal disputes or in criminal courts. AAFS has achieved international prestige and recognition, presently counting more than 5,600 members from 50 different countries worldwide. These professionals represent different fields of expertise such as **medicine** (legal medicine, public health, **autopsy**, **toxicology**, **pathology**, **epidemiology**, genetics, infectious disease), physical **anthropology**, jurisprudence, **criminology**, sociology, **psychiatry** and behavioral sciences, molecular biology, chemistry, engineering, education, archeology, **geology**, and **odontology**. Additionally, other persons with technical expertise, such as document analysis and graphology, are important members of the forensic sciences community.

AAFS is dedicated to the promotion of **training** programs for professionals, the exchange of information among the scientists of the above disciplines, the development of new forensic techniques, the advancement of forensic sciences, the support of new research, and the development of emerging forensic techniques and disciplines. Among the latter, examples are techniques involving **photography** superposition, forensic **skull** reconstruction, computer image enhancing, voice and diction analysis, account auditing, and improved polygraph examinations. Another AAFS goal is to preserve and impart ethical standards of professional conduct among its members.

AAFS publishes the *Journal of Forensic Sciences*, and holds an annual scientific meeting along with several regional seminars. The Academy also provides educational information to the general public and to those considering pursuing a career in one of the many fields of the forensic sciences. Programs of continuing education and accreditation in forensics for professionals and college graduates are another service under the responsibility of the following AAFS sections: **criminalistics**, engineering sciences, general, jurisprudence, odontology, pathology and biology, physical anthropology, psychiatry and behavioral science, **questioned documents**, and toxicology.

SEE ALSO Civil court, forensic evidence; Evidence; Expert witnesses; Federal rules of evidence; Forensic science; Medical examiner; Polygraphs; Professional publications; Toxicology; Voice analysis.

Ammunition and weapons, examination and identification

SEE Ballistics

Ammunition size

SEE Caliber

Amphetamines

Amphetamines are a family of chemical compounds that are indirect stimulants of the central nervous system (CNS). Amphetamines cause the increased release into the brain of dopamine and norepinephrine, two endogenous (produced by the body) chemical messengers, which in turn stimulate the nervous system. Many drug abusers seeking a boost of physical energy and mental stimulation consume amphetamines due to their cocaine-like behavioral effects. Determining the presence or absence of amphetamines in the **blood** is included in most forensic drug screening tests.

Effects of amphetamines that may be experienced include: increased alertness, appetite inhibition, insomnia, decreased fatigue, and emotional euphoria. In high doses, amphetamines can induce delirium, panic attacks, confusion, aggressiveness, and suicidal tendencies. Chronic users sometimes develop a state of amphetamine-induced psychosis that shares similarities with an acute schizophrenic crisis. Drug abusers usually inject amphetamines intravenously or inhale them by smoking.

MDMA (Methylenedioxymethamphetamine), an amphetamine derivative also known as Ecstasy, is swallowed in tablets or capsules, in doses ranging from 60–120 milligrams, usually in association with alcoholic drinks. Drug abusers in general tend to consume these stimulants together with alcohol or marijuana, whose alkaloids further enhance the effects of amphetamines. The amphetamine-induced euphoric state lasts an average of 4–6 hours, which is more than twice the time of cocaine effects.

Like cocaine, some amphetamines also cause addiction and progressive tolerance within a few weeks of use, leading its users to increase doses to achieve the same initial effects. Other physical effects of amphetamine abuse are cardiac arrhythmias, dangerously high blood pressure, chest pain, circulatory collapse, chills, excessive perspiration, and headaches. Nausea, anorexia, diarrhea, vomiting and abdominal cramps, and coma may also occur. A national survey by the Drug Abuse Warning Network under commission of the Substance and Mental Health Services Administration, reported that between 1999 and 2001, more than 86% of all life-threatening cases of intoxication recorded by hospital emergency services in the U.S. were associated with the use of MDMA in combination with either alcohol, marijuana, cocaine, or heroin.

The U.S. Department of Justice, Drug Enforcement Administration (**DEA**), classifies both illegal and controlled substances under five levels of Schedules, I to V. Most amphetamines are categorized in Schedule I, along with other substances such as LSD, marijuana, peyote, mescaline, heroin, etc. A drug or substance scheduled at level I is thus classified because the drug has a high potential for abuse, has no currently accepted medical use in treatment in the United States, and there is a lack of accepted safety for use of the drug. Therefore, amphetamine parent chemicals scheduled under level I cannot be prescribed by physicians in the United States.

Other amphetamine derivatives such as methamphetamine, phenmetrazine, and methylphenidate are under Schedule II, along with cocaine. Schedule II drugs are described as drugs with a high potential for abuse and physical or psychological dependence, but with currently accepted medical uses in the United States with severe restrictions. Schedule II drugs are tightly regulated and require a written prescription from a licensed physician.

Schedule III–V amphetamines also require prescription by a physician, but their manufacture and supply are less controlled and the potential for abuse is less. Therapeutic drugs such as some appetite suppressants and some drugs prescribed for attention deficit disorder fall into this category. Some amphetamines are approved by the Food and Drug Administration either as ingredients of pharmaceutical drugs or as a one-salt drug, such as methylphenidate, used in the treatment of narcolepsy, a clinical condition that induces patients to an uncontrollable state of sleepiness that leads to suddenly falling asleep anywhere and at any time.

SEE ALSO FDA (United States Food and Drug Administration; Illicit drugs; Narcotic; Nervous system overview; Neurotransmitters.

Analytical instrumentation

Forensic science can involve determinations of the presence or absence of compounds or materials. For example, if a victim has died of a stab wound, then noting that a knife was found near the body can be an important piece of **evidence** in trying to decipher the details of the death.

This sort of presence or absence level of detail produces qualitative information. The data does not have an amount associated with it or information concerning the composition of a sample.

In contrast, other useful information can be gained by quantitative examinations; examinations that tell how much of a material is contained within a sample. For example, if the knife noted above has **blood** on the blade, a blood sample can be vital to learning the blood type and the composition of the **DNA** carried in the blood, as well as indicating the presence and amount of any **toxins** or chemical poisons.

For quantitative forensic analyses, specialized instruments are used. A variety of analytical instruments exist, which have their respective advantages depending on what is being examined and the potential target molecules that could be contained within it.

Another area of forensic analysis that uses analytical instrumentation is **gunshot residue** analysis. When a rifle or a handgun is fired, the residue that propelled the bullet out of the barrel is also propelled outward. The residue can attach to exposed skin or the clothing of the person who fired the gun, or on a nearby person or surface.

The residue contains spherical particles that are comprised of lead, antimony, and barium. The particles' shapes and elemental compositions mean that they can be detected using a scanning electron microscope equipped with an energy dispersive x-ray analyzer. The analyzer operates by trapping electrons from the scanning microscope that have bounced off of the sample surface. The surface interaction causes an energy loss. Depending on the nature of that surface, the electrons will lose a certain amount of energy. As well, some of the electrons that were part of the object's surface can be dislodged by the force of the bombardment. By analyzing the pattern of energy levels of the reflected and dislodged electrons, the instrument can be used to determine the elements that are present in the sample and even how much of each element is present. Also, the scanning electron microscope allows the spherical residue particles to be directly visualized. Some instruments are equipped to visually display the elemental pattern on the sample image.

The elemental pattern that is obtained consists of various peaks rising above the background signal. Each peak represents a single element. If the pattern obtained from a sample recovered from a person matches the pattern of a sample obtained from a suspect, then it can be powerful evidence linking the suspect to the fired weapon.

Another important facet of forensic science is the use of DNA typing to identify individuals. The subtle differences in the arrangement of DNA that exist from person to person are every bit as unique as a **fingerprint**, and so have the potential to identify a DNA sample as belonging to a particular individual.

An especially powerful DNA examination technique is known as the **polymerase chain reaction** (**PCR**). The technique uses an enzyme (polymerase) to make many copies of a minute amount of target DNA. The amount of DNA that can be made permits other analyses to be done on material that otherwise would have been present in too low a quantity.

PCR allows DNA to be recovered and analyzed from samples such as cigarette butts, the sealing flaps of envelopes, or pieces of hair and bone, even if the samples have been exposed to the environment or are contaminated with other compounds or microorganisms.

Another analytical instrument, the **gas chromatograph-mass spectrometer**, is adept at analyzing fluid samples. Separation of the various compounds that make up the fluid is accomplished by the gas chromatograph. The sample is injected into the machine and is immediately vaporized. The now-vaporized chemicals are carried through the **chromatography** column by a non-reactive gas such as helium. Depending on the chemical properties of the column, different compounds move at different rates of speed and so appear at the other end of the column at different times. This allows the different compounds to be separated from each other.

The separated compounds are then analyzed by the mass spectrometer. The sample's molecules are hit by a beam of electrons, which causes some of the sample's electrons to be dislodged (ionization). The ionization pattern can be used to identify the molecules and even to determine the mass of the compounds.

Databases that contain the mass spectrometric information on thousands of compounds exist in various state and federal law enforcement agencies. This information can be accessed to help identify the composition of a sample mixture with great precision.

SEE ALSO Air plume and chemical analysis; Biodetectors; Chemical and biological detection technologies; DNA fingerprint; Gas chromatograph-mass spectrometer; Laser ablation-inductively coupled plasma mass spectrometry; Micro-fourier transform infrared spectrometry; Mitochondrial DNA analysis; PCR (polymerase chain reaction); Visible microspectrophotometry.

Anatomical nomenclature

Over the centuries, anatomists developed a standard nomenclature, or method of naming anatomical structures. Terms such as "up" or "down" obviously have no meaning unless the orientation of the body is clear. When a body is lying on its back, the thorax and abdomen are at the same level. The upright sense of up and down is lost. Further, because anatomical studies, and particularly embryological studies, were often carried out in animals, the development of the nomenclature relative to comparative anatomy had an enormous impact on the development of human anatomical nomenclature. There were obvious difficulties in relating terms from quadrupeds (animals that walk on four legs), who have abdominal and thoracic regions at the same level, to human bipeds in whom an upward and downward orientation might seem more obvious.

In order to standardize nomenclature, anatomical terms relate to the standard anatomical position. When the human body is in the standard anatomical position it is upright, erect on two legs, facing frontward, with the arms at the sides with each rotated so that the palms of the hands turn forward.

In the standard anatomical position, *superior* means toward the head or the *cranial* end of the body.

The term *inferior* means toward the feet or the *caudal* end of the body.

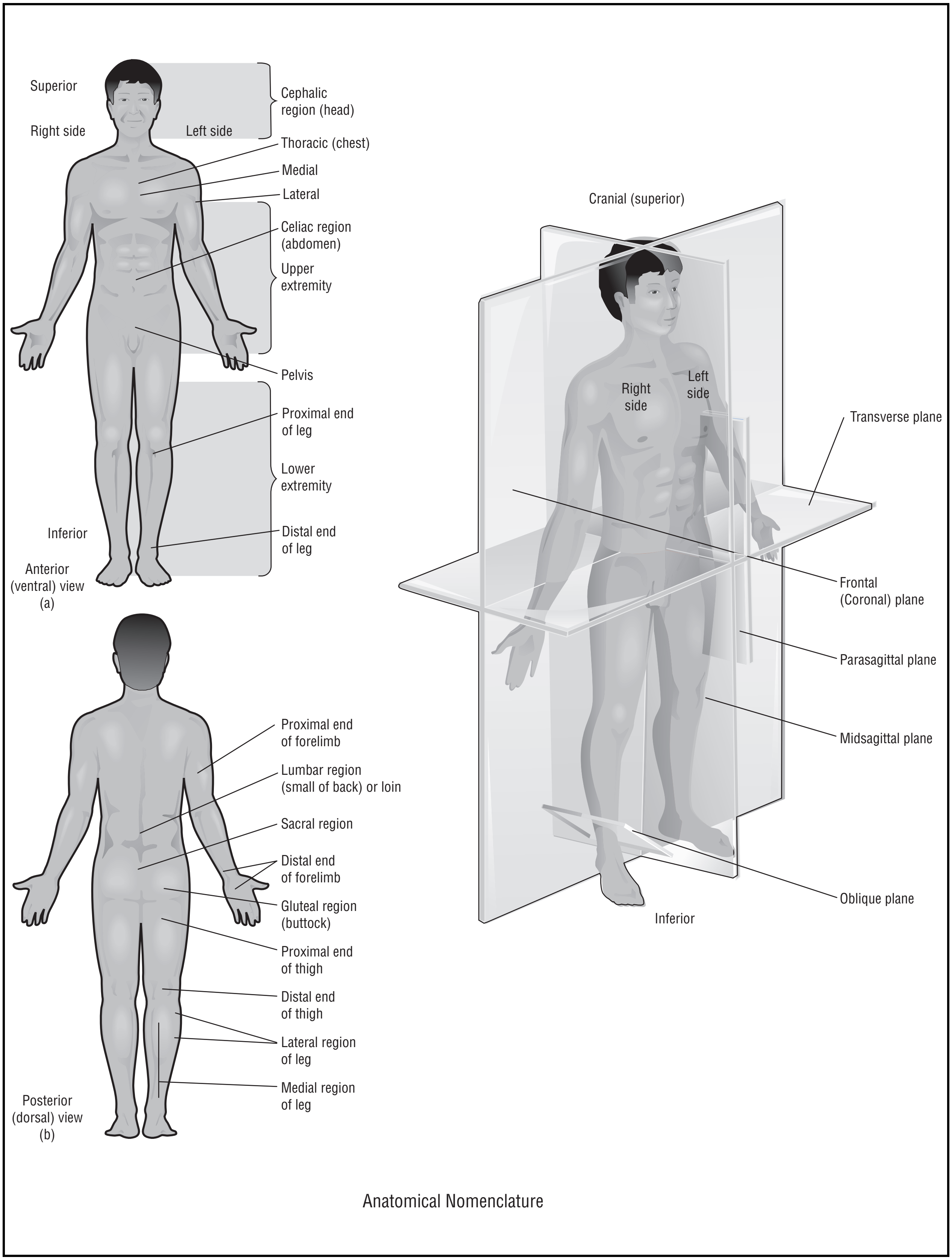
The frontal surface of the body is the *anterior* or *ventral* surface of the body. Accordingly, the terms "anteriorly" and "ventrally" specify a position closer to—or toward—the frontal surface of the body. The back surface of the body is the *posterior* or *dorsal* surface and the terms "posteriorly" and "dorsally" specify a position closer to—or toward—the posterior surface of the body.

The terms *superficial* and *deep* relate to the distance from the exterior surface of the body. Cavities such as the thoracic cavity have internal and external regions that correspond to deep and superficial relationships in the midsagittal plane.

The bones of the **skull** are fused by sutures that form important anatomical landmarks. Sutures are joints that run jaggedly along the interface between the bones. At birth, the sutures are soft, broad, and cartilaginous. The sutures eventually fuse and become rigid and ossified near the end of puberty or early in adulthood.

The sagittal suture unties the parietal bones of the skull along the midline of the body. The suture is used as an anatomical landmark in anatomical nomenclature to establish what are termed *sagittal planes* of the body. The primary sagittal plane is the sagittal plane that runs through the length of the sagittal suture. Planes that are parallel to the sagittal plane, but that are offset from the midsagittal plane are termed *parasagittal planes*. Sagittal planes run anteriorly and posteriorly and are always at right angles to the coronal planes. The *medial plane* or *midsagittal plane* divides the body vertically into superficially symmetrical right and left halves.

The medial plane also establishes a centerline axis for the body. The terms *medial* and *lateral* relate positions relative to the medial axis. If a structure is medial to another structure, the medial structure is closer to the medial or center axis. If a structure is lateral to another structure, the lateral structure is farther way from the medial axis. For example, the lungs are lateral to the heart.



Three views of anatomical nomenclature (clockwise), anterior (ventral) view, cranial (superior) view, posterior (dorsal) view, illustration ILLUSTRATIONS CREATED BY ARGOSY.

The coronal suture unites the frontal bone with the parietal bones. In anatomical nomenclature, the primary *coronal plane* designates the plane that runs through the length of the coronal suture. The primary coronal plane is also termed the *frontal plane* because it divides the body into frontal and back halves.

Planes that divide the body into superior and inferior portions, and that are at right angles to both the sagittal and coronal planes are termed transverse planes. Anatomical planes that are not parallel to sagittal, coronal, or transverse planes are termed oblique planes.

The body is also divided into several regional areas. The most superior area is the *cephalic region* that includes the head. The *thoracic region* is commonly known as the chest region. Although the *celiac region* more specifically refers to the center of the *abdominal region*, celiac is sometimes used to designate a wider area of abdominal structures. At the inferior end of the abdominal region lies the *pelvic region* or *pelvis*. The posterior or dorsal side of the body has its own special regions, named for the underlying vertebrae. From superior to inferior along the midline of the dorsal surface lie the *cervical*, *thoracic*, *lumbar* and *sacral* regions. The buttocks are the most prominent features of the *gluteal region*.

The term *upper limbs* or *upper extremities* refers to the arms. The term *lower limbs* or *lower extremities* refers to the legs.

The *proximal* end of an extremity is at the junction of the extremity (i.e., arm or leg) with the trunk of the body. The *distal* end of an extremity is the point on the extremity farthest away from the trunk (e.g., fingers and toes). Accordingly, if a structure is proximate to another structure it is closer to the trunk (e.g., the elbow is proximate to the wrist). If a structure is distal to another, it is farther from the trunk (e.g., the fingers are distal to the wrist).

Structures may also be described as being medial or lateral to the midline axis of each extremity. Within the upper limbs, the terms radial and ulnar may be used synonymously with lateral and medial. In the lower extremities, the terms fibular and tibial may be used as synonyms for lateral and medial.

Rotations of the extremities may be described as medial rotations (toward the midline) or lateral rotations (away from the midline).

Many structural relationships are described by combined anatomical terms (e.g. the eyes are anterio-medial to the ears).

There are also terms of movement that are standardized by anatomical nomenclature. Starting from the anatomical position, *abduction* indicates the movement of an arm or leg away from the midline or midsagittal plane. *Adduction* indicates movement of an extremity toward the midline.

The opening of the hands into the anatomical position is *supination* of the hands. Rotation so the dorsal side of the hands face forward is termed *pronation*.

The term *flexion* means movement toward the flexor or anterior surface. In contrast, *extension* may be generally regarded as movement toward the extensor or posterior surface. Flexion occurs when the arm brings the hand from the anatomical position toward the shoulder (a curl) or when the arm is raised over the head from the anatomical position. Extension returns the upper arm and or lower to the anatomical position. Because of the embryological rotation of the lower limbs that rotates the primitive dorsal side to the adult form ventral side, flexion occurs as the thigh is raised anteriorly and superiorly toward the anterior portion of the pelvis. Extension occurs when the thigh is returned to anatomical position. Specifically, due to the embryological rotation, flexion of the lower leg occurs as the foot is raised toward the back of the thigh and extension of the lower leg occurs with the kicking motion that returns the lower leg to anatomical position.

The term *palmar surface* (palm side) is applied to the flexion side of the hand. The term *plantar surface* is applied to the bottom sole of the foot. From the anatomical position, extension occurs when the toes are curled back and the foot arches upward and flexion occurs as the foot is returned to anatomical position.

Rolling motions of the foot are described as *inversion* (rolling with the big toe initially lifting upward) and *eversion* (rolling with the big toe initially moving downward).

SEE ALSO Anthropometry; Autopsy; Biometrics; Pathology; Skeletal analysis; Skeletal system overview (morphology).

Ancient cases and mysteries

Modern **forensic science** has provided historians, archeologists, and anthropologists with new tools to investigate mysteries whose roots extend back hundreds, even thousands, of years. **DNA** analysis, for example, has shed light on such cases as that of the **Peruvian Ice Maiden**, the 500-year-old mummified body of a young girl sacrificed to the gods by Incan priests, discovered in 1995. It has also identified with certainty the skeletal remains of the Romanovs, the Russian royal family killed by revolutionaries in 1918. In 2005 Spanish researchers hope to use DNA analysis to settle a dispute over whether the remains of explorer Christopher Columbus are buried in Spain or the Dominican Republic.

Forensic scientists have unlocked the secrets of human remains, such as the mummy of ancient Egyptian king Tutankhamen. The discovery of King Tut and his tomb in 1922 was the most significant archeological find of its generation. The burial chamber, which had survived intact for over 3,000 years, was filled with gold, ivory, and carved wooden treasures, including a now-famous funerary mask. But some features of the tomb puzzled archeologists. The burial chamber's small size suggested that it was built for a non-royal. It appeared to be unfinished and to have been hastily decorated, with paintings marred by splotches of paint that were never cleaned up. The tomb's artifacts were originally marked with other people's names, which were rubbed out and replaced with Tut's name. These features suggested that King Tut, who died at the early age of eighteen and who was the son of a controversial, and by some, hated, leader, may have died unexpectedly and of unnatural causes. Further, buckets of unguents dumped over the mummy raise the question of whether an attempt was made to cover up a **murder**.

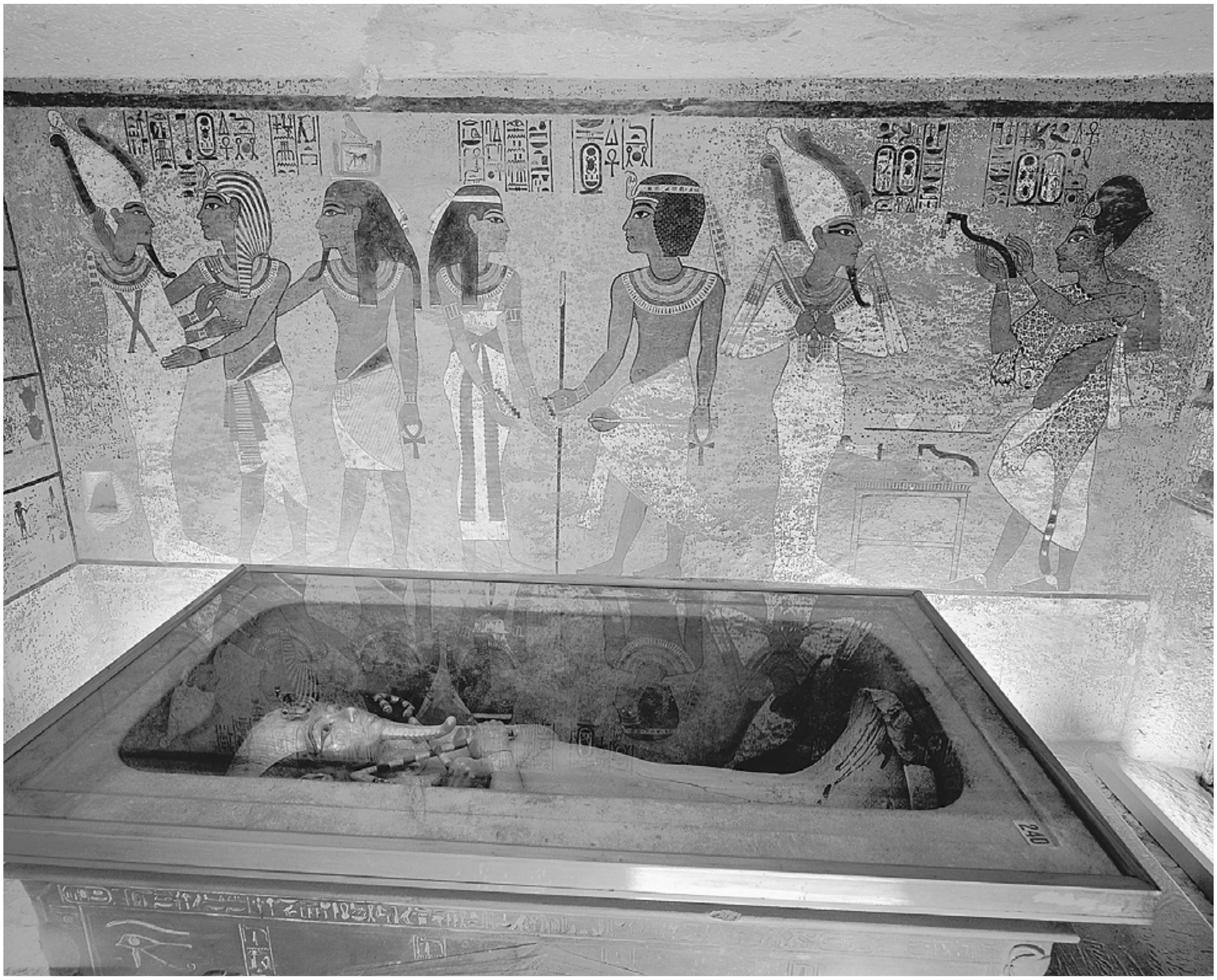
In 1968 researchers from the University of Liverpool x-rayed the King Tut mummy and found a sliver of bone in the brain cavity and an area at the base of the **skull** that may have been a blood clot, clues suggesting that the king may have died from a lethal blow to the back of his head. Later, medical experts examined the x rays and spotted more clues. They found abnormalities in the bones above the king's eye sockets, consistent with injuries that occur when a head strikes the ground sharply in a backward fall and the brain snaps forward. Additionally, the vertebrae in the king's neck were fused, **evidence** of a condition called Klippel-Fell syndrome that makes a person highly susceptible to serious injury from a fall or a push. If Tut was murdered, suspects include Maya, his royal treasurer; Horemheb, his military commander; Ankhesenamen, his wife; and Ay, his prime minister, who assumed the throne after Tut's death. Additional forensic evidence was gathered in 2005, when Tut's mummy was removed from his tomb and scanned in a CT scanner. The resulting evidence may never solve the crime, but it may establish whether or not a crime took place. In March 2005, scientists were also considering the possibility that Tutankhamen could have died from complications of a fracture, when the CT results revealed evidence of a broken left thighbone.

Other forensic scientists focus not only on a body, but also on the physical environment in which a historical person died, searching for clues as to the **cause of death**. Such is the case with French emperor Napoleon, who in October 1815, after the Battle of Waterloo, was exiled by the British to the island of Saint Helena, where he died on May 5, 1821. The official cause of death was listed as a perforated stomach ulcer that had turned cancerous. In 1955 though, the diaries of his valet, Louis Marchand, were published. Marchand's descriptions of the emperor and his behavior in the months before his death created suspicion that he had been poisoned to death with arsenic administered over a long period of time.

In 2001 the Strasbourg Forensic Institute in France bolstered this suspicion by examining a lock of the emperor's hair. Arsenic, usually in the form of white arsenic, or arsenic oxide, works as a poison by binding with sulfur atoms in proteins and enzymes, interfering with their ability to regulate body chemistry. The protein keratin, found in hair, contains sulfur atoms, so evidence of arsenic poisoning will survive in the hair. What's more, because hair grows, a histogram of segments of the hair, created by subjecting the hair sample to x-ray **fluorescence spectroscopy**, can show how arsenic levels changed over time. The Strasbourg researchers concluded that during the time in which the sample of hair grew, Napoleon's body contained arsenic concentrations of seven to thirty-eight times higher than normal.

The central question is: Was Napoleon deliberately poisoned to death, perhaps by his captors, by a disgruntled staff member, or by French Bourbons who wanted to ensure that he never resumed the throne? Some researchers say no. The head of the **toxicology** department for the Paris police noted that hair samples from 1805 and 1814 show similar concentrations of arsenic. If arsenic had caused the emperor's death, he would have died much earlier. Further, arsenic was at the time a common ingredient in some medicines and in hair tonics.

In the nineteenth century, mysterious cases of arsenic poisoning were turning up in Europe, but it was not until 1893 that an Italian chemist named E. Gosio worked out what was happening: that when wallpaper containing a particular pigment became damp and moldy, the mold converted a compound in



View of King Tutankhamun's tomb and wall paintings near Cairo, Egypt. In early 2005, researchers briefly removed King Tut's mummy for a CT scan in order to determine Tut's age at the time of his early death, along with the cause of death. © ROYALTY-FREE/CORBIS

the pigment, copper arsenite, into a vaporized form of arsenic. Anyone who breathed the vapor would get a form of arsenic poisoning that came to be called Gosio's disease. The pigment in question, called Scheele's Green, had been developed around 1770 by a Swedish chemist and was used widely in fabrics and wallpapers. Historical investigation showed that the wallpaper in the drawing room of Napoleon's house indeed was colored with Scheele's Green and that the house had a tendency to be damp. Further, the island's governor, Sir Hudson Lowe, was worried that the emperor would try to escape, so he posted sentries around the house. In an effort to avoid their watchful eyes, Napoleon spent more and more time in the house, especially the drawing room, where he inhaled the arsenic vapor as he spent hours looking out the windows or through holes that he had bored in the shutters. Thus, modern investigators conclude that the likely source of the arsenic in Napoleon's system was his wallpaper, not a murderer.

Forensic investigation has also proven useful in authenticating or disproving claims made about artifacts. One is the Shroud of Turin, a 14-by-3 1/2-foot (4.27-by-1-meter) bloodstained burial cloth that shows faint images of a man who appears to have been tortured and crucified. The cloth came to light in 1204, when the Crusaders sacked the city of Constantinople. The cloth had been removed from the Middle Eastern city of Edessa in 944, where it had been discovered in 544. It was displayed in Lirey, France, in the 1350s but later moved to Chambery, France, where it was almost destroyed by fire in 1532. Many scientists assert that the Edessa Cloth and what is today called the Shroud of Turin (in Turin, Italy) are one and the same. Many people believe that the shroud is the burial cloth of Jesus Christ and that the images are his; some believe that the images are the product of a miracle.

The Shroud of Turin has intrigued modern forensic scientists, especially chemists, whose central question is whether the shroud could have been Christ's burial shroud—that is, whether it was a Greco-Roman burial shroud that can be placed in Jerusalem two thousand years ago. The nature of the cloth, the presence of travertine aragonite limestone dirt particles on it, and pollen grains, some from species now extinct, support claims that the shroud was in the environs of Jerusalem. In 1988 carbon-14 dating apparently proved that the cloth dated from the medieval period, and was hence a fake. More recent studies insist that the carbon-14 sample used in those tests was invalid, contaminated by a later repair patch, and that the cloth dates from an earlier century. The image shows coins on the man's eyes, a common burial practice at the time, and evidence suggests that the coins were struck during the first century A.D.

Scientists have also probed the images on the cloth, subjecting them to a panoply of scientific tests, including visible and ultraviolet spectrometry, infrared spectrometry, x-ray fluorescence spectrometry, thermography, pyrolysis-mass-spectrometry, lasermicroprobe analyses, and microchemical testing. Such tests reveal that the images were not formed by dyes or pigments, meaning that they were not somehow "painted" onto the cloth. Rather, the images are superficial (200–600 nanometers thick) and fully contained in a layer of starch and saccharides (simple sugars) coating the outermost layers of the fabric. Further, a faint image on the reverse side of the cloth corresponds exactly with the image on the outside. Analysis shows that this image, too, is superficial, meaning that nothing soaked through the cloth from the inside to form the image on the outside. The color, often described as caramel-like, was likely the result of a complex chemical reaction, called a Maillard reaction, between amines, or ammonia derivatives, that are released by decaying bodies, and saccharides in a carbohydrate residue covering the **fibers** of the shroud and likely originating with soap that was used to clean the cloth. Put simply, the images appear to have a natural explanation and are not the result of fakery. Despite these tests, the debate continues, and the Shroud of Turin remains a chief exhibit in the debate between faith and science.

SEE ALSO Infrared detection devices; Mummies; Paint analysis; Peruvian Ice Maiden; Skeletal analysis; Spectroscopy.

Animal evidence

Evidence of animals, especially animal hair, is often discovered at crime scenes. Pet or other animal hairs can be found on the clothes of the victim or on other items of **physical evidence** collected at the crime scene. The **identification** and analysis of human and animal hairs from a crime scene can indicate physical contact between the victim and a suspect, or provide other investigative leads. Transferring of pet hairs to the victim, to a suspect, or to the crime scene may happen when the perpetrator is a pet owner (or when the victim owns a pet), or when the crime was committed in a place where animals are kept, such as barns, stables, basements, or transport vehicles.

Through microscopic analysis, hairs can be identified as belonging to a particular species of animal. In the case of a known suspect, animal hair identified on the victim's clothing can be compared to hairs found either in the suspect's home, car, or clothing in search of a match. If the pet of the victim or of the suspect is available, further forensic analysis can be made to confirm whether that particular pet is the source of the hair in question. The pet's bed or brush can also provide samples for such identification.

When human remains are found outdoors, forensic procedures are conducted to establish whether the **cause of death** was due to homicide, suicide, accident, animal attack, or natural illness (i.e., heart attack, stroke, or other pathological condition). Perforation wounds, bullet holes, blunt force injuries, and other lesions normally point to a criminal act as the cause of death. However, animal access to corpses may cause such destruction of the remains that the real cause of death can be impossible to determine in certain cases. Animals feeding on a dead body leave distinct marks on bones and tissues. The signs of wild carnivores and scavenger birds, for instance, are recognizable through characteristic marks left on the bones and soft tissues by claws, fangs, and beaks. Nevertheless, even bodies found in urban areas or inside doors can suffer animal destruction by rodents and domestic animals, such as dogs and ferrets.

Forensic anthropologists are experts in determining the gender, race, and age of unrecognizable remains (usually by studying the bones) and in identifying what kind of animal activity was responsible by the destruction of those remains. Bodies of drowned individuals found on seashores or riverbanks can also display signs of animal activity, such as from crabs or fish.

Animal evidence in human remains has been systematically registered and studied since 1943, including the action of a variety of species, such as wild dogs, large cats, bears, cows, horses, poisonous snakes, marine animals, constricting snakes, rodents, birds, and domestic dogs. The types of injuries and typical feeding behaviors of various species are also well documented. One of the indications of animal scavenging on human remains involves bones or body parts that are scattered, such as a **skull** found some distance from the body, with teeth lost after death. This is common in bodies left on the surface or buried on shallow graves in woods or country areas. Missing body parts or bones are often retrieved from dens of coyotes, foxes, or skunks along tracks and pathways used by these animals.

The types of postmortem marks left on human remains by animals allow the identification of the species involved because of the known specific anatomical features and feeding behavior of each species. Seagulls, crows, owls, and other carrion-eating birds leave puncture wounds in the flesh, caused by their hard sharp bills. Vultures damage bones with their talons and beaks as they remove the flesh. Coyote, fox, and other wild and domestic canids puncture, tear, and crush the soft tissues by gnawing and shaking their heads, splintering bones, and leaving jagged bone edges through the action of their posterior teeth. Rodents have sharp paralleled incisors that leave parallel furrows in flesh and bones, with a pattern of layered destruction of tissues. Big cats leave v-shaped punctures from their canine teeth, claw slashes, and abrasions, and great amounts of crushed and splintered bones. Big cats, wolves, and wild dogs have a preference for eating the internal organs first, therefore eviscerating the body. Domestic dogs also can eat human remains when they are hungry, causing great destruction of the corpse. Such situations can pose extra challenges to forensic investigators in determining the circumstance, time, and real cause of death.

SEE ALSO Anthropology; Crime scene investigation; Death, cause of; Evidence; Microscope, comparison; Skeletal analysis; Taphonomy.

Animal poaching (forensic detection) SEE Wildlife forensics

Animation

In movies, computer animation has become astonishingly adept at mimicking reality. The animation power of computers and computer-aided design (CAD) software is now being exploited as a forensic tool.

Forensic animation seeks to produce images that recreate eyewitness accounts of crime scenes, vehicle accidents, and other events. The animation is intended primarily for a jury in a courtroom trial. Instead of relying solely on a verbal account of an eyewitness, jury members can watch a recreation of the testimony.

As an example, animation can recreate the weather conditions visible from the inside of a moving car on the night of a motor vehicle accident, to provide the viewer with a much better appreciation of what a driver faced than what could be realized from verbal testimony.

In another example, an animated reconstruction can be made of a crime scene. The simulation can duplicate the appearance of the scene. In addition, the view of the crime scene can be shifted from a ground level to an overhead view. This can provide a much richer appreciation of the crime scene than would listening to testimony alone or even looking at a series of photographs.

In one real-life example, animation was used in a liability suit in Iowa over a 1993 collision that killed University of Iowa basketball player Chris Street. In the accident, Street was struck and killed by an oncoming snowplow when he pulled out to pass a truck. The driver of the truck acknowledged that he was speeding 10 miles per hour over the speed limit at the time of the crash.

The driver's admission was key to the US$14-million lawsuit filed against him by Street's parents, who contended that his negligence resulted in the death of their son.

The animation formed part of the defense. Using reports from the police, an accident investigator who reconstructed the incident, and measurements of the actual braking distances required for the snowplow at various speeds, two computer animations were created. The first displayed the accident when the snowplow was traveling at 55 miles per hour in the 45 miles per hour zone. In that animation, as in the real-life accident, the snowplow struck the center of the car.

In the second animation, the snowplow was traveling at the speed limit. Then, the plow still struck the car, this time at the rear of the vehicle. The defense argued that, despite the different impact points, the crash that likely would have occurred at the legal speed limit would still have been fatal. In viewing the animations, the jury decided that the accident was caused by Street's failure to properly assess traffic conditions before pulling out in front of the truck.

In another example, an animated recreation of the shooting death of a Scraton, Pennsylvania woman was a vital piece of **evidence** that led to the conviction of her husband for **murder**. The man, a former police officer with a history of domestic violence, had claimed that he shot his wife in self defense as she tried to attack him with a knife.

Based on the photographic information gathered at the crime scene by forensic investigators, an animation was created that presented a three-dimensional view of the room. The detail and multi-perspective view of the scene was used convincingly by the prosecution to argue that the **blood** pattern on the victim was not consistent with her husband's explanation of the death.

Implicit in the above examples is the accuracy of the information that forms the database of the animation file. The intent of forensic animation is to accurately present the testimony of eyewitnesses or experts to a jury, not to create a situation that is not based in reality.

Similar concerns have been voiced in the past about the reliance on expert testimony and the use of other forensic reconstructions that attempt to indicate what a long-missing person might appear like in the present day.

The normal sharing of information by prosecution and defense will hopefully circumvent this recognized risk that animation could be misused to create a fictitious reality. For example, in the Chris Street case, the opposing attorneys were able to view the animations prior to their presentation in court, giving them time to formulate their response strategy. As well, an animation can be presented frame-by-frame, with questioning and expert commentary provided for each frame.

Another concern surrounding forensic animation, exemplified by the above example, is the cost of producing an animation. The high cost of producing a high quality animation, in the tens of thousands of dollars, is often beyond the budget of a defense team.

SEE ALSO Accident reconstruction; Computer forensics; Crime scene staging.

Antemortem injuries

Antemortem injuries are those injuries a body has received before death. They may be a contributing factor in the death or even its cause. On the other hand, they may have occurred many years ago. During an **autopsy**, the pathologist assesses the age of antemortem injuries, as well as distinguishing them from postmortem injuries—that is, injuries occurring after death. Postmortem injury can come from various sources such as deliberate mutilation of a body by a murderer following a homicide, predation by wild animals, or careless handling in the mortuary. Postmortem injuries can cause confusion over the manner and **cause of death**.

One major difference between an antemortem and a postmortem injury is the presence of signs of bleeding. While the person is still alive, the blood is circulating and any injuries such as cuts or stabs will bleed. After death, the body usually does not bleed. However, there are exceptions. For instance, when a person drowns, their body usually floats face down and this results in the head becoming congested with blood. If the cadaver receives a head injury by being buffeted around in the water and colliding with boats or propellers, then there could be some **evidence** of bleeding. Scalp wounds sustained after death may also leak some blood.

It can be especially difficult to distinguish between injuries inflicted in the very last few minutes of life and those caused postmortem. If the person collapses, there may be areas of laceration (cuts or scrapes) to the head and scalp which may be very hard to interpret.

After death, the blood stays liquid in the vessels and no longer clots. Careless handling of a cadaver may produce some post-mortem bruising which may need to be distinguished from antemortem bruising. Blood also tends to pool under gravity after death, causing a bruised appearance in the lower limbs, arms, hands, and feet known as **lividity**. Some of the smaller vessels may even hemorrhage under the pressure of this pooled blood. These bruises could be confused with antemortem bruising.

Recent research has focused on improved techniques for distinguishing between an antemortem and a postmortem injury by analyzing damaged tissue. Antemortem injuries show signs of inflammation, while postmortem injuries do not. Chinese scientists have found that tissue from antemortem injuries contains a chemical involved in inflammation leukotriene B4 (LTB4). Postmortem injuries were found to have no LTB4. This could help the pathologist classify injuries more accurately.

SEE ALSO Blood; Body marks; Pathology; Wound assessment.

Anterior SEE Anatomical nomenclature

Anthrax

Forensic science can involve the investigation of an outbreak of illness or the death of an individual that is caused by a microorganism. Some microbes are especially toxic, and so are of forensic concern. A good example is anthrax.

While anthrax is an ancient bacterial disease, the disease again sprang to prominence following the September 11, 2001, terrorist attacks on the World Trade Center buildings in New York City and the Pentagon in Washington, D.C. In the months following these attacks, letters containing a powdered form of *Bacillus anthracis*, the bacteria that causes anthrax, were mailed to representatives of the U.S. government and the media, among others. Five people who acquired the disease died.

Bacillus anthracis can enter the body via a wound in the skin (cutaneous anthrax), via contaminated food or liquid (gastrointestinal anthrax), or can be inhaled (inhalation anthrax). The latter in particular can cause a very serious, even lethal, infection.

The disease has been present throughout recorded history. Its use as a weapon stretches back centuries. Hundreds of years ago, bodies of anthrax victims were dumped into wells, or were catapulted into enemy encampments. Development of anthrax-based weapons was pursued by various governments in World Wars I and II, including those of the United States, Canada, and Britain.

Humans naturally acquire anthrax from exposure to livestock such as sheep or cattle or wild animals. The animals are reservoirs of the anthrax bacterium.

While all three types of anthrax infections are potentially serious, prompt treatment usually cures the cutaneous form. Even with prompt treatment, the gastrointestinal form is lethal in 25%–75% of those who become infected. The inhaled version of anthrax is almost always lethal.

When *Bacillus anthracis* is actively growing and dividing, it exists as a large "vegetative" cell. But, when the environment is threatening, the bacterium can form a spore and become dormant. The spore form can be easily inhaled. Approximately 8,000 **spores**, hardly enough to cover a snowflake, are sufficient to cause the inhalation form of anthrax when the spores resuscitate and begin growth in the lungs.

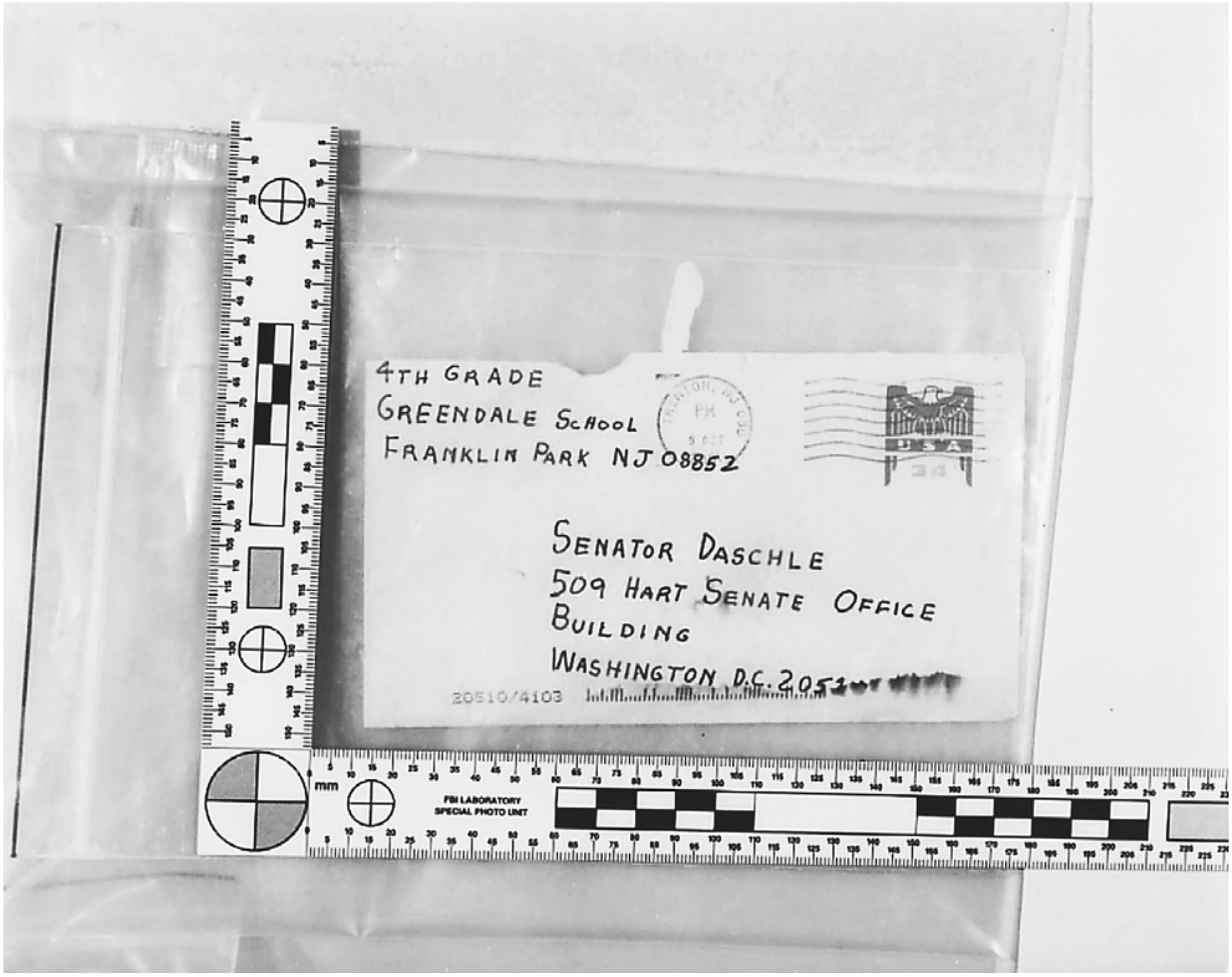
The growing *Bacillus anthracis* cells have several characteristics that make them so infectious. First, the formation of a capsule around the bacterium can mask the surface from recognition by the body's **immune system**. The body can be less likely to mount an immune response to the invading bacteria. Also, the capsule helps fend off antibodies and immune cells that do respond. This protection can allow the organism to multiply to large numbers.

The capsule also contains a protein that protects the bacterium. This protective **antigen** dissolves other protein molecules that form part of the outer coating of host cells. This allows the bacterium to evade the host's immune response by burrowing inside host cells such as the epithelial cells that line the lung.

A toxic component called lethal factor actively destroys the host's immune cells. Finally, another toxic factor called the edema factor (edema is the build up of fluid in tissues) disables a host molecule called calmodulin. Calmodulin regulates many chemical reactions in the body.

With the various toxic factors, *Bacillus anthracis* is able to overcome the attempts of the host to deal with the infection. Bacterial **toxins** enter the bloodstream and circulate throughout the body. The destruction of blood cells and tissues can be lethal.

The early symptoms of anthrax infections are similar to other, less serious infections, such as the flu. By the time the diagnosis is made, the infection can be too advanced to treat. This can make the recognition of a deliberate anthrax attack difficult to recognize until large numbers of casualties have resulted. While the bacteria can be killed by



Envelope in which an anthrax-laced letter was sent to Senate Majority Leader Tom Daschle, in Washington D.C., October 23, 2001.

antibiotics, in particular an antibiotic called ciprofloxacin, the antibiotic needs to be administered early in an infection.

A vaccine to anthrax does exist, although the possibility of serious side effects has limited its use to only those at high risk for infection (i.e., soldiers, workers in meat processing plants, anthrax researchers). Vaccine researchers are exploring the possibility that the edema factor and the capsule could be exploited as targets of **vaccines**. The idea is that the vaccines would stop the bacteria from getting into host cells. This would make it easier for the immune response to kill the invading bacteria.

SEE ALSO Antibiotics; Biological warfare, advanced diagnostics; Biological weapons, genetic identification; Bioterrorism; Vaccines.

Anthrax, investigation of 2001 murders

The 2001 **anthrax** letter attacks brought the first known deaths ever caused by **bioterrorism** in the United States. The fear that subsequently paralyzed the nation focused attention on the new field of microbial forensics, which is responsible not only for tracing outbreaks of microbial diseases but also on collecting data that must meet legal standards for **evidence**.

The anthrax attacks began with the illness of Robert Stevens, a sixty-three year old British immigrant employed as a photo editor at the *Sun*, a supermarket tabloid newspaper published by American Media, Inc. in Boca Raton, Florida. Stevens became ill on September 29 while vacationing with his wife in

North Carolina. Initially, he felt fatigued and weak. Later, he became feverish and had trouble breathing. He then began vomiting and became delirious. Stevens, having driven home, was admitted on October 2 to JFK Medical Center in the West Palm Beach, Florida suburb of Atlantis. The presumptive diagnosis was meningitis, an inflammation of the membrane covering the brain.

In the United States, only eighteen cases of anthrax from inhaled **spores** were recorded in the twentieth century. Despite the rarity of anthrax, Stevens' physician, Dr. Larry Bush, suspected the bacteria. He had a sample of Stevens' **blood** sent to Anne Beall, the lead medical technologist at Integrated Regional Laboratories in Ft. Lauderdale. To detect anthrax, Beall conducted a series of tests. She first determined the motility of the bacteria or whether they were capable of spontaneous movement. Motility can be observed through the microscope or, occasionally, through the spread of growth in a **culture** medium. Beall then checked the action of the bacteria upon red blood cells. When placed in a medium containing red blood cells, some bacteria destroy the cells in a process called hemolysis. The tests took hours to complete because quantities of bacteria had to first be grown for the procedures. The bacteria taken from Stevens were nonmotile and nonhemolytic. These are characteristics of anthrax bacteria.

In 1999, the Centers for Disease Control established a bioterrorism preparedness and response program. The Florida State Laboratory in Jacksonville, part of the **CDC** network, received the Stevens' samples according to protocol. Dr. Philip Lee, Florida's biological defense coordinator, examined the bacteria according to CDC procedures for suspected anthrax.

Lee conducted three tests: capsular staining, a polysaccharide test of the cell wall, and a gamma phage test. Capsular staining identifies whether the bacillus has a capsule, a thick outer coating. The test by itself is not conclusive for anthrax because some other bacteria are also encased in capsules. The polysaccharide test checks to see whether the cell wall contains a specific sign, a polysaccharide, which is specific to anthrax and a few other bacteria. A positive result is not a confirmation of anthrax. However, if both the capsular and polysaccharide tests are positive, the bacteria are almost certainly anthrax. The gamma phage test is based on the knowledge that certain viruses, known as phages, can enter and infect bacteria. A gamma phage can infect anthrax. The test involves introducing gamma phages to suspected anthrax. If the bacterial cells split open, or lyse, they are virtually certain to be anthrax. All three tests indicated anthrax.

With anthrax confirmed, the CDC needed to determine how Stevens became exposed to the bacteria and to identify other possible cases. Stevens, who died on October 5, never recovered sufficiently to assist in the investigation. Investigators initially suspected that he had encountered anthrax, which typically strikes animals, by drinking from a stream in North Carolina. CDC-organized teams of federal, state, and local investigators interviewed people, swabbed surfaces, and collected samples for testing at the places where Stevens worked, lived, shopped, fished, hiked, and visited in Florida and North Carolina.

At this point, American Media employees recalled that a mailroom clerk had gone home sick with symptoms similar to those of Stevens. The clerk had entered a Miami hospital on October 1 and had received large doses of the antibiotic ciprofloxacin or Cipro. The clerk survived. Cipro, more than any other antibiotic, is effective against a large variety of anthrax strains.

Preliminary testing indicated that *Bacillus anthracis* was present in samples taken from the American Media building where Stevens worked and the computer keyboard that he used. There was no reason why anthrax should be present in these areas. Investigators concluded that Stevens had been deliberately exposed. Jean Malecki, director of the Palm Beach County Health Department, ordered the American Media building closed. It has never reopened. About 1,000 people who were considered at risk of developing anthrax by being present in the building some time since August 1 had their nostrils swabbed to test for the presence of anthrax, and were given a ten-day supply of **antibiotics**.

The ill mailroom clerk indicated the mode of transmission of anthrax into the American Media building. Some *Sun* employees recalled a trifolded letter containing powder and a small, plastic, gold-colored Star of David charm. They were uncertain of the text of the letter. Stevens had taken the letter and sat down at his keyboard with it on September 19.

On October 15, the Florida Department of Health announced that anthrax had been found in the Boca Raton post office. Spores were found in an area where mail was sorted for pickup by American Media.

Meanwhile, an NBC employee in New York City received a diagnosis of cutaneous anthrax (anthrax lesions of the skin) on October 12. By October 25, nasal swabs had been taken from 2,580 people in

New York City and preventive Cipro had been given to 1,306. All seven confirmed cases were connected to the media: two at NBC, three at the *New York Post*, and one each at ABC and CBS.

Health authorities recovered the letter sent to NBC. Addressed to anchorman Tom Brokaw, it contained hand-printed capital letters that stated, "This is next. Take precautions now. Death to America. Death to Israel. Allah is Great." Three other anthrax letters were later found and all were postmarked Trenton, New Jersey, the imprint made at the large postal sorting and distribution center on Route 130 in Hamilton Township, ten miles from Princeton. Investigators swabbed 561 mailboxes and delivered the cotton tips to state laboratories. Only one mailbox, on a street corner in Princeton, tested positive for anthrax.

On October 15, anthrax was found in letters sent to prominent U.S. Senators Tom Daschle (D-South Dakota) and Russell Feingold (D-Wisconsin). Twenty members of Daschle's staff were exposed, as were two Feingold workers and six responders from the Capitol Hill Police. The Hart Office Building, home to Daschle and Feingold, was ordered closed on October 16 and would not open again until January 2002, when decontamination had been completed. The Capitol and all five remaining Congressional office buildings were also closed for screening. In subsequent weeks, suspicions of anthrax prompted closings throughout the Washington, D.C. area, including parts of the Federal Reserve Building, the U.S. Supreme Court, the Pentagon, and the State Department.

The mail processing facility that served Congress is located on Brentwood Road in Washington, D.C. Four of the Brentwood employees became ill with inhalation anthrax and two died. In a postal center, anthrax spores might settle not only in the nasal passages or skin of workers but also on sorting machines and other mail. Each newly infected piece of mail could become a potential anthrax carrier. Inhalation anthrax, apparently spread through cross-contaminated mail, killed Kathy Nguyen, a Vietnamese immigrant hospital supply worker in Manhattan on October 31 and Ottilie Lundgren, an elderly rural Connecticut woman on November 21.

Naming the anthrax investigation "Amerithrax," the Federal Bureau of Investigation released a profile of the suspect on November 9. According to the **FBI**, the anthrax mailer was likely an adult male with a scientific background or a strong interest in science. He had access to a source of anthrax, knew how to refine it, and had familiarity with the Trenton, New Jersey area. A non-confrontational person and a loner, the mailer probably tended to hold grudges for a long time.

Some scientists and journalists publicly speculated that the anthrax mailer had ties to the government since anthrax is not easy to obtain. The anthrax that had been discovered in the New York City and Washington, D.C. letters belonged to the Ames strain of anthrax. First acquired by the U.S. army for vaccine research at Fort Detrick, Maryland, Ames anthrax was discovered when it infected some cows in Texas in 1981. When samples were later sent to other military and civilian labs, the strain was named "Ames" after the return address label of a government lab in Ames, Iowa. Some samples of the Ames strain were sent to allies overseas, including one batch that went to the British biological defense establishment at Porton Down.

The timing of the anthrax attacks, right after the September 11 terrorist attacks on the Pentagon and World Trade Center, also raised suspicions that foreign terrorists were responsible. Two of the September 11 hijackers had lived in South Florida, not far from American Media headquarters, and one was reportedly treated for cutaneous anthrax. The FBI, preferring the theory of a lone domestic terrorist, continues to pursue leads as of 2005.

SEE ALSO Anthrax; Antibiotics; Bacterial biology; Bacteria, classification; Biological weapons, genetic identification; Bioterrorism; Criminal profiling; Cross contamination; FBI (United States Federal Bureau of Investigation); Mail sanitization; September 11, 2001, terrorist attacks (forensic investigations of).

Anthropology

Anthropology is the study of the behavior, origin, and physical and social development of humans. The term forensic refers to the gathering of scientific **physical evidence** for use in a court of law. Thus, forensic anthropology is the use of anthropology to gather and examine scientific **evidence**. Forensic anthropologists use a blend of sciences, such as biology, chemistry, physics, and anatomy to aid in the investigation of crimes.

One of the primary roles of a forensic anthropologist at a crime scene is to identify human remains. A forensic anthropologist uses scientific methods and technologies to answer key questions about the crime such as: how many victims are present? Who are they? When did they die? How did they die? Most of

A member of the Guatemalan Forensic Anthropology Unit cleans a human skull in 2004 that was exhumed from a mass grave after a decades-long armed conflict in Guatemala left a toll of 500,000 people killed and 250,000 still missing. © CARLOS LOPEZ-BARILLAS/CORBIS

the answers to these questions come from studying human skeletal remains.

The **skull** provides the most information for physical anthropologists. Craniosacral, or skull measurements (especially between the eye sockets and the jaw bone,) often help forensic anthropologists determine the race, age, and sex of a body. Forensic anthropologists can sometimes recreate the likeness of a person from skeletal measurements. Teeth can be compared to dental records as a means of **identification**. Holes, fissures, stains, and other abnormalities indicate trauma and may help to determine **cause of death**.

Forensic anthropologists also look at the size and shape of the pelvis, as well as signs of wear in the hip joint, to help determine the age and sex of remains. They can tell whether a broken bone happened before, during, or after death. Evidence of bones that were broken during childhood and later healed may help identify an adult body.

Forensic anthropologists may even be able to determine what kind of career a victim may have had by examining skeletal remains. Ridges that form where muscle tissue attaches to bone indicate that a person's job required physical labor. Ridges may also indicate if a person was right or left handed. Looking at microscopic lines in bone fragments yields clues about the overall health of person before death.

Often, physical anthropologists must work with badly decomposed, charred, or damaged remains instead of well-preserved, whole skeletons. When working with fragments, forensic anthropologists employ technologies such as CAT scans and x rays. They may attempt to gather **DNA** evidence to identify remains.

Forensic anthropology is not only used to investigate present-day crimes, but is also applied to examine historical events. For example, forensic anthropologists have played a significant role in identifying the remains of wartime military personnel, even decades after the event. This type of forensic anthropology is sometimes referred to as forensic **archaeology**.

SEE ALSO Ancient cases and mysteries; Anthropometry; Archaeology; Careers in forensic science; DNA mixtures, forensic interpretation of mass graves; Identification of war victims in Croatia and Bosnia; War forensics.

Anthropometry

The measurement of the human body, its component parts and relative dimensions, such as body weight, height, length of limbic bones, pelvic bones, **skull**, etc., is known as anthropometry. The word anthropometry comes from the Greek *anthropos*, meaning man, plus the word *metron*, meaning measure. Anthropometry is a scientific tool presently used in several fields including **medicine**, **anthropology**, archeology, and **forensic science** to study and compare relative body proportions among human groups and between genders. For instance, by comparing relative body and bone proportions between two groups of children of the same age, under normal and abnormal conditions, physicians can determine the impact of malnourishment upon the physical development during childhood. Anthropologists compare cranial and body proportions to identify sets of characteristics common to individuals of a given race and the morphological differences among races. Paleontologists are able to tell historical periods using anthropometry—such as whether a set of skeletal remains pertains to a Neanderthal (man, woman, or child) or to a *Homo Sapien*.

Anthropology is the discipline that has developed anthropometrical comparison studies into a set of reliable standardized data and mathematical formulae, which are now useful for both modern forensic science and archeology. Presently, anthropometry is a well-established forensic technique, which uses anthropological databanks to calculate computational ratios of specific bones and skull features associated with differences between genders and with specific races. For instance, the size and conformation of pelvic bones and skull structures can indicate gender; the length of the long bones of limbs allows the estimation of height. The metric proportions of skull features, given by the size, shape, and relative position of structural bones such as the temporal bones and the mastoid process, superciliary ridge, supraorbital foramen, zygomatic bone, nasal bone, mandible, ocular orbits, etc., may indicate race (Caucasian, Asian, African, or Native American), age (fetus, newborn, child, young adult, etc.), and gender.

When a complete skeleton is available, the level of reliability in establishing sex, age, and race through anthropometrics is almost 100%. Pelvic bones alone offer a 95% reliability, while pelvic bones plus the skull result in an accurate estimation 98% of the time. Sex can be determined by studying the size and shape of some skull bones and by comparing them with the well-established dimorphisms (differences in shape) between human male and female skulls. For instance, the mastoid process, a conic protuberance forming the posterior part of the right and left temporal bones, is large enough in males for the skull to rest on it on the surface of a table. In the female skull, however, the mastoid process will tilt backward to rest on the occipital area or other portions of the skull. This happens because the mastoid process in the female skull is not large enough to keep it in a balanced position on a flat surface. Gender dimorphisms are also found in many other human bones.

Forensic anthropometry may also indicate the nutritional status of an individual, along with existing degenerative diseases or infections at the time of death. Such information may be combined with other kind of circumstantial and forensic data to identify human remains and to determine the **cause of death**.

Anthropometry was not always considered a true science, however, because it initially gave rise to several political and social pseudo-scientific assumptions, and even to some poorly based medical theories, especially during the nineteenth and early twentieth centuries. Cesare Lombroso (1836–1908), an Italian physician, published a series of essays, “The Criminal Man” (1875), “Algometrics of the Sane and the Alienated Man” (1878), “The Delinquent Man” (1897), and, in 1900, “The Crime, Causes and Remedies,” stating that two types of criminal temperaments existed, the criminoid and the natural-born criminal. Lombroso claimed that some specific anthropometrical body proportions were associated with each type of criminal. According to Lombroso, the natural-born criminal, whose urge to commit crimes was beyond his own will due to a hereditary psychological illness and compulsion, had prominent, long jaws and low eyebrows. The criminoid type of criminal, such as

Engraving ca.1885-1900 of a man taking measurements of a criminal's ear according to an anthropometrical system for criminal identification developed by Alphonse Bertillon.

pickpockets and petty thieves, had long narrow fingers and scanty beards. Through facial, skull, and hand anthropometrics, Lombrose developed what came to be known as these Lombrosian Types.

Paul Broca (1824–1880), a French surgeon interested in brain morphology, published his anthropometrical studies in his essays "General Instructions for the Anthropological Investigation" and "Craniological and Craniometrical Instructions." Broca declared that women should be denied higher education because their cranial volume was smaller than a man's. According to Broca, the reduced cranial volume of women indicated that human females were less intelligent than males.

Another example of pseudo-scientific use of anthropometrics involved claims by Nazi scientists during World War II (1939–1945) that they could establish racial profiles of pure Aryan populations, along with profiles of non-Aryans that they considered inferior, on the basis of measurements of skull and facial proportions and other body characteristics.

These unfounded misuses of anthropometrics gave way to more sound scientific approaches after 1950. Besides forensics, anthropometrics are now also used in industry for sizing clothing, machines, and other products to fit the people who use them.

SEE ALSO Anthropology; Osteology and skeletal radiology; Pathology; Pseudoscience and forensics; Sex determination; Sexual dimorphism.

Antibiotics

A variety of infectious diseases are caused by bacteria. Some bacterial infections can be treated using compounds that are collectively known as antibiotics. Antibiotics act only on bacteria, and are not effective against viruses.

The presence of antibiotics in **blood** or tissue samples obtained after death (post-mortem samples) can be an important clue to the presence of an infection in the deceased.

The unique chemical structure of an antibiotic, relative to the natural tissue, can allow the compound to be detected. For example, cephalosporin antibiotics have been successfully detected in post-mortem samples using the technique of high-pressure liquid **chromatography**, which separates compounds based on their differing rates of movement through a porous support material.

Antibiotics can be naturally produced. For example, the first antibiotic discovered (penicillin; discovered in 1928 by Sir Alexander Fleming) is produced by a species of a mold microorganism. There are a variety of different naturally produced antibiotics, while many other antibiotics have been chemically produced.

Prior to the discovery of penicillin there were few effective treatments to battle or prevent bacterial infections. Pneumonia, tuberculosis, and typhoid fever were virtually untreatable. And, in those persons whose immune systems were not functioning properly, even normally minor bacterial infections could prove life-threatening.

In nature, antibiotics (or antimicrobials) help protect a eukaryotic cell (i.e., plant cell) or bacteria from invading bacteria (in some environments, bacteria may be in competition). In the laboratory, this protective advantage is evident as the inhibition of growth of bacteria in the presence of the antibiotic-producing species. Screening for antimicrobial activity is done on preparations that are obtained from a variety of sources (soil, water, plant extracts). This screening can be automated so that thousands of samples can be processed each day.

The chemical synthesis of antibiotics is now very sophisticated. The antibiotic can be tailored to affect a specific target on the bacterial cell. Three-dimensional modeling of the bacterial surface and protein molecules is an important aid to antibiotic design.

Penicillin is in a class of antibiotics called beta-lactam antibiotics. The name refers to the chemical ring that is part of the molecule. Other classes of antibiotics include the tetracyclines, aminoglycosides, rifamycins, quinolones, and sulphonamides. The action of these antibiotics is varied. The targets of the antibiotics are different. Some antibiotics disrupt and weaken the cell wall of bacteria (i.e., beta-lactam antibiotics), which causes the bacteria to rupture and die. Other antibiotics disrupt enzymes that are vital for bacterial survival (aminoglycoside antibiotics). Still other antibiotics target genetic material and stop the replication of deoxyribonucleic acid (**DNA**) (i.e., quinolone antibiotics).

Antibiotics can also vary in the bacteria they affect. Some antibiotics kill only a few related types of bacteria and are referred to as narrow-spectrum antibiotics. Other antibiotics such as penicillin kill a variety of different bacteria. These are the broad-spectrum antibiotics.

Following the discovery of penicillin, many different naturally occurring antibiotics were discovered and still many others were synthesized. They were extremely successful in reducing many infectious diseases. Indeed, in the 1970s the prevailing view was that infectious diseases were a thing of the past. However, beginning in the 1970s and continuing to the present day, resistance to antibiotics is developing.

As of 2005, the problem of antibiotic resistance is so severe that many physicians and scientists think that the twenty-first century will initiate the "post antibiotic era." In other words, the use of antibiotics to control infectious bacterial disease will no longer be an effective strategy.

Resistance to a specific antibiotic or a class of antibiotics can develop when an antibiotic is overused or misused. If an antibiotic is used properly to treat an infection, then all the infectious bacteria should be killed directly, or weakened such that the host's immune response will kill them. However, if the antibiotic concentration is too low, the bacteria may be weakened but not killed. The same thing can happen if antibiotic therapy is stopped too soon. The surviving bacteria may have acquired resistance, which can be genetically transferred to subsequent generations of bacteria. For example, many strains of *Mycobacterium tuberculosis*, the bacterium that causes tuberculosis, are resistant to one or more of the antibiotics currently used to treat the lung infection. Some strains of the *Staphylococcus aureus* bacteria that causes boils, pneumonia, or bloodstream infections, are resistant to most (and with one strain, all) antibiotics.

SEE ALSO Anthrax; Bioterrorism; L-Gel decontamination reagent; Pathogens.

Antibody

Among the many techniques used in **forensic science** are those that involve the specific immunological recognition of a protein (the **antigen**). The protein molecule that recognizes an antigen is called an antibody.

An antigen-antibody reaction is exquisitely specific. This permits the unequivocal detection of a protein. As well, some antigen-based methods are highly sensitive, and so permit the quantification of very small amount of the protein antigen.

Antibodies are also referred to as immunoglobulins (Igs). Specific genes for antibodies direct the construction of antigen specific regions of the antibody molecule. Such antigen-specific regions are located at the ends of the arms of the Y-shaped immunglobulin molecule. The central core of the immunoglobulin is more constant in construction. Genetic engineering and the use of various mutational mechanisms allows the construction of a vast array of antibodies (each with a unique genetic sequence).

There are five different antibody types (Ig G, A, M, D, and E), each with a different Y-shaped configuration and function.

IgG is the most common type of antibody. It is the chief Ig against microbes. It acts by coating the microbe to hasten its removal by other **immune system** cells. It gives lifetime or long-standing immunity against infectious diseases. It is highly mobile, passing out of the blood stream and between cells, going from organs to the skin where it neutralizes surface bacteria and other invading microorganisms. This mobility allows the antibody to pass through the placenta of the mother to her fetus, thus conferring a temporary defense to the unborn child.

The antibody responsible for allergic reactions, IgE, acts by attaching to cells in the skin called mast cells and basophile cells (mast cells that circulate in the body). In the presence of environmental antigens like pollens, foods, chemicals, and drugs, IgE releases histamines from the mast cells. The histamines cause the nasal inflammation (swollen tissues, running nose, sneezing) and the other discomforts of hay fever or other types of allergic responses, such as hives, asthma, and in rare cases, anaphylactic shock (a life-threatening condition brought on by an allergy to a drug or insect bite). An explanation for the role of IgE in allergy is that it was an antibody that was useful to early man to prepare the immune system to fight parasites. This function is presently overextended in reacting to environmental antigens.

The presence of antibodies can be detected whenever antigens such as bacteria or red blood cells are found to agglutinate (clump together), or where they precipitate out of solution, or where there has been a stimulation of the plasma complement system. Antibodies are also used in laboratory tests, including the analysis of forensic samples, for blood typing and for the **identification** of target microorganisms or **toxins**.

The use of antibodies in forensic investigations is also called forensic **serology**. Blood typing is a common example of forensic serology. Here, antibodies against the A or B proteins that can be present on the surface of a blood cell are used to differentiate the four types of blood (A, B, AB, and O). If blood cells have only the A antigen present, then in the presence of the anti-A antibody, the cells can agglutinate. However, in the presence of anti-B antibody, which does not recognize the antigen, the cells will not agglutinate.

Antibodies are also used to discriminate blood from someone with a blood-related malady (i.e., sickle-cell anemia), based on the presence or one or more abnormal enzymes in the blood.

Other forensic serology applications include the detection of drugs, noxious compounds like toxins, and past exposure to specific microorganisms.

SEE ALSO Analytical instrumentation; Antigen; Biosensor technologies; Immune system.

Antigen

Antigens, which are usually proteins or polysaccharides, stimulate the **immune system** to produce antibodies. The antibodies inactivate the antigen and help to remove it from the body.

This ability of antigens to stimulate **antibody** production is very useful in forensic analyses. Detection of an antibody to a target molecule (**botulinum toxin**, for example) provides powerful evidence that a victim or suspect had been exposed to the particular antigen. In the case of a death, this evidence can help determine the course of events.

By definition, anything that makes the immune system respond to produce antibodies is an antigen. Antigens are living foreign bodies such as viruses, bacteria, and fungi that cause disease and infection. Or they can be dust, chemicals, pollen grains, or food proteins that cause allergic reactions.

Antigens that cause allergic reactions are called allergens. A large percentage of any population, in varying degrees, is allergic to animals, fabrics, drugs, foods, and products for the home and industry. Not all antigens are foreign bodies. They may be produced in the body itself. For example, cancer cells are antigens that the body produces. In an attempt to differentiate its "self" from foreign substances, the immune system will reject an organ transplant that is trying to maintain the body or a blood transfusion that is not of the same blood type as itself.

There are some substances such as nylon, plastic, or Teflon that rarely display antigenic properties. For that reason, nonantigenic substances are used for artificial blood vessels, component parts in heart pacemakers, and needles for hypodermic syringes. These substances seldom trigger an immune system response, but there are other substances that are highly antigenic and will almost certainly cause an immune system reaction. Practically everyone reacts to certain chemicals, for example, the resin from the poison ivy plant, the venoms from insect and reptile bites, solvents, formalin, and asbestos. Viral and bacterial infections also generally trigger an antibody response from the immune system. For most people penicillin is not antigenic, but for some there can be an immunological response that ranges from severe skin rashes to death.

Another type of antigen is found in the tissue cells of organ transplants. If, for example, a kidney is transplanted, the surface cells of the kidney contain antigens that the new host body will begin to reject. These are called human leukocyte antigens (HLA), and there are four major types of HLA subdivided into further groups. In order to avoid organ rejection, tissue samples are taken to see how well the new organ tissues match for HLA compatibility with the recipient's body. Drugs will also be used to suppress and control the production of helper/suppressor T-cells and the amount of antibodies.

Red blood cells with the ABO antigens pose a problem when the need for blood transfusions arises. Before a transfusion, the blood is tested for type so that a compatible type is used. Type A blood has one kind of antigen and type B another. A person with type AB blood has both the A and B antigen. Type O blood has no antigens. A person with type A blood would require either type A or O for a successful transfusion. Type B and AB would be rejected. Type B blood would be compatible with a B donor or an O donor. Since O has no antigens, it is considered to be the universal donor. Type AB is the universal recipient because its antibodies can accept A, B, AB, or O.

SEE ALSO Analytical instrumentation; Antibody; Anthrax, investigation of 2001 murders; Biosensor technologies; Immune system.

Archaeology

Forensic archaeologists use archaeological techniques to help solve or study crimes. The term forensic relates to the law, often describing material appropriate for presentation in court. Archaeology is the scientific study of the past through the analysis of materials (artifacts) and remains within their context, or surrounding area. Using a blend of many sciences, forensic archaeologists examine human skeletal remains and other materials to gather **physical evidence**. Not all sites examined by forensic archaeologists are linked to a crime or a court case.

A forensic archaeologist who is examining a site attempts to gather **evidence** about the events that took place at that site. They may seek answers to questions such as: who is buried here? Did the person die here or somewhere else? How many people were here? What materials did they leave behind? How old is this site? Is it related to another historical or criminal event? What other activities happened here?

Investigating both recent and historical events, the work of forensic archaeologists aids both law enforcement and historians. When studying historical sites, forensic archaeologists use many of the same investigative techniques as they do when examining present-day crime scenes. Forensic archaeologists have located sites of mass murder in Rwanda and the former Yugoslavia. They have investigated historical sites associated with the Holocaust. Law enforcement employed forensic archaeologists to investigate the World Trade Center site of the September 11, 2001, terrorist attacks in New York.

Forensic archaeologists employ in the field many of the same techniques that forensic anthropologists use in the lab. Often, forensic archaeologists work to recover information from the smallest of materials, such as a single hair, tooth, clothing fiber, or bone fragment. Modern medical and scientific investigative technologies aid their research. A forensic archaeologist may use CAT scans or x rays to examine ancient remains, such as **mummies**, without destroying them. **DNA** analysis is used to determine if or how remains found in close proximity are related to each other. They study human skeletal remains and teeth for clues about age, sex, health, trauma, and date and manner of death. For example, a forensic archaeologist may examine damage to a **skull** to determine that the victim died from a trauma to the head. They may even be able to tell what kind of weapon, from an ancient projectile point to a modern gun, inflicted the injury.

Forensic archaeologists also carefully scrutinize the area that surrounds remains. The relationship between remains and the environment in which they are found is known as context. They may use complex **remote sensing** technologies to look below ground and locate burials or other sites. Alternatively, a forensic archaeologist may use classical archaeological techniques such as using probes to feel for loose dirt, observing patterns of discolored surface soil, or surveying an area for abnormal surface features, like shallow depressions or small mounds.

SEE ALSO Ancient cases and mysteries; Anthropology; Careers in forensic science; Crime scene investigation.

Architecture and structural analysis

Since the collapse of the World Trade Towers in New York on September 11, 2001, there has been greatly increased emphasis on studies of structural analysis and the design of architecture able to withstand acts of terrorism. Historically, structural analysis has also been employed in the construction of biochemical, petrochemical, and industrial plants, in order that they might withstand accidental chemical explosions.

Since 9/11, buildings, and the sites upon which they are constructed, have become increasingly designed to withstand and minimize the devastating effects of terrorist weapons and bomb blast loads. In addition, emphasis has been placed on retrofitting existing structures, in order to make them less vulnerable to terrorist attack. Much structural analysis research (also called blast mitigation research) has been done since 9/11, with the goal of understanding the mechanisms and factors that cause structural damage in a blast, minutely characterizing the sequence of structural responses during a blast, and quantifying the likely effects on the human inhabitants of the building in the event of a blast. There are a variety of means of gathering this data: extensive study of the aftereffects of actual terrorist events (such as the World Trade Towers, the Murrah Building in Oklahoma City, the Pentagon, and the Khobar Towers bombing in Saudi Arabia), assessment of existing architecture, creating controlled explosions in experimental structures, and the use of **computer modeling** sequences.

There has been much forensic, architectural, and structural analysis of the debris remaining after the collapse of the World Trade Towers, in part because there was a general expectation that the structures should have been able to withstand the impact of the aircraft. The Towers were built between the mid-1960s and the early 1970s, and were intended as a model of modern architecture. They utilized modular construction, and were comprised of very lightweight materials. The World Trade Towers were squared; the width of each face measured 64 meters (209.97 feet). They spanned 411 meters (1348.43 feet) above street level, and were placed on foundations that reached 21 meters (68.90 feet) below the ground. The height to width ratio of the Towers was 6.8. Each Tower weighed approximately 500,000 tons (1,000,000,000 pounds), and was built to stand firm against hurricane wind force of 225 kilometers per hour (139.81 miles per hour) and to withstand a wind load of 2 kilopascals (41.77 pounds per square foot) and a lateral wind load of 5,000 tons (10,000,000 pounds). In order to meet all of the structural integrity requirements, the architecture comprised a "perimeter tube" design, containing 244 exterior columns of 36 centimeter square (1.18 feet) steel box sections on 100 centimeter (3.28 feet) centers. Inside each perimeter tube was a 27-meter (88.58 feet) by 40-meter (131.23 feet) core, which was designed to support the weight of the Tower. The elevators, stairwells, mechanical risers, and the utilities were also housed within the core. The core was attached to the perimeter at each floor level by web joists that were 80 centimeters (2.62 feet) tall; these were covered with concrete slabs used to create the floors of the structures.

This type of building design is often referred to as an egg crate structure; it is actually about 95% air and 5% solid material. In comparison, most other buildings constructed during the same era contained massive columns seated on 5 meter (16.40 feet) centers, with enormous amounts of masonry designed to carry the brunt of the structural load.

The "airiness" of the Towers was the reason that the rubble and debris left by the buildings' collapse only rose a few stories above the ground. The strength of the structures resulted from their redundancy; that is, the architecture was such that if a few columns were destroyed, the load would redistribute among the remaining columns, with no appreciable loss of structural integrity.

Each Tower contained more than 1,000 times the mass of the aircraft that crashed into it, and had been constructed to be able to withstand steady wind loads of 30 times the weight of each plane. Had the blasts been confined only to impacts, with no resultant fires, the Towers could probably have remained standing. The Towers' collapse resulted from the fires caused by the explosion, and resultant ignition, of approximately 90,000 liquid gallons of jet fuel. Initially, it was hypothesized that the heat of the fire melted the steel girders in the structures, causing the Towers to collapse. After forensic investigation and structural analysis, that was found to be incorrect. The fire caused by the blast was characterized as "diffuse and fuel-rich," meaning that the fuel and air mixed together in unpredictable and uncontrolled ways after the blast, and there was more fuel than there was fire. In fuel-rich fires, the excess fuel is heated, but unburned. This was apparent in the Trade Tower fires because of the copious amounts of thick, black smoke given off; which was a by-product of incompletely burned fuel. The structural analysts estimated that the temperature during the fire was in range of 750°C–800°C (1382°F–1472°F), which is generally too low to melt steel (requiring a minimum of 1,500°C or 2732°F). Structural steel starts softening at about 425°C (797°F), and its strength is halved at 650°C (1202°F). However, even loss of half their structural steel strength should not have caused the Towers to collapse. The critical issue was the uncontrolled nature of the fire: it caused differential buckling and structural distortion in some areas, leading to the buildings' collapse.

As the structural analysts reconstructed the scenario, using both direct examination of rubble and structural steel, computer modeling, and simulation scenarios, the perimeter tubes of the World Trade Towers were able to withstand the initial impacts of

Remains of the World Trade Center in New York after the September 11, 2001, terrorist attack. Scientists studied the remaining structural beams to help determine the mechanism of the buildings' collapse. © PAUL COLANGELO/CORBIS

the aircrafts, shifting loads from severed or damaged columns to those left standing. The extraordinary speed of the fire's spread generated very high heat, causing weakening, softening, twisting, and buckling of structural steel. The Towers' most vulnerable points were deemed by the analysts to be the angle clips connecting the floor joists between the core structure and the columns on the perimeter walls. As the joists fell away on the most seriously burned floors, the outer box columns began to bow outward. The outward bowing caused the affected floors to collapse and fall downward; it also caused the floors above them to implode downward, setting in motion a domino effect that caused the Towers to collapse vertically within approximately 10 seconds, hitting the ground at a velocity of about 200 kilometers (124.27 miles) per hour.

Overall, the analysts deemed the Towers did not contain structural defects; they were simply not created to withstand the intentional impact of airliners filled with incendiary jet fuel. Their conclusion: the buildings were impossible to save; rather than attempting to build terrorist impervious structures, it is more practical to focus on creating better emergency preparedness (communications, emergency response, and evacuation) systems.

SEE ALSO Aircraft accident investigations; Building materials; Computer modeling; Endothermic reaction; Exothermic reactions; Explosives; Fire debris; First responders; NTSB (National Transportation Safety Board).

Arson

Arson is typically defined as the malicious burning of property. It is important to understand that arson is a legal term, and the definition varies from one country to another or even between different states within a country. The Uniform Crime Report (UCR) of the Federal Bureau of Investigation defines arson as: "any willful or malicious burning or attempt to burn, with or without intent to defraud, a dwelling house, public building, motor vehicle or aircraft, personal property of another, etc." When a fire occurs, fire investigators, crime scene investigators, or forensic scientists are called to the scene to determine the origin and cause of the fire and the potential of arson.

The general definition of arson means that somebody deliberately or intentionally set fire to a property in order to destroy it, with a criminal intent. The person who decides to burn dead leaves in a backyard is normally not charged with arson, as it is his/her own property and there is no criminal intent. Criminal intent can be very broad. It includes gain of profit, fraud, persecution, or causing injury. The crime of arson is a very serious offense, punishable by several years of imprisonment. Also, there are some state's statutes, such as those in Georgia, which extend the crime of arson to fires that are accidentally created during the execution of a **felony**. These recent statutes were created in order to respond to the accidental fires and explosions that took place in neighborhood drug laboratories, such as methamphetamine labs. With these new statutes, law enforcement agencies and prosecutors can, for example, charge a criminal with arson if a house was burned down due to an accidental fire started during the manufacturing of methamphetamine. In intentional burnings, the charge of arson can extend in some states to the person who ordered the burning and not only to the person who actually performed the act of setting the property on fire.

Individuals who commit arson (arsonists) can be characterized in a variety of ways. About 90% of arsonists are men and about 50% are younger than 18 years old. Juvenile fire setters are a great concern, and several programs have been created in the United States to identify these juveniles and address their problem behaviors. There are different motives for committing arson and they are usually classified into categories, such as profit, spite, excitement, crime concealment, and vandalism.

Arson for profit includes all arsons committed with the expectation of obtaining a gain from the perpetrator (arsonist). It is important to note that the perpetrator does not necessarily need to obtain gain, but to show the intent that gain was going to be obtained. The gain can be direct or indirect. An example of direct gain would be the collection of the insurance money for the replacement of a burned house. Indirect gain would be an increase of business by eliminating (burning) the competitor who was doing business across the street. One of the most important arsons for profit committed in the United States is insurance fraud. This kind of criminal act is relatively widely spread in the United States. Some arsonists found it easier to burn their homes rather than to invest money to repair them. Also, when a vehicle arrives at the end of a lease and the mileage is excessive, arsonists have burned the car, simulating an accidental fire, rather than paying for the extra mileage.

Arson for spite is also known as arson for revenge. This type of arsonist wants to take revenge against a person, a group of persons, an organization or institution, or against society, in general. Some activist organizations for peace, or groups who fight violence against animals, for example, have regularly committed arson and destroyed laboratories or headquarters of research facilities for the sake of their cause.

Arson for excitement is committed by people who are bored, in need of attention, or sexually stimulated by the crime of arson. These criminals are considered dangerous, as they do not have a particular target, and will burn any place or thing that would fulfill their need for excitement, attention, or get them the recognition they think they deserve. Because of the random nature of excitement motivated arsons, when one arsonist commits several burning acts, they are often difficult to profile.

Arson for crime concealment is performed when criminals try to hide another crime. For example, after murdering an individual, the house is set on fire, destroying the body and much of the **evidence** of the **murder** activities. In some instances, a vehicle that was stolen for a joy ride or to commit another crime, such as a robbery, is set on fire in order to destroy evidence that would link the authors to the theft. Criminals are aware that fire is a powerful weapon to achieve destruction of evidence. Fortunately, there are many forensic techniques that have been developed throughout the years to retrieve different evidence, such as **blood** patterns or fingerprints, after a fire.

Arson for vandalism is typically performed by young criminals or juvenile fire setters for no apparent reason. Schools or educational facilities are often the target of such crimes.

In the United States, the crime of arson is typically first investigated by the fire department. The fire department is the first agency to be on scene to proceed with extinguishing the fire. The fire chief usually determines if the fire occurred among suspicious circumstances and if arson investigator needs to be called. If the fire is considered as arson, either the fire department pursues the investigation, or other law enforcement agencies are contacted for assistance. Most states have state fire marshal offices that specialize in arson investigation. Also, at the federal level,

Students at Centenary College (Hackettstown, New Jersey) observe burning patterns in several staged fires during an arson investigation course, taught by former Somerset County arson investigator Professor Norman Cetuk, March 4, 2004. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

the Bureau of Alcohol, Tobacco, Firearms (**ATF**), is also involved in arson investigation and has the greatest number of arson investigators at the federal level. The ATF also has several National Response Teams (NRT), which can travel to assist other law enforcement agencies. While most fires are in the jurisdiction of local authorities, there is one exception to this rule: church fires. In 1996, in order to respond to an increase in the number of deliberate church fires, President Bill Clinton formed the National Church Arson Task Force (NCATF). The goal of the NCATF was to allocate federal resources to the investigation of church fires around the country. The ATF and the **FBI** are the main agencies that investigate these fires. The NCATF coordinated investigations of 945 church arsons or bombings that occurred between January 1, 1995, and August 15, 2000, which led to the arrest of 431 suspects in connection with 342 incidents. This represents a clearance rate of about 36%, more than twice than the national average.

Arson is a serious problem in many countries and more particularly in the United States. This is reflected in local and national statistics. In 2003, there were 37,500 structure fires reported as arson in the U.S. These fires resulted in 305 deaths and 692 million dollars in damage. They represented approximately 3% of all structure fires that occurred in 2003 in the United States. In addition, there were about 30,500 vehicle fires reported as arson that resulted in a dollar loss of approximately 132 million dollars. Fortunately, these figures are in regression for the last ten years as there were 90,500 structure fires in the United States for the year 1995, resulting in 1.6 billion dollars of direct loss. The UCR reports approximately the same number of offenses for 2003, but adds the proportion of cleared offenses, which is 16.7%. It also specifies that arson occurs at the rate of 30.4 offenses per 100,000 inhabitants.

There are several organizations that provide programs and information or **training** to fight against the crime of arson. The National Fire Protection Association (NFPA) provides training documents and statistics for fire and arson investigators. The National Insurance Crime Bureau (NICB) provides statistics and training. The Insurance Committee for Arson Control (ICAC) provides publications and seminars to increase public awareness of the arson problem and help insurance companies fight the problem of arson.

SEE ALSO Accelerant; Fire debris; Profiling.

Art forgery

The imitation of works of art, from paintings to sculpture, has been carried out for hundreds of years. Students and followers have always made copies of the works of master artists as part of their instruction. There are many artists, both amateur and professional, who like to paint or draw in the style of those they admire. There is nothing morally wrong or illegal with this kind of copying or imitation. Art forgery, however, is different. It involves passing a copy of the artist's work off as created by the original artist, usually for financial gain. Where fraud or deception is involved, establishing whether a work of art is a forgery becomes a forensic investigation.

Art forgery can be extremely difficult to detect and investigate. There may be many forged works of art in museums and galleries around the world, and in private collections. Experts may be unaware if the forgery is accomplished cleverly, of the existence of a

Four old frescoes adorning the walls of St. Mary's Church in Luebeck, Germany, are considered expertly painted and "aged" forgeries. A German artist, Lothar Malskat, claimed they were painted by him in the 1950s. © BETTMANN/CORBIS

forged artwork, or they may be reluctant to admit they have been deceived. Sometimes the forger is more interested in getting the better of a dealer or collector than they are in their own financial gain. In such cases, transactions may be covered up and it is difficult to prove whether a criminal act has actually taken place.

For instance, the Spanish surrealist painter Salvador Dali (1904–1989) gave away around 20,000 blank sheets of paper with his signature, triggering a flood of forged Dali prints. Dealers would pay $2,000 to $20,000 for these fake prints. The art world also abounds with fake Picasso, Chagall, and Miró prints—to the extent that some experts are now reluctant to authenticate prints from certain modern artists because of the sheer volume of work it involves.

Distinguishing an authentic work of art from a forgery requires a blend of technical expertise and a profound knowledge of art history and the work of individual artists. Forgers do, however, often give themselves away even before laboratory analysis of their work begins. They often add an element of their own natural style, or they may unknowingly include some contemporary period detail that the historian will notice immediately. Art experts also comment on a "lack of freedom" to many forgeries, as the forger sometimes uses more rigid brush strokes or lines to capture details of the original work. After all, the thought processes of a grand master creating a work of art is quite different from those of someone far less talented who is merely trying to imitate him or her. Often this difference will spill out into the work, although the forger may not be aware of it.

A full analysis of a possible forgery, however, must rely on more than the expert opinion of an art historian. A laboratory analysis of the materials used to create the work is required, using techniques such as X-radiography and infrared reflectography. Modern artistic materials, such as paper, inks, and paints are different in composition today from those used hundreds of years ago. It is true that old materials can be re-created and used today, so one could, theoretically, fake a Rembrandt in the twenty-first century using seventeenth century style materials. However, the presence of acrylic paints, which first became available in the 1930s, would readily give away a Rembrandt fake. Rembrandt remains one of the most imitated artists of all time. To complicate matters, his signature is often found on works done by lesser artists. Works of art also age from the moment they are created owing to exposure to the atmosphere, handling, and other factors. The expert forger may try to artificially age his or her work to make it look as if it was created long ago.

Although many types of artwork are forged, the examination of a typical oil painting illustrates many of the general principles of detecting a forgery. A painting is composed of four layers: support, ground layer, paint layer, and varnish. The support is often made of wood or canvas. The analysis of a wood support can be very informative because modern fakes are often painted on older wood panels to make them look authentic. **Dendrochronology**, the examination of growth ring patterns, can sometimes be used to age the wood itself. X rays will penetrate to the wood layer and reveal the construction of a panel, including features like saw marks. Manual saws were used to make artists' supports before the introduction of mechanical saws during the nineteenth century Industrial Revolution. Manual saws leave characteristic uneven marks. If the investigator finds regular saw marks on a painting claimed to be of seventeenth century origin, this will be a strong indication of a fake.

The investigator might focus on the edge of the painting, using a special magnifier or infrared light to detect the nature of the ground layer. Such testing is non-destructive to the painting. Sometimes an invasive test might be carried out. This is not quite a bad as it sounds; a tiny pinprick is made in the painting, perpendicular to its surface and the sample extracted. If the sample is taken at the edge of a painting, or at an area that is already damaged, the harm done to the work is minimal. This cross-sectional sample can then by studied by x-radiography or microscopy to reveal all four layers and their composition. These can be compared with cross sections of authenticated work from the artist to see if there is a resemblance.

A technical examination of the paint layer can help to confirm a work's age and authenticity. The investigator will look at the materials themselves and how they were handled, which may be characteristic of the individual artist. The pigments that give paints their color have evolved over time and this history is quite well known. Earth colors, derived from **minerals** such as iron oxide came first, followed by greens (malachite), blues (azurite), and black (charred animal bone). Animal and vegetable dyes such as indigo and saffron also have a long history. The nineteenth century saw the introduction of synthetic dyes such as the anilines. These were far more chemically and physically stable. Analysis by visible **spectroscopy** can reveal the chemical composition of an organic pigment and x-ray analysis might be used for inorganic pigments such as titanium dioxide. If the pigments prove too modern for its alleged date, then there are various possibilities. The work may be a forgery, a genuine painting which has been touched up, or the dating may be in error.

Examination and **photography** of the paint layer with a microscope or magnifying glass, perhaps using light directed at an angle, is important. Surface irregularities may be observed, as well as features such as tiny particles arising from the use of hand-mixed pigments. Ready-mixed pigments, which have a smoother appearance, are a more modern development. Examination of the paint layer in ultraviolet light can show re-painted areas as dark spots. A re-paint is not necessarily a sign of forgery; some artists re-painted as a matter of course. If a re-paint is found in the work said to be of an artist who did not alter their work, then it is cause for suspicion. This may be a sign of a forger trying to correct a mistake. Similarly, infrared reflectography can reveal underdrawings in a painting. The paint layer is transparent to infrared light that passes through, but is absorbed by drawing lines beneath and reflected by the rest of the ground layer. This creates an image of the underdrawings in infrared light that can be photographed. While some artists would begin their work with a sketch used as a basis for the painting, others never did. The investigator would be alerted if an underdrawing was revealed in work alleged to come from one of the latter. Conversely, the lack of an underdrawing might be indicative of forgery, if it was said to come from an artist who never did them.

The aging of paint shows itself by a characteristic cracking pattern known as craquelure. Examination of the surface of the paint with a magnifying glass will reveal whether the extent of the craquelure matches the alleged age of the painting. Many paintings are varnished to protect them and enhance their appearance. Like paint, different varnishes have evolved over time. Ultra-violet light can distinguish between varnishes. Synthetic varnish gives a clear or lavender **fluorescence** (emission of light), while shellac fluoresces orange. Varnish discolors with time and this can also help date a painting.

Besides examining the four layers of a painting, the investigator will also look out for other significant signs of authenticity. Some manufacturers of artists' material marked their products with a stamp and there are databases giving information, including dates, of these stamps. The presence of collectors' marks or other signs that a painting has been owned, sold, exhibited, or framed can help establish the history of a work of art. Some artists signed their work and the forger may attempt to forge their signature. Strange as it may sound, a forger may create a copied artwork, complete with the artist's signature, quite legitimately. It is only when they offer this work for sale at an inflated price and attempt to represent the work as an original, that they enter the realms of forgery. The law on selling, buying, and owning forged works of art varies from country to country. Therefore, the amount of criminal investigation that will be carried out into a particular work depends upon context and circumstances. However, the forging of a certificate of authenticity to accompany the work of art is always considered a criminal offense, and can also be investigated by a forensic document examiner.

SEE ALSO Art identification; Document forgery; Paint analysis.

Art identification

The **identification** of works of art follows the same general procedures as detecting a forgery or determining the treatment needed to restore a damaged item. The technical specialist works with the art historian or curator to discover who was the actual executor of a particular painting, drawing, or sculpture. This kind of work is particularly significant when large sums of public money are to be committed to a major purchase for an art gallery. The question is often whether a newly discovered work, typically a painting, is really that of a well-known artist. It is not uncommon for such finds to be made in an antique shop or someone's attic. Determining their authenticity is a significant challenge for the investigating team. Often the claim proves to be unsubstantiated, but there is always a chance of discovering a lost or previously unknown Grand Master.

It is important to determine the history of the artwork under question in as much detail as possible. Sometimes this is difficult. Families may pass art collections down through generations and accompanying documentation can be lost. Paintings are stolen or lost and can disappear for many years. For instance, the upheavals of World War I and World War II led to the dispersal of many valuable artworks by looting. Some may have since been acquired by art dealers, museums, and private collectors, but questions remain as to their authenticity.

An important task in art identification is to compare the questioned item with examples from the artist's main body of work. This falls to the art historian, who has specialist knowledge of the artist's approach, themes, favorite materials, and techniques. The extent of technical examination needed depends very much on the context and circumstances—it can be relatively easy to disprove or prove authenticity in some cases, but other cases may be more challenging. The investigation begins with a visual investigation of the painting, accompanied by **photography** in normal, infrared, and ultraviolet light. Photographs are taken in front of the painting with both normal illumination and tangential illumination, the latter revealing surface irregularities.

A painting is generally made up of four distinct layers: the support; the ground, which serves as a foundation for the paint; the paint itself; and varnish. The materials used in each layer are often characteristic of the time of creation of the painting. Most old materials can be re-created, so their presence alone cannot confirm a painting's age. However, the presence of acrylic paint means a work that has been made in the twentieth or twenty-first century.

The support is usually made of wood or canvas. The age of wood such as oak can readily be determined by **dendrochronology**, which is the examination of tree rings. Canvas age can be solved by carbon-14 dating. When it comes to pigments, the presence of lead-tin yellow can always exclude the nineteenth century. This pigment was widely used in the fifteenth, sixteenth, and seventeenth century, but disappeared completely around 1850. It was rediscovered in 1941. Another yellow pigment that has been used in identification is cadmium yellow, which was introduced about 1800. In 1942, the St. Louis Art Museum bought a still life said to be by the Spanish master Francisco de Zurbaran (1598–1664). However, the discovery of cadmium yellow in the painting meant it could not date back to the seventeenth century.

The presence of underdrawings, as revealed by infrared reflectography, is an interesting aid to identification. The paint layer is transparent to infrared light, but it is absorbed by lines drawn on the ground layer. The rest of the infrared is reflected back by the ground. Thus an infrared photograph reveals any underdrawing that the artist may have done. The absence of underdrawings may be indicative of a forgery, because they may not be necessary if someone is just making a copy.

X-radiography can also reveal what is beneath the surface of a painting. The technique is not unlike the x rays that are used to examine the human body. Most elements of the paint layer are transparent to x-radiation, save for white pigments containing lead and vermilion, a red that contains mercury. X-radiography can show revisions and additions to the painting if these have been done with lead or mercury-containing pigments. It can also reveal the structure of the support, showing any marks that have been made in its construction.

In one well-known case, a painting long assumed to be a copy was identified as being authentic, thanks to technical testing. A small panel of the Virgin and Child first attributed to Jan Gossaert (1478–1532) had been consigned to the storerooms of the National Gallery in London because it had been decided it was only a copy, probably made in the eighteenth or nineteenth century. Further testing in 1994 involved studying the surface and cross-section samples in ultraviolet light. This showed re-painting and addition of a varnish layer had been done in the nineteenth century. However, there were older paint layers containing a red pigment from the sixteenth century. Dendrochronology showed the support to be equally old. Removal of the later paint and varnish restored the original Gossaert, which matched an engraved copy from 1589. The painting was the original in a group of six closely related paintings which survive.

SEE ALSO Art forgery; Holocaust, property identification; Paint analysis.

Artificial fibers

Investigation of a crime or accident scene involves the collection of **evidence**. This collection must be scrupulous; every piece of evidence is important in deciphering the course of events, identifying the victim, and in implicating a suspect.

One piece of evidence that can be important is **fibers**; the material that makes up clothing and other material. Even wigs may be comprised of fibers.

Fibers can be made of a natural material (i.e., wool) or a synthetic compound or blend. The differentiation of these fibers types can be important. For example, if a suspect was wearing rayon trousers, then it would be of interest to determine if the fibers found at the scene were rayon.

Most synthetic fibers are polymer-based, and are produced by a process known as spinning. This process involves extrusion of a polymeric liquid through fine holes known as spinnerets. After the liquid has been spun, the resulting fibers are oriented by stretching or drawing out of the fibers. This increases the polymeric chain orientation and degree of crystallinity, and has the effect of increasing the modulus and tensile strength of the fibers.

Fiber manufacture is classified according to the type of spinning that the polymer liquid undergoes: melt spinning, dry spinning, or wet spinning.

Melt spinning is the simplest of these three methods, but it requires that the polymer constituent be stable above its melting temperature. In melt spinning, the polymer is melted and forced through the spinnerets, which may contain from 50 to 500 holes. The diameter of the fiber immediately following extrusion exceeds the hole diameter. During the cooling process, the fiber is drawn to induce orientation. Further orientation may later be achieved by stretching the fiber to what is known as a higher draw ratio.

Melt spinning is used with polymers such as nylon, polyethylene, polyvinyl chloride, cellulose triacetate, and polyethylene terephthalate, and in the multifilament extrusion of polypropylene.

In dry spinning, the polymer is first dissolved in a solvent. The polymer solution is extruded through the spinnerets. The solvent is evaporated with hot air and collected for reuse. The fiber then passes over rollers, and is stretched to orient the molecules and increase the fiber strength. Cellulose acetate, cellulose triacetate, acrylic, modacrylic, aromatic nylon, and polyvinyl chloride are made by dry spinning.

In wet spinning, the polymer solution is spun into a coagulating solution to precipitate the polymer. This process has been used with acrylic, modacrylic, aromatic nylon, and polyvinyl chloride fibers. Viscose rayon is produced from regenerated cellulose by a wet spinning technique.

In a forensic examination, fibers are most easily collected using adhesive tape. The collected fibers are separated based on color and other appearance characteristics (i.e., wooly versus string-like).

Forensic analysis of fibers is conducted in several ways. Synthetic fiber polymers can be suited to examination using infrared **spectroscopy**. Specified guidelines exist for this type of examination, which makes the technique standard and so more easily legally admissible.

The constituents of the dye that has been used to color fibers can be separated using **chromatography**, which can separate compounds based on differences of size or charge.

Artificial fibers can also act as lenses, by virtue of the drawing out process of manufacture. Based on the optical properties of a fiber, shining a light on it will either focus the light towards the center or the edge of the fiber. This can aid in identifying the nature of a fiber sample.

SEE ALSO Crime scene investigation; Evidence; Fourier transform infrared spectrophotometer (FTIR).

David Robinson Ashbaugh

3/11/1946–
CANADIAN
FORENSIC SPECIALIST, POLICE OFFICER

David R. Ashbaugh has spent his career in the fields of law enforcement and **forensic science**, working as a sergeant and forensic identification specialist in Canada. He has focused his research and expertise on the science of ridgeology, a term Ashbaugh coined in 1982. He has written, lectured, and consulted extensively on ridgeology, and wrote a fundamental text on the subject, *Quantitative-Qualitative Friction Ridge Analysis*.

For more than thirty years, Ashbaugh has worked in law enforcement, most recently as a staff sergeant for the Royal Canadian Mounted Police and the detachment commander in Hope, British Columbia. In addition, he has worked for more than twenty years as a certified forensic identification specialist. Over these years, Ashbaugh has conducted extensive research on the science behind friction ridge identification. As a result, he is considered an expert in the field and has lectured and consulted on the topic internationally.

In 1983, Ashbaugh published the article "Ridgeology: Our Next Evaluative Step," in the *Royal Canadian Mounted Police Gazette*. With the article, he was using the word ridgeology for the first time. By Ashbaugh's definition, ridgeology was the process of friction ridge identification based on quantitative-qualitative analysis. The article marked the first of many papers and books Ashbaugh has written on the subject of ridgeology.

In 1999, Ashbaugh wrote and published *Quantitative-Qualitative Friction Ridge Analysis: An Introduction to Basic and Advanced Ridgeology*, a book considered to be an essential resource for latent print examiners. The book gives an overview of the history of friction ridge identification, as well as detailed discussions of ridgeology methods, including poroscopy, edgeoscopy, pressure distortion, and problem print analysis. Ashbaugh also includes the methodology he developed for palmar flexion crease identification.

Ashbaugh also serves as director of Ridgeology Consulting Services, a firm that provides friction ridge identification **training** for law enforcement officials. Among his many professional affiliations, he is a distinguished member of the **International Association for Identification**, a fellow of the Fingerprint Society of the United Kingdom, and an editorial board member of the *Journal of Forensic Identification.*

SEE ALSO Fingerprint analysis (famous cases); Ridge characteristics.

Aspermia

Aspermia, put plainly, describes the condition where there are no **sperm** present in the male **semen**. In fertile males with a completely functional reproductive system, the testes constantly produce sperm. Sperm cells are collected in the epididymus (a small sac connected to each testicle) and stored there until a later time when the male reaches orgasm and ejaculates. During the process of ejaculation, a thick, highly concentrated mass of sperm cells (approximately 100 million cells) from the epididymus travels through the vas deferens, a tubular passageway connecting the testicles to the prostate gland. In the prostate gland, sperm are mixed with a more fluid secretion from the prostate gland, seminal vesicles, and Cowper's gland, resulting in the ivory colored fluid (semen) that is released from the penis during ejaculation.

The function of the sperm cells is to provide male germ cells capable of fertilizing an egg. By far, the vast majority of cells present in semen are sperm cells from the testicles. The function of the glandular fluid is to provide a medium for transporting the sperm and an ideal environment in which the sperm cells can swim toward the egg.

From birth through early childhood, the testes naturally do not produce sperm. After the onset of puberty during adolescence, the sperm-producing cells of the testes normally become active, and remain active throughout most of adulthood.

Two common causes of aspermia in males are mechanical obstruction (usually in the vas deferens) and lack of sperm production in the testes. When the passageway between the testes and prostate gland is in some way disrupted, the testes may continue to produce sperm, but there is no physical means for the sperm to mix with glandular **fluids** and enter the ejaculate. Males may have natural obstructions or be born without a functional passageway joining the testes and the prostate gland. The vas deferens may intentionally be cut surgically in a procedure called a vasectomy as a means of birth control. Some mechanical forms of aspermia can be corrected surgically, and vasectomy is often reversible. In some males, sperm production never begins, or it may cease after a relatively short period of time.

The result of aspermia is that the semen does not contain any significant amount of cellular material and is therefore incapable of causing fertilization of an egg. Since the ejaculate in males with aspermia is not cellular, there is also very little **DNA** present that might be used in forensic testing. Males with aspermia are generally able to reach orgasm and ejaculate, however, and are typically, therefore, sexually active.

At **autopsy**, aspermia may provide clues to death caused by prolonged exposure to some **toxins**, such as thallium, which was used in rodenticides (rat poisons) before being banned. Also, aspermia identified

Man with his dead cattle after volcanic activity under Lake Nyos in Cameroon produced a cloud of carbon dioxide that asphyxiated 1,746 villagers and many animals in 1986. © PETER TURNLEY/CORBIS

in seminal fluids may help to exclude individuals in paternity issues, and can sometimes provide preliminary information about possible assailants in cases of rape.

SEE ALSO Paternity evidence.

Asphyxiation (signs of)

Asphyxiation is a term that describes death that occurs due to the lack of oxygen. This lack of oxygen affects the functioning of the brain, which in turn catastrophically affects the functioning of the remainder of the body.

Asphyxiation can be caused by a number of events. Strangulation, the deliberate squeezing of the neck, can cut off oxygen to the brain. Other accidental or deliberate means of asphyxia include suffocation, where air movement into the body through the nose and mouth is restricted. The classic movie murder image of someone being smothered by a pillow is an example of suffocation.

Another cause of asphyxiation is drowning, where the air in the lungs is replaced by water. The airway can also be blocked when a victim chokes on an object such as a small toy or piece of food. Finally, the airway can also be physically be blocked by hanging, when a person is suspended in the air by a rope or other object wrapped around their throat. Asphyxiation from hanging can occur quickly if the trachea is compressed, or can occur as a result of strangulation if the carotid arteries are compressed.

When investigating a suspected case of asphyxiation, a forensic investigator will look for telltale signs. For example, in the case of strangulation, neck injury could be evident when an **autopsy** is done on the victim. The squeezing of the neck, whether manually or via an object tied around the neck, can produce distinctive injuries. So will larynx injury resulting from blows to the neck.

Signs of suffocation-related asphyxiation such as strangulation can include bruises and fingernails scratches on the neck, bleeding around the throat, and in some cases, the fracture of the U-shaped hyoid bone at the base of the tongue. **Evidence** of suffocation may include small red or purple splotches in the eyes and on the face and neck as well as the lungs (petechial hemorrhages).

Asphyxiation may also produce foam in the airways as the victim struggles to breathe and mucus from the lungs mixes with air. This is especially typical in drowning. Other changes can include an enlarged heart and an altered **blood** chemistry.

By assessing these types of external or internal injuries, the forensic scientist can gain a better understanding if death resulted from asphyxiation and whether the asphyxiation was deliberate or accidental.

SEE ALSO Choking, signs of; Death, mechanism of; Hypoxia.

Assassination

Assassination is a sudden, usually unexpected, act of **murder**, typically with a political or military leader as its target. The practice of assassination goes back to ancient times, and extends into the present day. Assassinations have occurred throughout history, in places all over the globe. At one time, the most widely used tool for assassination was a knife or dagger. Modern day assassinations more often use guns, bombs, poisons, and biological agents such as **toxins**.

In the United States, the President has been a frequent target. In 1865 Abraham Lincoln became the first American president killed by an assassin's bullet, followed by James A. Garfield in 1881, William McKinley in 1901, and John F. Kennedy in 1963. Unsuccessful attempts were made on Franklin D. Roosevelt, Harry S Truman, Gerald Ford, and Ronald Reagan.

The assassination of Austrian Archduke Francis Ferdinand in 1914 precipitated World War I, and, 30 years later, the attempted assassination of Adolf Hitler by his generals very nearly ended World War II. In India, not only Mohandas K. Gandhi in 1948, but Prime Minister Indira Gandhi (no relation) in 1984, and her son and successor, Rajiv Gandhi in 1991, fell victim to assassin's bullets. Leaders in various countries throughout the Middle East have been killed by assassins: King Abdullah of Jordan in 1951, President Anwar Sadat of Eygpt in 1981, and Israeli Prime Minister Yitzhak Rabin in 1995 were all victims of assassination. Interestingly, all of these leaders were killed by extremists on their own political side. On the other hand, extremist leaders are as likely as any to become targets of assassins. Senator Huey Long of Louisiana was assassinated in the 1930s and Nation of Islam leader Malcolm X was killed 30 years later. George Lincoln Rockwell, leader of the American Nazi Party, and Pim Fortuyn, founder of a Dutch radical anti-immigrant party, were also slain by assassins.

Targets of assassination are not necessarily national leaders, formal office-holders, or even political leaders. When a Turkish assassin attempted to shoot Pope John Paul II in 1981, it was clearly a political act even though the pope was not a political leader per se. Martin Luther King and Robert Kennedy, both assassinated in 1968, were political leaders, but King held no formal office and Kennedy, although he was a senator and presidential candidate, symbolized a larger cultural atmosphere of optimism and activism. Furthermore, his status as John F. Kennedy's brother added greatly to the symbolic impact of the event.

In the aftermath of any assassination, **forensic science** may be used to try to determine the method of death and to identify those responsible. Forensic science is not concerned with the aims or the political implications of assassinations. Rather, the battery of tests and skills of the forensic investigators are geared toward deducing how the murder was carried out.

Even in an obvious case of an assassination by means of gunshot, a forensic investigation can possibly identify the firearm that was used. Furthermore, **ballistics** and **gunshot residue** studies can be used to implicate a suspect.

Forensic **identification** techniques for poisonous **inorganic compounds** and biological agents such as bacterial toxins can be valuable in unraveling the nature of assassinations that involve these harder to detect weapons.

SEE ALSO Assassination weapons, biochemical; Assassination weapons, mechanical; Kennedy assassination; Lincoln exhumation; Ricin; Sarin gas.

Assassination weapons, biochemical

Assassination is usually defined as politically inspired **murder**. The term is probably derived from the Arabic word for hemp (Hashish), which was apparently used by Hasan-ban-Sabah (c.1034–1124) to induce motivation in his followers. These "hashishins" or assassins were assigned to carry out political and other murders, usually at the cost of their own lives. Thus, at the etymological level, there is already a connection between assassination and compounds derived from nature.

Forensic science is often a part of the follow-up investigation in an assassination. The various forensic techniques and skills of the investigators are utilized to try to unravel the nature of the assassination. Their efforts may involve determining if a biochemical agent was involved and how the agent was delivered.

Knowledge of the possible biochemical agents that can kill someone are helpful in such an investigation. Various agents will have different physiological effects.

Biochemicals in the context of assassination involve mostly plant-derived drugs or **toxins**. They can be **organic compounds** such as alkaloids, diterpenes, cardiac and cynogenic glycosides, nitro-containing compounds, oxalates, resins, certain proteins, and amino acids. A selection of these biochemicals was effectively used in assassination attempts throughout history.

The ancient civilizations of the Near East, Greece, and Rome developed the use of poisons in political homicide to a high degree of efficiency. In classical Rome, mushroom poisons were expertly administered by Agrippina (A.D. 16–A.D. 59), wife of the Emperor Claudius and mother of Nero. She successfully disposed of several political rivals, including Marcus Silanus, who was to succeed Claudius, and eventually Claudius himself. Agrippina probably employed the properties of Amanita species, which contain amanitin polypeptides that produce degenerative changes in the liver, kidney, and cardiac muscles. In ancient Egypt, Queen Cleopatra, in her search for a suitable suicide compound, became familiar with the properties of henbane (*Hyoscyanus niger*) and belladonna (*Atropa belladonna*), although she judged death by these plants to be rapid, but painful. Cleopatra was also disappointed with *Strychnos nux-vomita* (a tree whose seeds yield strychnine). Strychnine causes stimulation of the central nervous system, produces generalized convulsions, and distorted facial features at death. The latter did not suit Cleopatra, who eventually settled for the bite of an asp (Egyptian cobra), which produced a more serene and prompt death worthy of a queen.

Hemlock is another notorious biochemical used in political murders. The hemlock plant contains coniine, an alkaloid, and was used to execute the Greek philosopher Socrates (c.479 B.C.–399 B.C.). The drug causes progressive motor paralysis extending upwards from the extremities until death results from respiratory failure. Some of the deadliest political poisons were concocted by the alchemists of the Middle Ages. La Cantrella was a secret assassination weapon used by Cesare Borgia (1476–1507) and Lucrezia Borgia (1480–1519) to dispatch their enemies. Even today its exact composition is not known, but it was most probably a mixture of naturally derived copper, arsenic, and crude phosphorus.

In later times, cyanide became more widely used as a homicidal poison. Today, cyanide is usually derived in large quantities from industry, but it has its source in biochemical processes involving cyanogenic glycosides. Amygdalin is one of the most widely distributed glycosides, yielding hydrocyanic acid (HCN) as a product of hydrolysis. It is present in the Rosaceae plant family and found in the seeds of apples, cherries, peaches, and plums. HCN inhibits the action of the enzyme cytochrome oxidase and prevents the uptake of oxygen by cells. As little as 0.06 g can cause death in humans. Consumption of a lethal dose of HCN is usually followed by collapse and death within seconds. As an assassination weapon, it was famously employed in the killing of the Russian monk Gregory Efimovich Rasputin (c.1872–1916). Legend has it that Rasputin's unnaturally strong constitution allowed him to ingest enough cyanide to kill six men, yet he continued to breathe and eventually received his *coup de grace* from a gun shot.

Ricin is found in the shell casing of castor beans and is easily produced, thus having the potential to be a large-scale murder weapon. Ricin came to public attention in 1978 when it was used in the assassination of Bulgarian dissenter Georgi Markov in the United Kingdom. Markov worked as a broadcaster for the British Broadcasting Corporation, and relayed pro-Western material to his communist homeland. Markov died several days after being jabbed by an umbrella at a bridge in London. The poison-tipped umbrella injector was designed by the Soviet intelligence agency KGB, whose Bulgarian agent carried the umbrella and delivered the ricin to the victim. An **autopsy** revealed that a platinum-iridium pellet the size of a pinhead had been implanted in Markov at the site of his injury. The pellet was cross-drilled with 0.016-inch (0.4-mm) holes to contain the ricin.

Ricin is an extremely toxic poison, and thus can kill even if applied in a small amount. The chemical is particularly deadly because it can be inhaled, ingested, or swallowed and is quickly broken down in the body and is virtually undetectable. There is currently no antidote to ricin, although a prospective vaccine has been developed that has been successfully tested in mice.

In the 1950s and 1960s Sidney Gottlieb (1918–), a talented chemist and poisons expert, worked for the United States Central Intelligence Agency (CIA). He also operated under the name Joseph Scheider. In the 1960s, Gottlieb was involved in various chemical and biochemical projects, none of which were apparently successful. Gottlieb created devices that could deliver poisons by which the CIA could carry out assassinations of political leaders who were assumed to be a threat to U.S. national security. One of these leaders was Fidel Castro, whose liking for Havana cigars was considered to be a possible means of administering poison pellets. Gottlieb is thought to have inserted poison into Havana cigars that were sent to Castro, but the cigars were somehow intercepted and never arrived. Gottlieb then tried to create a poisoned wetsuit, which Castro never wore. Another assassination attempt involving Gottlieb was planned by the CIA on General Abdul Karim Kassem of Iraq by planting a poisoned handkerchief in his suit pocket, but this plan also failed. Gottlieb adopted a slightly different tactic in the planned assassination of African leader Patrice Lumumba, the left-wing Prime Minster of the Congo (now Zaire). In September 1960, he constructed an assassination package that included a biological agent able to induce **tularemia** (rabbit fever), brucellosis (undulant fever), **anthrax**, **smallpox**, tuberculosis, and Venezuelan equine encephalitis (sleeping sickness). This agent was mixed with toothpaste and placed in a tube that could be slipped into Lumumba's traveling kit. Gottlieb delivered this package to Lawrence Devlin, the CIA station chief, instructing him to kill Lumumba. However, the operation also did not achieve its aim, as Lumumba's enemies in the Congo murdered him first in January 1961.

SEE ALSO Assassination weapons, mechanical; Kennedy assassination; Lincoln exhumation; Ricin; Sarin gas.

Assassination weapons, mechanical

The deliberate **murder** of a political leader, figurehead or other important person can be accomplished using the variety of weapons. Some means of **assassination** involve biological agents. Others use the brute mechanical force of guns, knives, and other hardware.

In the aftermath of an assassination, **forensic science** can be valuable in establishing the nature of the weapon used. For example, the trauma inflicted by a bullet and the chemical traces left by the residue are easily distinguished from a knife wound and its effects, such as the scouring of bone by the knife blade.

The various analytical forensic analysis techniques and skills of the forensic investigator can be used to ferret out the details of the assassination, such as the type of bullet used and the firearm that the bullet came from.

A forensic investigator can also benefit from knowledge of the operative principles of the various mechanical means of assassination. To varying degrees, all of these use the mechanical principles of force, pressure, and momentum, which are related through various ratios involving the fundamental physical interactions of mass, length, and time. Additionally, several are variations on the three classic "simple machines" of classical mechanics: the inclined plane (knife), the lever (the firing mechanism of a pistol), and the hydraulic press (some types of firing devices other than pistols).

Firearms also employ chemical properties. The gunpowder in a bullet undergoes a chemical, rather than a merely physical change. A physical change, such as the freezing of water, is reversible, but once gunpowder has chemically been altered by the addition of heat and the process of combustion brought about by interaction with oxygen, it turns into fire, smoke, and ash—and a fraction of it becomes energy—such that it can never become gunpowder again.

Mechanical firing devices can also be a means of deploying a poison. A classic example is the poison pen, most effectively employed by the Soviet KGB. Disguised as an ordinary writing pen, one such device fired hydrocyanic acid in the form of gas. Another KGB pen used as a weapon fired pellets of **ricin**, a poison long favored by agents in the assassination squad known as SMERSH.

SMERSH used variations on this technique to eliminate several Bulgarian dissidents living abroad in the 1970s. The most famous example of this occurred in London, where SMERSH caught up with journalist Georgi Markov in September 1978. As an unsuspecting Markov stood waiting in a crowd for a bus at Waterloo Bridge, a man walked past him and jabbed him in the thigh with the pointed end of his umbrella. Within a few days, Markov was dead. The man with the umbrella was a SMERSH assassin, and the pointed tip of his umbrella had fired a platinum pellet containing ricin. So clever was this method of murder that it took some time before Western intelligence operatives realized what had happened, and arranged for Markov's body to be exhumed. Only then did they discover the pellet.

In this and other such cases, a biochemical agent actually caused death, yet the method of delivery was mechanical. In the same way, poison that passes through a syringe (a hydraulic pump) into the victim's body is a biochemical weapon delivered by mechanical means. By contrast, when the Aum Shinrikyo cult employed ricin to kill 12 commuters, and injure thousands more, in a Tokyo subway in 1995, they used it in the form of gas—an almost purely biochemical technique. Victims inhaled the gas, which went to work immediately on their systems.

More conventional mechanical assassination weapons include bludgeons; knives and other sharp objects; guns and other firing devices; and miscellaneous weapons. An encyclopedic treatment of such weapons would fill an entire book, especially where guns are concerned. Therefore, the focus here is confined to weapons noted for their clever design or means of concealment that were developed by and for covert action organizations or similar groups. Even then, it is possible only to touch on a few notable examples.

Bludgeons and blunt instruments are used to deliver a blow when the victim and assassin are very close together. Forensically, the injury would be evident as a fractured **skull** or other signs of blows to other parts of the body.

Another mechanical weapon is a knife, edge weapon, or pointed instrument. All can deliver a cut or slash or sever a vital artery. Such assassination technology can be quite sophisticated. British special forces in World War II, for example, used the push dagger and the thrust weapon, both sharp instruments that are more like stakes or spikes than knives. Other British forces, serving as commandos in North Africa, employed a combination of knife and brass knuckles, by which the user could first stun the victim before using the knife.

As with most assassination weapons, concealment is a key issue. Hence, many units responsible for special operations in World War II used thumb knives, which were so small they could only be gripped with the thumb and forefinger. Their size made them easy to hide in the user's clothing, or even in a closed hand. Also during the war, the British Special Operations Executive (SOE) designed an ingenious knife kit for the U.S. Office of Strategic Services (OSS), the forerunner of CIA. The kit, made to fold up and fit neatly in a pocket, contained a plethora of knives and sharp instruments, ranging from a tiny knife painted a nonreflective black to a fierce-looking open-handled dagger.

There are also miscellaneous assassination devices that either combine aspects of the bludgeon and edge weapon, or use strangulation as a means of killing. A notorious example of the latter is the garrote, typically used when the killer is able to approach the victim unexpectedly from the back. Consisting of two handles joined by a thin, strong wire a little longer than a man's shoulders, the garrote is a highly effective low-tech weapon. Again, a pattern of injury that is produced that is distinctive to the instrument used. This can aid a forensic investigator in identifying the weapon utilized.

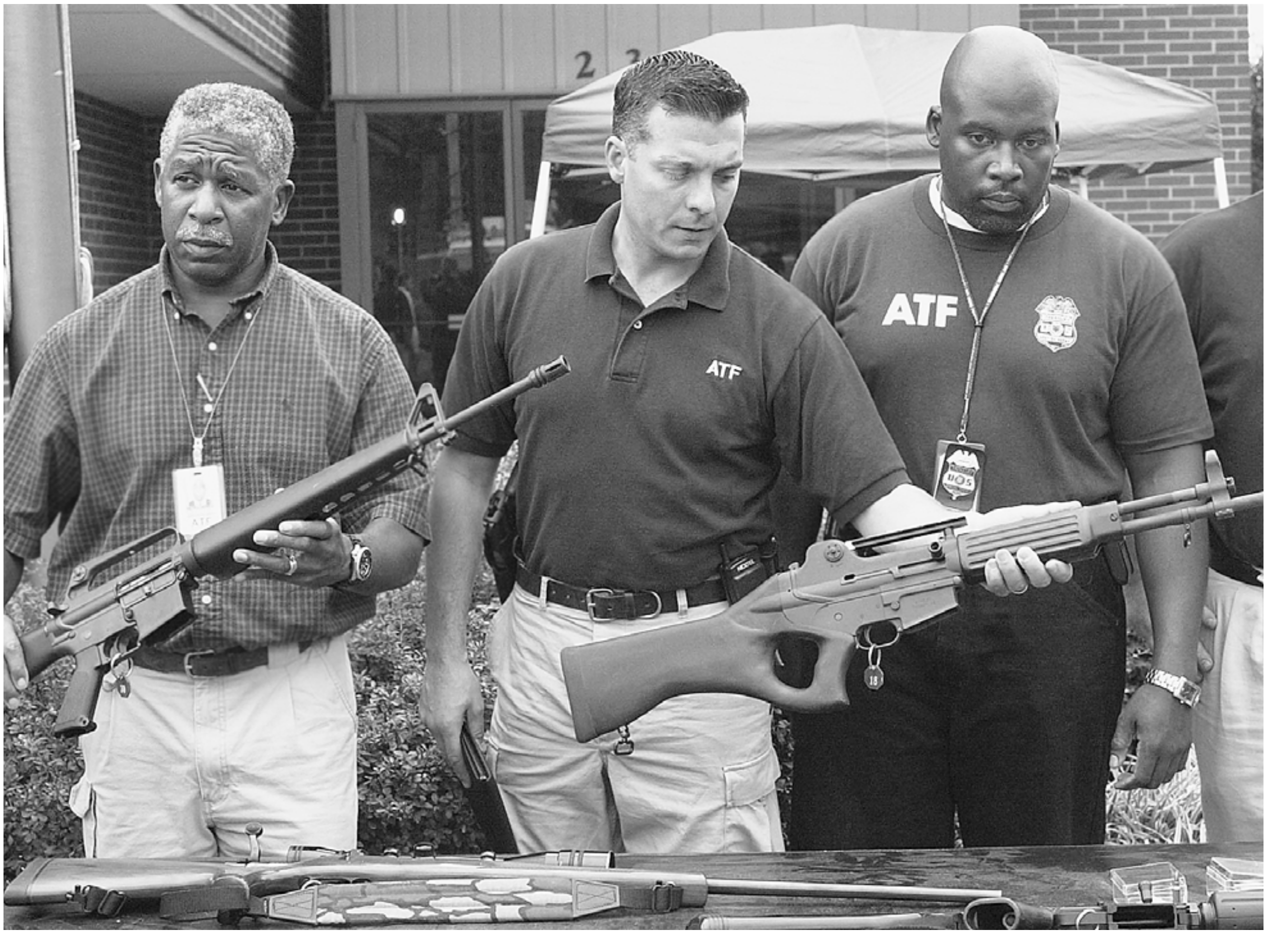
SEE ALSO Assassination weapons, biochemical; Kennedy assassination; Lincoln exhumation; Ricin; Sarin gas.

ATF (United States Bureau of Alcohol, Tobacco, and Firearms)

United States federal agencies, like The Bureau of Alcohol, Tobacco, and Firearms, and Explosives (ATF or BATF), can provide useful information in a forensic investigation. The ATF is responsible for enforcing federal law with regard to the sale and use of alcohol, tobacco, firearms, and explosives. In accordance with the Homeland Security Act of 2002, on January 24, 2003, the ATF was transferred from the Department of the Treasury to the Department of Justice. Though the Bureau has had authority over explosives since 1972, its name did not reflect this until its transfer in 2003; it still retains the initials ATF.

Although the ATF itself was created in 1972, at that time making it the youngest tax-collecting office of the Treasury Department, its roots go back to the founding days of the Republic. The order of items in its name corresponds to the order in which Treasury began to assume control over the items themselves: alcohol in the post-Revolutionary War era, tobacco around the time of the Civil War, and firearms during the Great Depression.

Alexander Hamilton, the first Secretary of the Treasury, suggested that Congress impose a tax on imported spirits to pay a portion of the debt incurred



Three Bureau of Alcohol, Tobacco and Firearms (ATF) agents, from left, Walter Dandridge, Joe Anarumo and Steve Gerido, display rifles as examples of the type of guns that could have been used in the Maryland sniper shootings, Rockville, Maryland, 10/04/2002.

in the War of Independence. Congress passed a resolution calling for such a tax, and in 1789 gave Treasury responsibility for collecting it. An Act passed in 1862 created the Office of Internal Revenue, whose responsibilities included the collection of taxes on spirits and tobacco products. Renamed the Bureau of Internal Revenue (BIR) in 1877, in 1886 it established a laboratory that in time would assume responsibility for analyzing a variety of alcohol and tobacco products, as well as firearms and explosives.

Following the passage of the Eighteenth Amendment, which banned the sale, distribution, and consumption of alcohol, Treasury in 1920 established the Prohibition Unit. The deeds of "revenuers" and "T-men" such as Eliot Ness in the years that followed would become legendary, as would the less admirable exploits of gangsters such as Al Capone. Nationwide concern over the violence associated with organized crime led to the passage of the National Firearms Act in 1934. Four years later, Congress passed the Federal Firearms Act, and BIR became responsible for collecting taxes on firearms.

After a number of changes in the section of BIR concerned with alcohol taxes, in 1940 this division became the ATU, or Alcohol Tax Unit. In 1942 Congress gave ATU responsibility for enforcing the Firearms Act.

Throughout much of the preceding century, BIR had included a Miscellaneous Tax Unit (MTU), which had responsibility for tobacco taxes and, between 1934 and 1942, taxes on firearms. In 1952, MTU was dismantled, and its firearms and tobacco tax functions fell under ATU. At the same time, BIR received a new name, one familiar to millions of Americans today: the Internal Revenue Service (IRS). ATU then came under IRS control as the Alcohol and Tobacco Tax Division, an arrangement that lasted for two decades.

In 1968, when Congress passed the Gun Control Act, the old BIR/IRS laboratory became responsible for analyzing firearms and explosives, and the Alcohol and Tobacco Tax Division became the Alcohol, Tobacco, and Firearms (ATF) Division. The 1970 passage of the Organized Crime Control Act made the role of the ATF Division more explicit, and signaled a shift away from IRS purview. On June 1, 1972, the Treasury Department issued Order No. 120-1, which separated the ATF from the IRS.

The order gave the new bureau authority not only over the three items listed in its name, but also over explosives. During the 1970s, ATF and its laboratory became involved in **arson** investigations, and in 1982, Congress amended Title XI of the Organized Crime Control Act to make arson a federal crime and formalize the ATF's role in investigating it.

During the 1990s and the beginning of the twenty-first century, the ATF undertook a number of new efforts toward fighting and investigating crime. Among these was the Integrated Ballistic Identification System, a computerized program for matching weapons and ammunition fired from them. In the mid-1990s, after its abortive 1993 raid on a Waco, Texas, compound controlled by the Branch Davidian cult, the bureau became the focus of hostility on the part of fringe right-wing groups.

By the turn of the twenty-first century, the ATF annually collected more than $13 billion in revenue for the federal government.

SEE ALSO Integrated Ballistics Identification System (IBIS).

Athletic souvenirs SEE Souvenirs from athletic events

Audio tape analysis SEE Tape analysis

Automated Fingerprint Identification System (AFIS)

The Automated Fingerprint Identification System (AFIS) is a computerized storage system for tens of millions of fingerprint images. The database picks out the most likely matches to the new print being fed into the system, narrowing the search parameters for investigators. Final analysis of the print and the retrieved images is done by AFIS Technicians to ensure accuracy of identification. The comparison takes the computer only minutes to do a job which would have taken weeks before computerization of the system.

Prior to the 1970s, trained officers analyzed inked fingerprints and various items were noted. Minutiae details, such as ridge endings, ridge dots, bifurcations, and enclosures would be coded and the fingerprint cards filed according to patterns (whorls, loops, arches) from the Henry classification system. This method meant that it could take weeks or months for a fingerprint to be processed, as the prints would have to be analyzed at a central fingerprint bureau.

In the late 1970s and early 1980s, an analog system combined manual coding with filing codes on computers. Trained staff would then check the current print against a short computer-generated list of hard-copy inked images. Still the process was laborious and only relieved when the AFIS database was released commercially to agencies in 1986. A barrage of private software vendors marketed their AFIS products, resulting in incompatible databases and a confused market. By 2005, a small number of companies had developed universal standard applications to bring together national databases for comprehensive libraries of prints, making the selection of software upon which to run the AFIS database easier for agencies.

Simon A. Cole, author of *Suspect Identities: A History of Fingerprinting and Criminal Identification* (2001) explains that the AFIS can work in three ways. Ten-prints (prints of all digits from one individual) lifted from a crime scene or a body can be checked against the database of catalogued ten-prints; a single latent print can be checked against the ten-print catalogue; and a ten-print from a scene can be checked against single latent prints stored in the database. "Unsolved" fingerprints can be stored in the AFIS system and automatically checked against with each new entry.

Fingerprint identification has become more scientific with the use of computers and portable scanners (the no-ink solution to fingerprint collection) than prior to the 1970s. The AFIS is an effective system for identifying people and establishing the criminal history of offenders. However, automated identification methods are not foolproof, and it still takes at least two experienced pairs of eyes to positively match current fingerprints with stored images.

SEE ALSO Fingerprint; Identification; Integrated automated fingerprint identification system; Latent fingerprint.

Automobile accidents

Automobile accidents are still a major source of injury to pedestrians, drivers, and passengers, although mortality has gone down owing to the introduction of seat belts and other safety measures such as air bags. The forensic investigator is usually called in when a crime, such as a hit and run incident, speeding, drunk driving, or even homicide, is suspected. An investigation is also necessary when insurance claims for damages by the injured parties arise from the accident. A medical examination and assessment of the injuries sustained in an automobile accident form a vital part of the total investigation of an automobile accident. The medical and **pathology evidence** can be integrated into **physical evidence**, such as tire marks or impact damage, at the scene of the accident to help reconstruct what happened before, during, and after the accident.

An automobile may collide with another vehicle or with a stationary object like a wall, lamppost, or a pedestrian. The amount of damage inflicted depends on many factors such as the weight, velocity, and condition of the vehicle; the state of the road; and the condition of the driver. Injuries occur when the momentum and kinetic energy of the vehicle are brought to zero on impact, since the energy is transferred to the skeleton and surrounding tissues of the victim(s). There are three types of victims in an automobile accident: pedestrians; cyclists (motor or pedal); and the occupants of the vehicle, be it the driver or front or back seat passenger(s). Most often, it is the pedestrian who is most vulnerable to injury in an automobile accident, particularly in areas where potential contact between pedestrians and vehicles is high, such as at crossings or in built-up areas. Pathologists note characteristic patterns of injuries in these different victim groups that can be very revealing about the circumstances of the accident.

Pedestrians generally suffer two kinds of injuries when they come into contact with moving vehicles. Primary injuries arise from contact with the vehicle itself. Secondary injuries occur when the impact with the car forces the pedestrian into contact with some other object or surface, such as the road itself. Often it is the secondary injuries that do the most damage and which are the cause of most fatalities arising from automobile accidents.

For an adult hit by a car, the bumper generally strikes them first, around knee level at the front, side, or back of the leg, depending on their location relative to the vehicle. Further contact, generally with the hood of the car, produces injuries further up the body, usually to the pelvis, thigh, or hip. If victims are hit by a larger vehicle, such as a truck, the corresponding primary injuries will be higher up the body. If a child is hit, then the primary injury pattern is also higher up the body. Older people and children are more vulnerable to being hit by a car because the former tend to be less mobile and the latter may not be sufficiently vigilant or able to judge the speed of an oncoming vehicle. What happens after the initial impact depends on how fast the vehicle is going. Up to 10 mph, the pedestrian will likely be thrown off the hood of the car onto the road. If the car is traveling up to 35 mph—just beyond the speed limit for most built-up areas—then the victim tends to pitch forwards on the hood and the victim's head may strike the windshield. At higher speeds, the victim may be flung into the air, over the car, and hit the road with some considerable force. A pedestrian who may survive a 30 mph impact with a car could well be killed if that same vehicle is traveling at 40 mph. The pathologist's evidence can be vital in accidents caused by speeding.

Automobile accidents produce a wide range of secondary injuries to pedestrians. Skidding across the road will produce extensive abrasions. Direct contact often causes fractures of the **skull**, spine, and limbs. It is usually the internal damage associated with such fractures that is lethal rather than the fracture itself. Brain damage, even without a skull fracture, is common if the moving head hits a road surface.

Being "run over" by a car is actually quite unusual. When it does occur, though, injuries can be very extensive. Their nature depends on what part of the body is involved, the speed of the vehicle, and its weight. The skull may be crushed, and internal organs disrupted. If the car runs over the victim's chest, there will be multiple fractures to the ribs. Sometimes the rotation of the wheel will strip off a huge area of the skin, giving rise to a characteristic "flaying" injury. Occasionally, someone is run over deliberately, but more often it happens when someone is knocked down accidentally and then run over if the car cannot stop in time.

Most automobile accidents involve the front or front sides of the vehicle. Those occurring by impact from behind or from the side, which may cause the car to roll over, are somewhat less common. The front seat occupants, if unrestrained by a seat belt, will continue moving as the car decelerates on

Kansas Highway Patrol troopers and Olathe firefighters work at the site of a fatal accident, near State Routes 10 and 7. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

impact. The head and face hit the windshield, possibly causing skull fractures and brain damage. The driver's chest and abdomen can hit the steering wheel, causing damage to the ribs, heart, and liver. The force of impact may even tear the body's main artery, the aorta, an injury that is generally fatal. The impact of the crash on the legs is transmitted upwards, potentially causing multiple fractures of the legs and pelvis. On very severe impacts, the front occupants may even be flung through the windshield to hit the road and sustain secondary injuries. On a fast-moving highway, such victims may be in danger of being run over by other vehicles. The back seat occupants are prone to similar, but usually less severe, injuries through impact with the front seats and the front seat occupants. If the impact is very severe, they may be flung through the windshield.

Seat belts, worn by both front and back seat occupants, have undoubtedly reduced fatalities from road traffic accidents. They work by preventing contact between the occupant's body and forward obstructions like the steering wheel and windscreen. They also spread the force of impact on the body and increase deceleration time slightly so that the force per unit area of body is less, which reduces the severity of any injuries. A seat belt also stops an occupant from being flung out of any doors or windows that burst open on impact. Airbags, a more recent development, provide a "cushion" between the vehicle and any object with which it collides. This also protects front seat occupants from injury. However, some critics have argued that the presence of an airbag produces a sense of complacency among drivers, making them less careful than they should be because they assume the air bag will protect them in the event of an accident.

Motorcyclists generally fall from their machine onto the road when in collision with another vehicle or object. This causes, at the very least, severe abrasions. Injuries to the limbs, chest, and spine are also common when the motorcyclist becomes entangled with the machine, which may fall on top of the motorcyclist, or with another object. Head injuries are a common cause of injury and death among motorcyclists involved in an accident, even if a helmet is worn. In many countries, a helmet is compulsory and its presence or absence may be a factor in any criminal case or litigation. But, protective clothing and a good helmet can go a long way to reducing the severity of injury to motorcyclists in an accident.

Most bicycles travel at relatively low speeds, which means that most injuries sustained in an accident are mild to moderate. However, collision with a vehicle traveling at low speed may well produce fatal injuries if the cyclist is thrown against the vehicle and then falls onto the road. Cycles are inherently unstable and even the most gentle of collisions is likely to make the rider fall off, potentially into the path of a moving vehicle, when they may be "run over" and sustain severe, and potentially fatal, internal injuries.

Whatever the type of victim, be it pedestrian, car occupant, or cyclist, the principles of the forensic medical exam are the same. The investigator will first, of course, offer medical assistance to living victims. Then an external exam is done to note all the injuries, recording, measuring them with a ruler and taking photographs. Sometimes tire marks are present in the form of bruising or abrasions and these can be helpful in identifying the vehicle used by a hit and run driver. The victim's clothing should also be examined for **trace evidence**, such as **glass**, paint, or rust, which might help identify the vehicle involved. It is always possible that alcohol or drugs have contributed to the accident and **blood** samples are often taken from the victim and drivers, if they are present, for laboratory analysis.

SEE ALSO Accident reconstruction.

Automobile crash investigations

SEE Airbag residues

Autopsy

Autopsy means "see for yourself." It is a special surgical operation, performed by specially trained physicians, on a dead body. Its purpose is to learn the truth about the person's health during life, and how the person died.

There are many advantages to getting an autopsy. Even when the law does not require it, there is always something interesting for the family to know—something worth knowing that wasn't known during life is often found. Even at major hospitals, in approximately one case in four, a major disease is found that was unknown in life. Giving families the explanations they want is often stated as one of the most satisfying things that a pathologist does. A pathologist is a physician with a specialty in the scientific study of body parts. This specialty always includes a year or more learning to do autopsies.

Under the laws of most states, an autopsy can be ordered by the government. The job of **coroner** is a political position, while a **medical examiner** is a physician, usually a pathologist. Exactly who makes the decisions, and who just gives advice, depends on the jurisdiction. Autopsies can be ordered in every state when there is suspicion of foul play. In most states, an autopsy can be ordered when there is some public health concern, for example a mysterious disease or a worry about the quality of health care. In most states, an autopsy may be ordered if someone dies unattended by a physician (or attended for less than 24 hours), or if the attending physician is uncomfortable signing the death certificate. If autopsy is not required by law, the legal next-of-kin must sign an autopsy permit.

When a loved one dies, a family can ask the hospital to perform an autopsy. If the family prefers, a private pathologist can do the autopsy in the funeral home. It does not matter much whether the body has been embalmed first. Whoever does the autopsy, there should not be a problem with an open-casket funeral afterwards. This is true even if the brain has been removed and the dead person is bald. The pillow will conceal the marks.

Most religions allow autopsy. If the body is that of an Orthodox Jew, pathologists are happy to have a rabbi present to offer suggestions. Many Muslims prefer not to autopsy.

Here's how an autopsy is done. In this example, there are three pathologists working together.

The body has already been identified and lawful consent obtained.

The procedure is done with respect and seriousness. The prevailing mood in the autopsy room is curiosity, scientific interest, and pleasure at being able to find the truth and share it. Most pathologists choose their specialty, at least in part, because they like finding the real answers. Many autopsy services have a sign, "This is the place where death rejoices to teach those who live." Usually it is written in Latin: *Hic locus est ubi mors gaudet succurrere vitae.* Autopsy practice was largely developed in Germany, and an autopsy assistant is traditionally called a "diener," which is German for "servant."

The pathologist first examines the outside of the body. A great deal can be learned in this way. Many pathologists use scalpels with rulers marked on their blades. The body is opened using a Y-shaped incision from shoulders to mid-chest and down to the pubic region. There is almost no bleeding, since a dead body has no blood pressure except that produced by gravity. If the head is to be opened, the pathologist makes a second incision across the head, joining the bony prominences just below and behind the ears.

When this is sewn back up, it will be concealed by the pillow on which the dead person's head rests.

The incisions are carried down to the **skull**, the rib cage and breastbone, and the cavity that contains the organs of the abdomen. The scalp and the soft tissues in front of the chest are then folded back. Again, the pathologist looks around for any abnormalities.

One pathologist prepares to open the skull using a special vibrating saw that cuts bone but not soft tissue. This is an important safety feature. Another pathologist cuts the cartilages that join the ribs to the breastbone, in order to be able to enter the chest cavity. This can be done using a scalpel, a saw, or a special knife, depending on the pathologist's preferences and whether the cartilages have begun to turn into bone, as they often do in older people. The third pathologist explores the abdominal cavity. The first dissection in the abdomen usually frees up the large intestine. Some pathologists do this with a scalpel, while others use scissors.

The skull vault is opened using two saw cuts, one in front, and one in back. These will not show through the scalp when it is sewn back together. The top of the skull is removed, and the brain is very carefully cut free of its attachments from inside the skull.

When the breastbone and attached rib cartilages are removed, they are examined. Often they are fractured during cardiopulmonary resuscitation. Freeing up the intestine takes some time. The pathologist carefully cuts along the attachment using a scalpel.

The chest organs, including the heart and lungs, are inspected. Sometimes the pathologist takes blood from the heart to check for bacteria in the blood. For this, he or she uses a very large hypodermic needle and syringe. The team may also find something else that will need to be sent to the microbiology lab to search for infection. Sometimes the pathologist will send blood, urine, bile, or even the fluid of the eye for chemical study and to look for medicine, street drugs, alcohols, and/or poisons.

Then the pathologist must decide in what order to perform the rest of the autopsy. The choice will be based on a variety of considerations. One method is the method of Virchow, which is removing organs individually. After the intestines are mobilized, they are opened using special scissors. Inspecting the brain often reveals surprises. A good pathologist takes some time to do this. The pathologist examines the heart, and generally the first step following its removal is sectioning the coronary arteries that supply the heart with blood. There is often disease here, even in people who assumed their hearts were normal.

After any organ is removed, the pathologist will save a section in preservative solution. Of course, if something looks abnormal, the pathologist will probably save more. The rest of the organ goes into a **biohazard bag**, which is supported by a large plastic container.

The pathologist weighs the major solid organs (heart, lung, brain, kidney, liver, spleen, sometimes others) on a grocer's scale. The smaller organs (thyroid, adrenals) get weighed on a chemist's triple-beam balance. The next step in this abdominal dissection will be exploring the bile ducts and then freeing up the liver, usually using a scalpel. After weighing the heart, the pathologist completes the dissection. There are a variety of ways of doing this, and the choice will depend on the case. If the pathologist suspects a heart attack, a long knife may be the best choice.

The liver has been removed. In our example of a fictitious autopsy, the pathologist finds something important. It appears that this man had a fatty liver. It is too light, too orange, and a bit too big. It is possible that this man had been drinking alcohol heavily for a while. The liver in this case weighs much more than the normal 49.4 ounces (1400 gm).

The pathologist decides to remove the neck organs, large airways, and lungs in one piece. This requires careful dissection. The pathologist always examines the neck very carefully. The lungs are almost never completely normal at autopsy. These lungs are pink, because the dead man was a nonsmoker. The pathologist will inspect and feel them for areas of pneumonia and other abnormalities. The pathologist weighs both lungs together, then each one separately. Afterwards, the lungs may get inflated with fixative. Dissecting the lungs can be done in any of several ways. All methods reveal the surfaces of the large airways, and the great arteries of the lungs. Most pathologists use the long knife again while studying the lungs. The air spaces of the lungs will be evaluated based on their texture and appearance.

The liver is cut at intervals of about a centimeter, using a long knife. This enables the pathologist to examine its inner structure.

The rest of the team continues with the removal of the other organs. They have decided to take the

A chief medical examiner in Texas performs an autopsy, initially searching for signs of external injury, providing a physical description of the body, and documenting any external substances collected for further testing. © SHEPARD SHERBELL/CORBIS SABA

urinary system as one piece, and the digestive system down to the small intestine as another single piece. This will require careful dissection. One pathologist holds the esophagus, stomach, pancreas, duodenum, and spleen. He will open these, and may save a portion of the gastric contents to check for poison. Another pathologist holds the kidneys, ureters, and bladder. Sometimes these organs will be left attached to the abdominal aorta. The pathologist will open all these organs and examine them carefully.

Before the autopsy is over, the brain is usually suspended in fixative for a week so that the later dissection will be clean, neat, and accurate. If no disease of the brain is suspected, the pathologist may cut it fresh.

The kidneys are weighed before they are dissected.

When the internal organs have been examined, the pathologist may return all but the portions they have saved to the body cavity. Or the organs may be cremated without being returned. The appropriate laws and the wishes of the family are obeyed.

The breastbone and ribs are usually replaced in the body. A pathologist prepares a large needle and thread used to sew up the body. The skull and trunk incisions are sewed shut ("baseball stitch"). The body is washed and is then ready to go to the funeral director.

The pathologists will submit the tissue they saved to the histology lab, to be made into microscopic slides. When the slides are ready, the pathologists will examine the sections, look at the results of any lab work, and draw their final conclusions.

The only finding in this imaginary autopsy was fatty liver. There are several ways in which heavy drinking, without any other disease, can kill a person. The pathologists will rule each of these in or out, and will probably be able to give a single answer to the police or family.

A final report is ready in a month or so. The glass slides and a few bits of tissue are kept forever, so that other pathologists can review the work.

SEE ALSO Anatomical nomenclature; Body Farm; Coroner; Death, cause of; Death, mechanism of; Decomposition; Identification; Medical examiner; Pathology; Pathology careers; Rigor mortis; Time of death; Toxicological analysis.

Autorad

Autorad is short for autoradiograph, the final result in a **DNA** analysis. An autorad resembles a bar code or a ladder and each different DNA sample will give a different pattern on an autorad. Therefore, an autorad can be an important piece of **identification evidence** in a forensic investigation. Autorads are also sometimes known as DNA fingerprints.

The procedure for creating an autorad has to be meticulously followed if the end result is to be of value in identification of a criminal. Thanks to advances in DNA technology, it is now possible to extract meaningful results from even tiny samples of DNA. The first step is to use specific chemical reagents to remove the DNA from the sample, be it **blood**, hair, or some other tissue. This depends on breaking down cell membranes and digesting proteins in the cell so the DNA can be released in a "clean" form ready for analysis.

DNA is a very long molecule and its analysis depends on chopping it into segments of a more manageable size. This is done using enzymes that produce a mixture of segments that are characteristic of the DNA in the sample. DNA from suspect A will give a mixture of segments of different lengths from the DNA of suspect B. The segments are then separated by first applying the mixture of segments to a slab of gel to which an electric current is applied. Shorter segments move faster through the gel than do longer segments. This creates the bar code pattern, but at this stage it is still invisible.

The pattern on the gel is transferred to a nylon membrane that is then exposed to radioisotopes. These attach to the DNA segments. The nylon membrane is now placed between two sheets of x-ray film and photographed. The segments now show up dark, through exposure to the film, and the familiar bar code pattern can be clearly seen. To make a comparison, DNA from a sample from the scene of the crime would be placed on the gel alongside DNA taken from a suspect, from their **saliva** or blood, for example, as well as with reference lab samples of DNA. The samples run in parallel. If the crime scene DNA is that of the suspect, then the two corresponding autorads will appear identical. If they do not, then this piece of evidence, at least, eliminates the suspect, although there may be other evidence linking the suspect to the crime.

SEE ALSO DNA fingerprint; DNA isolation methods; DNA profiling.

Aviation security screeners, United States

Forensic investigations attempt to determine the cause of accidents and even to reconstruct (at least conceptually) the course of events leading up to and including the incident. In the case of an aircraft accident, where much of the **evidence** may be destroyed or damaged by a crash, the task is particularly challenging. Analysis of all data complied before and during the flight is useful in piecing together what occurred.

Analysis of the flight data recorder that is installed on many aircraft is a well-known forensic tool. However, air travel security technologies, which are in place principally to thwart aircraft high-jacking and terrorist opportunities, can also provide information useful to a forensic investigation.

One such technology involves the security screening that is a part of the pre-flight process. Aviation security screeners focus on both the passenger and luggage. Airline passengers are familiar with walking through a metal detector and having security personnel examiner them more closely using a handheld metal detector. More recently, a walk-through machine has been introduced that can analyze the air flowing off of a person's body. The air can be rapidly analyzed, enabling the detection of non-metallic chemicals, which would otherwise escape the metal detector. The odor of the chemicals wafts off of the body along with the plume of heated air. Suspicious chemicals, such as those in plastic **explosives**, may be detected in this way.

Another routine part of air travel is the examination of carry-on and shipped baggage using an x-ray machine. The high energy x rays are able to penetrate through the suitcase to reveal the outline of the objects inside. A skilled operator is able to assess the contents based on their shape and translucency and focus on suspicious objects.

Chromatography is also routinely used to survey personal computers to verify that the computer case is not in fact housing an explosive. The object to be examined is swabbed using a fabric, which is then inserted into the chromatograph. The analysis takes only a few seconds to complete.

Documentation is another aspect of security screening. For example, passports provide an officially sanctioned photographic record and other information from a person. Concerns about the falsification of passports has led to the adoption of other documentation systems, including **fingerprint** and retinal scans.

Prior to the terrorist attacks of September 11, 2001, security screening at the more than 400 major commercial airports around the United States was the work of personnel employed by private firms that contracted with airlines. One outcome of the attacks was the Aviation and Transportation Security Act (ATSA), signed into law by President George W. Bush on November 19, 2001, which placed security screeners under the control of the newly created Transportation Security Administration (TSA). Early assessments of the new program were uneven, and TSA has encountered a number of challenges in what has proven to be one of the largest mobilizations of a civilian agency in U.S. history.

The fact that ATSA was written and passed just two months after the terrorist attacks serves to indicate the intensity of concern over air safety that prevailed in early fall of 2001. In fact, the bill would have passed even more quickly if it had not been for the thorny question of whether the government or private enterprise should control security screeners—and,

A security screener stands by a detection unit at JFK Airport in New York that provides explosive detection via a walk-through portal. The unit can detect particles and vapors of explosive materials by passing air over a person to release such particles. © RAMIN TALAIE/CORBIS

assuming government control, whether Transportation or Justice was the department better suited for this task.

As of January 2002, TSA had just 13 employees, but by November 2002, a year after the passage of ATSA, there were 47,000 newly trained federal security screeners at airports nationwide. TSA spokesman Robert Johnson compared the mobilization to the rush of enlistees that followed U.S. entry into World War II in December 1941. Others were not as sanguine in their appraisal. Representative Harold Rogers (R-KY) maintained that the average screener at his home facility, Kentucky Bluegrass Airport in Lexington, processed just four people per hour.

All checked bags are supposed to be screened for bombs by TSA workers as of December 31, 2002. Screeners earlier began a practice of matching bags to passengers—that is, ensuring that for each name listed as the owner of the bag, there was a passenger with that name. Bag matching had been a practice on international flights since the 1980s, but many critics maintained that it would do nothing to stop suicide bombers such as those who perpetrated the September 11, 2001, attacks.

Much of the information used for aviation security screening is part of databases. Proof of citizenship is one well-known example. As well, the data collected in luggage and passenger pre-boarding security checks can be maintained for a set period of time. If the latter records are still available, a forensic inspector is able to trace the pre-boarding history of each passenger.

SEE ALSO Air plume and chemical analysis; Aircraft accident investigations; Biometric eye scans; Explosives; Flight data recorders; Gas chromatograph-mass spectrometer; Metal detectors.

B

Bacteria, classification

The shapes of bacterial cells, often of keen interest to forensic investigators, are classified as spherical (coccus), rodlike (bacillus), spiral (spirochete), helical (spirilla), and comma-shaped (vibrio) cells. Many bacilli and vibrio bacteria have whiplike appendages (called flagella) protruding from the cell surface. Flagella are composed of tight, helical rotors made of chains of globular protein called flagellin, and act as tiny propellers, making the bacteria very mobile. On the surface of some bacteria are short, hairlike, proteinaceous projections that may arise at the ends of the cell or over the entire surface. These projections, called fimbriae, facilitate bacteria adherence to surfaces.

Other proteinaceous projections, called pili, occur singly or in pairs, and join pairs of bacteria together, facilitating transfer of **DNA** between them.

Oxygen may or may not be a requirement for a particular species of bacteria, depending on the type of metabolism used to extract energy from food (aerobic or anaerobic). Obligate aerobes must have oxygen in order to live. Facultative aerobes can also exist in the absence of oxygen by using fermentation or anaerobic respiration. Anaerobic respiration and fermentation occur in the absence of oxygen, and produce substantially less ATP than aerobic respiration.

During periods of harsh environmental conditions some bacteria can produce within themselves a dehydrated, thick-walled endospore. These endospores can survive extreme temperatures, dryness, and exposure to many toxic chemicals and to radiation. Endospores can remain dormant for long periods (hundreds of years in some cases) before being reactivated by the return of favorable conditions.

Pathogens are disease-causing bacteria that release **toxins** or poisons that interfere with some function of the host's body.

An understanding of the basic classification of bacteria found at crime scenes and taken from bodies at **autopsy** is critical to forensic investigators (including forensic epidemiologists) attempting to identify bacteria. The **identification** schemes of *Bergey's Manual* are based on morphology (e.g., coccus, bacillus), staining (gram-positive or negative), cell wall composition (e.g., presence or absence of peptidoglycan), oxygen requirements (e.g., aerobic, facultatively anaerobic) and biochemical tests (e.g., which sugars are aerobically metabolized or fermented).

Another important identification technique is based on the principles of antigenicity—the ability to stimulate the formation of antibodies by the **immune system**. Commercially available solutions of antibodies against specific bacteria (antisera) are used to identify unknown organisms in a procedure called a slide agglutination test. A sample of unknown bacteria in a drop of saline is mixed with antisera that has been raised against a known species of bacteria. If the antisera causes the unknown bacteria to clump (agglutinate), then the test positively identifies the bacteria as being identical to that against which the antisera was raised. The test can also be used to distinguish between strains of slightly different bacteria belonging to the same species.

SEE ALSO Anthrax; Bacterial biology; Bacteria, growth and reproduction; Bacterial resistance and response to antibacterial agents; Biological weapons, genetic identification; Biosensor technologies; Bubonic plague; Decontamination methods.

Bacteria, growth and reproduction

Forensic scientists often **culture** and grow bacteria found at crime scenes or extracted from remains. This process is often necessary to achieve a large enough population of bacteria upon which tests can then be performed.

An understanding of how bacteria grow, multiply, and change over time also helps explain many field or **autopsy** findings.

A population of bacteria in a liquid medium is referred to as a culture. In the laboratory, where growth conditions of temperature, light intensity, and nutrients can be made ideal for the bacteria, measurements of the number of living bacteria typically reveals four stages, or phases, of growth, with respect to time. Initially, the number of bacteria in the population is low. Often the bacteria are also adapting to the environment. This represents the lag phase of growth. Depending on the health of the bacteria, the lag phase may be short or long. The latter occurs if the bacteria are damaged or have just been recovered from deep-freeze storage.

After the lag phase, the numbers of living bacteria rapidly increases. Typically, the increase is exponential. That is, the population keeps doubling in number at the same rate. This is called the log or logarithmic phase of culture growth, and is the time when the bacteria are growing and dividing at their maximum speed.

The explosive growth of bacteria cannot continue forever in the closed conditions of a flask of growth medium. Nutrients begin to become depleted, the amount of oxygen becomes reduced, the pH changes, and toxic waste products of metabolic activity begin to accumulate. The bacteria respond to these changes in a variety of ways to do with their structure and activity of genes. With respect to bacteria numbers, the increase in the population stops and the number of living bacteria plateaus. This plateau period is called the stationary phase. Here, the number of bacteria growing and dividing is equaled by the number of bacteria that are dying.

Finally, as conditions in the culture continue to deteriorate, the proportion of the population that is dying becomes dominant. The number of living bacteria declines sharply over time in what is called the death or decline phase.

Bacteria growing as colonies on a solid growth medium also exhibit these growth phases in different regions of a colony. For example, the bacteria buried in the oldest part of the colony are often in the stationary or death phase, while the bacteria at the periphery of the colony are in the actively-dividing log phase of growth.

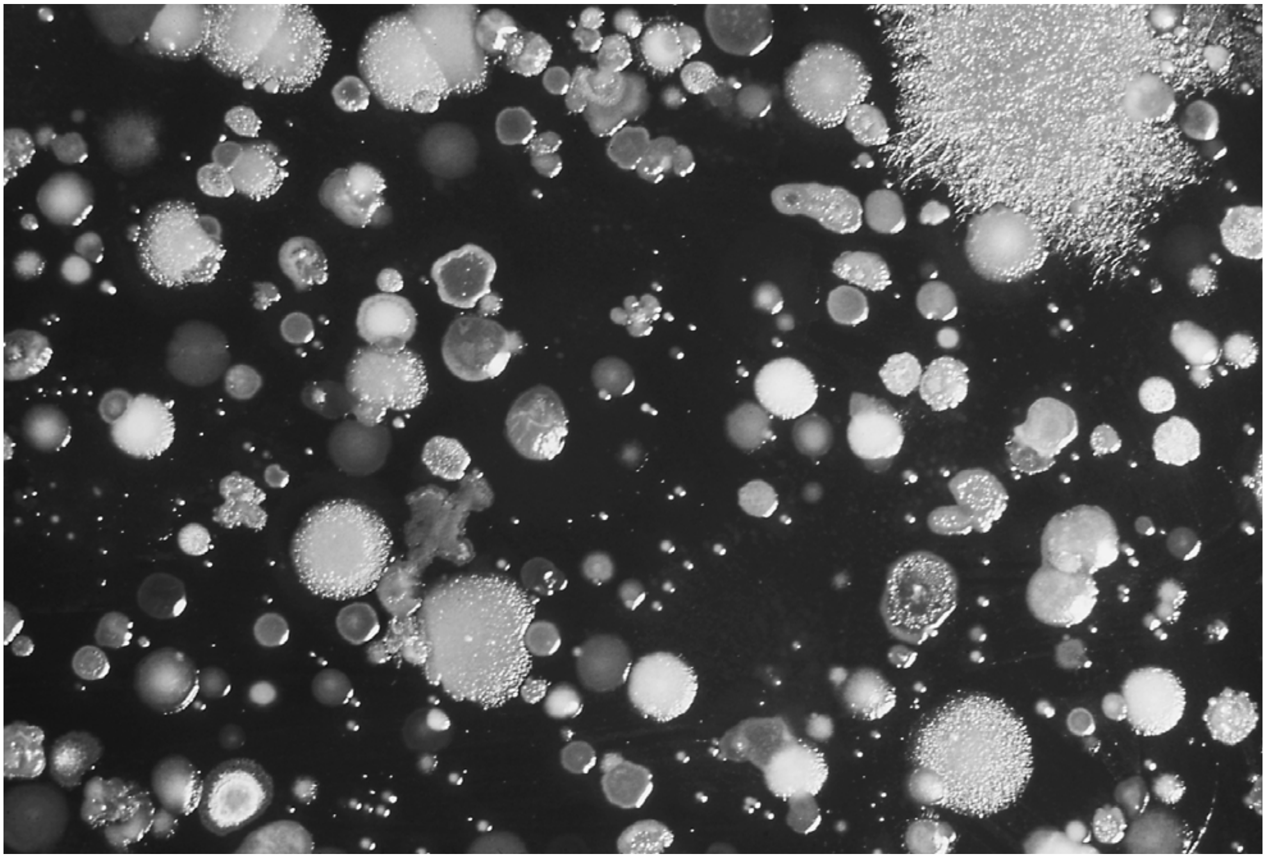
Culturing of bacteria is possible such that fresh growth medium can be added at rate equal to the rate at which culture is removed. The rate at which the bacteria grow is dependent on the rate of addition of the fresh medium. Bacteria can be tailored to grow relatively slow or fast and, if the set-up is carefully maintained, can be maintained for a long time.

Bacterial growth requires the presence of environmental factors. For example, if a bacterium uses organic carbon for energy and structure (chemoheterotrophic bacteria), then sources of carbon are needed. Such sources include simple sugars (glucose and fructose are two examples). Nitrogen is needed to make amino acids, proteins, lipids and other components. Sulphur and phosphorus are also needed for the manufacture of bacterial components. Other elements, such as potassium, calcium, magnesium, iron, manganese, cobalt and zinc are necessary for the functioning of enzymes and other processes.

Bacterial growth is also often sensitive to temperature. Depending on the species, bacteria exhibit a usually limited range in temperatures in which they can grow and reproduce. For example, bacteria known as mesophiles prefer temperatures from 20°C–50°C (68°F–122°F). Outside this range growth and even survival is limited.

Other factors, which vary depending on species, required for growth include oxygen level, pH, osmotic pressure, light, and moisture.

The events of growth and division that are apparent from measurement of the numbers of living bacteria are the manifestation of a number of molecular events. At the level of the individual bacteria, the process of growth and replication is known as binary division. Binary division occurs in stages. First, the parent bacterium grows and becomes larger. Next, the genetic material inside the bacterium uncoils from the normal helical configuration and replicates.



Blood agar culture plate showing anthtrax growth. © CDC/PHIL/CORBIS

The two copies of the genetic material migrate to either end of the bacterium. Then a cross-wall known as a septum is initiated almost precisely at the middle of the bacterium. The septum grows inward as a ring from the inner surface of the membrane. When the septum is complete, an inner wall has been formed, which divides the parent bacterium into two so-called daughter bacteria. This whole process represents the generation time.

Bacteria can exchange genetic material via conjugation. Genetic recombination between bacteria (or protists) occurs via a cytoplasmic bridge between the organisms. A primitive form of exchange of genetic material between bacteria involving plasmids also can occur. Plasmids are small, circular, extrachromosomal DNA molecules that are capable of replication and are known to be capable of transferring genes among bacteria. For example, resistance plasmids carry genes for resistance to **antibiotics** from one bacterium to another, while other plasmids carry genes that confer pathogenicity (the ability to cause disease). In addition, the transfer of genes via bacteriophages—viruses that specifically parasitize bacteria—also serves as a means of genetic recombination.

Bioengineering uses sophisticated techniques to purposely transfer DNA from one organism to another in order to give the second organism some new characteristic it did not have previously. For example, in a process called transformation, antibiotic susceptible bacteria that are induced to absorb manipulated plasmids placed in their environment can acquire resistance to that antibiotic substance due to the new genes they have incorporated. Similarly, in a process called transfection, specially constructed viruses are used to artificially inject bioengineered DNA into bacteria, giving infected cells some new characteristic.

Evolution has driven both bacterial diversity and bacterial adaptation. Some alterations are reversible, disappearing when the particular pressure is lifted. Other alterations are maintained and can even be passed on to succeeding generations of bacteria.

SEE ALSO Anthrax; Bacterial biology; Bacteria, classification; Bacterial resistance and response to

antibacterial agents; Biological weapons, genetic identification; Biosensor technologies; Bubonic plague; Decontamination methods.

Bacterial biology

The Dutch merchant and amateur scientist Anton van Leeuwenhoek was the first to observe bacteria and other microorganisms. Using single-lens **microscopes** of his own design, he described bacteria and other microorganisms as "animacules."

An understanding of the fundamentals of bacterial biology is critical to bacteriologists and other forensic investigators attempting to identify potential biogenic **pathogens** that may be exploited by bioterrorists. In addition, the reaction of the body to bacteria and the type of bacteria present often offer invaluable clues to forensic investigators.

Bacteria are one-celled prokaryotic organisms that lack a true nucleus (i.e., a nucleus defined by a membrane). Bacteria maintain their genetic material, deoxyribonucleic acid (**DNA**), in a single, circular chain. Bacteria also contain DNA in small circular molecules termed plasmids.

In addition to not being contained in a membrane bound nucleus, the DNA of prokaryotes is not associated with the special **chromosome** proteins called histones, which are found in higher organisms. In addition, prokaryotic cells lack other membrane-bounded organelles, such as mitochondria.

Although all bacteria share certain structural, genetic, and metabolic characteristics, important biochemical differences exist among the many species of bacteria. The cytoplasm of all bacteria is enclosed within a cell membrane surrounded by a rigid cell wall whose polymers, with few exceptions, include peptidoglycans—large, structural molecules made of protein carbohydrate. Bacteria also secrete a viscous, gelatinous polymer (called the glycocalyx) on their cell surfaces. This polymer, composed either of polysaccharide, polypeptide, or both, is called a capsule when it occurs as an organized layer firmly attached to the cell wall. Capsules increase the disease-causing ability (virulence) of bacteria by inhibiting **immune system** cells called phagocytes from engulfing them.

During the 1860s, the French microbiologist Louis Pasteur studied fermenting bacteria. He demonstrated that fermenting bacteria could contaminate wine and beer during manufacturing, turning the alcohol produced by yeast into acetic acid (vinegar). Pasteur also showed that heating the beer and wine to kill the bacteria preserved the flavor of these beverages. The process of heating, now called pasteurization in his honor, is still used to kill bacteria in some alcoholic beverages, as well as milk.

Pasteur described the spoilage by bacteria of alcohol during fermentation as being a "disease" of wine and beer. His work was thus vital to the later idea that human diseases could also be caused by microorganisms, and that heating can destroy them.

The first antibiotic (a substance designed to kill bacteria) was penicillin, discovered in 1928 by Sir Alexander Fleming. Since then, a myriad of naturally occurring and chemically synthesized **antibiotics** have been used to control bacteria. Introduction of an antibiotic is frequently followed by the development of resistance to the agent. Resistance is an example of the adaptation of the bacteria to the antibacterial agent.

Bacteria can multiply and cause an infection in the bloodstream. The invasion of the bloodstream by the particular type of bacteria is referred to as a bacteremia. If the invading bacteria also release **toxins** into the bloodstream, the malady can also be called blood poisoning or septicemia. *Staphylococcus* and *Streptococcus* are typically associated with septicemia.

The bloodstream is susceptible to invasion by bacteria that may gain entry in several ways, including: via a wound or abrasion in the protective skin overlay of the body; as a result of another infection elsewhere in the body; following the introduction of bacteria during a surgical procedure; or via a needle during injection of a drug.

Depending on the identity of the infecting bacterium and on the physical state of the human host (primarily with respect to the efficiency of the immune system), bacteremic infections may not produce any symptoms. However, some infections do produce symptoms, ranging from an elevated temperature, as the immune system copes with the infection, to a spread of the infection to the heart (endocarditis or pericarditis) or the covering of nerve cells (meningitis). In more rare instances, a bacteremic infection can produce a condition known as septic shock. The latter occurs when the infection overwhelms the ability of the body's defense mechanisms to cope. Septic shock can be lethal.

Septicemic infections usually result from the spread of an established infection. Bacteremic (and septicemic) infections often arise from bacteria that are normal residents on the surface of the skin or internal surfaces, such as the intestinal tract epithelial cells. In their normal environments the bacteria are harmless and even can be beneficial. However, if they gain entry to other parts of the body, these so-called commensal bacteria can pose a health threat. The entry of these commensal bacteria into the bloodstream is a normal occurrence for most people. In the majority of people, however, the immune system is more than able to deal with the invaders. Yet if the immune system is not functioning efficiently, the invading bacteria may be able to multiply and establish an infection. Examples of conditions that compromise the immune system are another illness (such as acquired immunodeficiency syndrome and certain types of cancer), certain medical treatments such as irradiation, and the abuse of drugs or alcohol.

Examples of bacteria that are most commonly associated with bacteremic infections are *Staphylococcus*, *Streptococcus*, *Pseudomonas*, *Haemophilus*, and ***Escherichia coli***.

The generalized location of bacteremia produces generalized symptoms. These symptoms can include a fever, chills, pain in the abdomen, nausea with vomiting, and a general feeling of ill health. Not all these symptoms are necessarily present at the same time. The nonspecific nature of the symptoms may not prompt a physician to suspect bacteremia until the infection is more firmly established. Septic shock produces more drastic symptoms, including elevated rates of breathing and heartbeat, loss of consciousness, and failure of organs throughout the body. The onset of septic shock can be rapid, so prompt medical attention is critical.

As with many other infections, bacteremic infections can be prevented by observance of proper hygienic procedures including hand washing, cleaning of wounds, and cleaning sites of injections to temporarily free the surface of living bacteria. The rate of bacteremic infections due to surgery is much less now than in the past, due to the advent of sterile surgical procedures, but is still a serious concern.

Bacterial infection does not always result in disease—even if the pathogen is virulent (able to cause disease). The steps of pathogenesis (the process of causing actual disease), can depend on a number of genetic and environmental factors. In some cases, pathogenic bacteria produce toxins released extracellularly (exotoxins) that migrate from the actual site of infection to cause damage to cells in other parts of the body.

Evidence of bacteremic infections can provide forensic investigators with valuable clues about the nature of wounds, the time wounds were inflicted, and even specifics about wound care after injury.

SEE ALSO Anthrax; Bacteria, classification; Bacteria, growth and reproduction; Bacterial resistance and response to antibacterial agents; Biological weapons, genetic identification; Biosensor technologies; Bubonic plague; Decontamination methods.

Bacterial resistance and response to antibacterial agents

An understanding of how bacteria adapt to their environment and how certain agents interact with bacteria is essential for forensic investigators and those charged with the ultimate cleaning of crime scenes. The condition of bacteria often yields important clues as to the treatment of a body after death and can even play an important part in the determination of the **cause of death**.

Bactericidal is a term that refers to the treatment of a bacterium so that the organism is killed. A bactericidal treatment is always lethal and is also referred to as sterilization. Bacteriostatic refers to a treatment that restricts the ability of the bacterium to grow.

Bacteria can develop resistance to agents intend to kill them. For example, antibiotic resistance can develop swiftly. In fact, resistance to penicillin (the first antibiotic discovered) was recognized almost immediately after introduction of the drug. As of the mid 1990s, almost 80% of all strains of *Staphylococcus aureus* were resistant to penicillin. Meanwhile, other bacteria remain susceptible to penicillin. An example is provided by Group A *Streptococcus pyogenes*.

The adaptation of bacteria to an antibacterial agent such as an antibiotic can occur in two ways. The first method is known as inherent (or natural) resistance. Gram-negative bacteria, which possess two membranes that sandwich a thin, supporting structure called the peptidoglycan (Gram positive bacteria have only one membrane and a much thicker peptidoglycan) are often naturally resistant to penicillin, for example. This is because these bacteria have another outer membrane, which makes the penetration of penicillin to its target more difficult. Sometimes when bacteria acquire resistance to an antibacterial agent, the cause is a membrane alteration that has made the passage of the molecule into the cell more difficult. This is adaptation.

The second category of adaptive resistance is called acquired resistance. This resistance is almost always due to a change in the genetic make-up of the bacterial genome. Acquired resistance can occur because of mutation or as a response by the bacteria to the selective pressure imposed by the antibacterial agent. Once the genetic alteration that confers resistance is present, it can be passed on to subsequent generations. Acquired adaptation and resistance of bacteria to some clinically important **antibiotics** has become a great problem in the last decade of the twentieth century.

Bacteria adapt to other environmental conditions as well. These include adaptations to changes in temperature, pH, concentrations of ions such as sodium, and the nature of the surrounding support. This adaptation is under tight genetic control, involving the expression of multiple genes.

Bacteria react to a sudden change in their environment by expressing, or repressing the expression of, a variety of genes. This response changes the properties of both the interior of the organism and its surface chemistry.

Another adaptation exhibited by a great many bacteria is the formation of adherent populations on solid surfaces. This mode of growth is called a biofilm. Bacteria within a biofilm and bacteria found in other niches, such as in a wound where oxygen is limited, grow and divide at a far slower speed than the bacteria found in the test tube in the laboratory. Such bacteria are able to adapt to the slower growth rate, once again by changing their chemistry and **gene** expression pattern. When presented with more nutrients, the bacteria can often very quickly resume the rapid growth and division rate of their test tube counterparts.

The phenomenon of chemotaxis is a further example of adaptation, whereby a bacterium can sense the chemical composition of the environment and either moves toward an attractive compound, or shifts direction and moves away from a compound sensed as being detrimental. Chemotaxis is controlled by more than 40 genes that code for the production of components of the flagella that propel the bacterium along, for sensory receptor proteins in the membrane, and for components that are involved in signaling a bacterium to move toward or away from a compound.

Bactericidal methods include heat, filtration, radiation, and exposure to chemicals. The use of heat is a very popular method of sterilization in a microbiology laboratory. The dry heat of an open flame incinerates microorganisms like bacteria, fungi, and yeast. The moist heat of a device like an autoclave can cause deformation of the protein constituents of the microbe, as well as causing the microbial membranes to liquefy. The effect of heat depends on the time of exposure in addition to form of heat that is supplied. For example, in an autoclave that supplies a temperature of 121° F (49.4° C), an exposure time of 15 minutes is sufficient to kill the so–called vegetative form of bacteria. However, a bacterial spore can survive this heat treatment. More prolonged exposure to the heat is necessary to ensure that the spore will not germinate into a living bacteria after autoclaving. The relationship between the temperature and the time of exposure can be computed mathematically.

A specialized form of bactericidal heat treatment is called pasteurization, after the inventor of the process, Louis Pasteur. Pasteurization achieves total killing of the bacterial population in fluids such as milk and fruit juices without changing the taste or visual appearance of the product.

Another bactericidal process, albeit an indirect one, is filtration. Filtration is the physical removal of bacteria from a fluid by the passage of the fluid through the filter. The filter contains holes of a certain diameter. If the diameter is less than the smallest dimension of a bacterium, the bacterium will be retained on the surface of the filter it contacts. The filtered fluid is sterile with respect to bacteria. Filtration is indirectly bactericidal since the bacteria that are retained on the filter will, for a time, be alive. However, because they are also removed from their source of nutrients, the bacteria will eventually die.

Exposure to electromagnetic radiation such as ultraviolet radiation is a direct means of killing bacteria. The energy of the radiation severs the strands of deoxyribonucleic acid in many locations throughout the bacterial genome. With only one exception, the damage is so severe that repair is impossible. The exception is the radiation resistant bacterial genus called *Deinococcus*. This genus has the ability to piece together the fragments of **DNA** in their original order and enzymatically stitch the pieces into a functional whole.

Exposure to chemicals can be bactericidal. For example, the gas ethylene oxide can sterilize objects. Solutions containing alcohol can also kill bacteria by dissolving the membrane(s) that surround the contents of the cell. Laboratory benches are routinely "swabbed" with an ethanol solution to kill bacteria that might be adhering to the bench top. Care must be taken to ensure that the alcohol is left in contact with the bacteria for a suitable time (e.g., minutes).

Otherwise, bacteria might survive and can even develop resistance to the bactericidal agent. Other chemical means of achieving bacterial death involve the alteration of the pH, salt or sugar concentrations, and oxygen level.

Antibiotics are designed to be bactericidal. Penicillin and its derivatives are bactericidal because they act on the peptidoglycan layer of Gram-positive and Gram-negative bacteria. By preventing the assembly of the peptidoglycan, penicillin antibiotics destroy the ability of the peptidoglycan to bear the stress of osmotic pressure that acts on a bacterium. The bacterium ultimately explodes. Other antibiotics are lethal because they prevent the manufacture of DNA or protein. Unlike bactericidal methods such as the use of heat, bacteria are able to acquire resistance to antibiotics. Indeed, such resistance by clinically-important (i.e., capable of causing disease) bacteria is a major problem in hospitals.

Bacteriostatic agents prevent the growth of bacteria. Refrigeration can be bacteriostatic for those bacteria that cannot reproduce at such low temperatures. Sometimes a bacteriostatic state is advantageous as it allows for the long-term storage of bacteria. Ultra-low temperature freezing and lyophilization (the controlled removal of water from a sample) are means of preserving bacteria. Another bacteriostatic technique is the storage of bacteria in a solution that lacks nutrients, but which can keep the bacteria alive. Various buffers kept at refrigeration temperatures can keep bacteria alive for weeks.

SEE ALSO Anthrax; Bacterial biology; Bacteria, classification; Bacteria, growth and reproduction; Biological weapons, genetic identification; Biosensor technologies; Bubonic plague; Decontamination methods.

Michael Baden

1934–
AMERICAN
FORENSIC PATHOLOGIST

Michael Baden, a longtime **medical examiner** for New York City, has helped publicize the work of forensic pathologists through his books and television appearances. Baden has focused particularly on the need for physicians trained in **pathology** to conduct autopsies and the importance of developing national standards for investigating unnatural deaths. He has served as an expert witness in several high-profile cases, including the examination of the remains of Tsar Nicholas of Russia, the death of comedian John Belushi, and the re-autopsy of civil rights leader Medgar Evers.

Baden was born in the Bronx section of New York City to Jewish immigrants from Russian Poland. A troubled juvenile, he was sent away at the age of six to live at the Hawthorne Reform School in Westchester County, New York. His housemother worked at the Bellevue Psychiatric Hospital and she impressed the boy by telling him that Bellevue was a place were great people cured the less fortunate. After paying a visit to Bellevue in 1947, Baden decided to become a physician.

As a medical student at the New York University School of Medicine, Baden planned to become an internist. The New York City Medical Examiner shared the morgue next door to Bellevue. Advised by a professor to examine the bodies, Baden began to assist in autopsies. Few other medical students had an interest in forensic pathology, which was widely regarded in the medical profession at the time as a refuge for alcoholics and others who could not meet the grade. Following his 1959 graduation, Baden interned in New York City hospitals while moonlighting as a medical examiner.

From 1961 to 1986, Baden worked as forensic pathologist in the Office of the Chief Medical Examiner in New York City. He and his colleagues examined the causes of death from auto accidents, which helped to demonstrate that seatbelts were important for preventing fatal injuries. Baden also helped to establish how suicides in jails, the most frequent **cause of death** there, could be prevented. Most jailhouse suicides were accomplished by hanging; Baden recommended putting up bars that would collapse under weight and taking away shoelaces and belts from prisoners.

Baden is one of only about three hundred fulltime forensic pathologists in the country. He served as the Chief Medical Examiner of New York City from 1978 to 1979. Conflict ensued in this capacity when Baden envisioned the office as scientific and apolitical, and the District Attorney considered the medical examiner an important arm of the prosecution.

Most coroners are untrained in medicine. Most jurisdictions require only that a **coroner** be an American citizen and over 21 years of age. Additionally, there are no national standards for investigating unnatural deaths and for protecting, documenting, and collecting **evidence** at the crime scene. The lack of standards has led to cases such as that of President John F. Kennedy, who was examined by hospital pathologists who had no **training** or

Michael Baden, New York police's forensic pathologist, examines evidence from a crime: a 9mm semiautomatic with bullets, a skull, and x rays. © NAJLAH FEANNY/CORBIS SABA

experience with gunshot wounds. Baden became the first forensic pathologist to examine Kennedy's wounds via photographs as the chairman of the Forensic Pathology Panel of the U.S. Congress Select Committee on Assassinations that investigated the deaths of President John F. Kennedy as well as the **murder** of Dr. Martin Luther King, Jr.

Baden has conducted more than 20,000 autopsies during his career. From 1981 to 1983, he was employed as the Deputy Chief Medical Examiner for Suffolk County in New York. He is currently co-director for the Medico-legal Investigative Unit of the New York State Police. As a forensic pathologist with a private practice, Baden travels around the country providing expert witness testimony. He testified for the defense in the case of Claus Von Bulow, accused of murdering his wife with an injection of insulin, and the trial of actor Marlon Brando's son Christian, who shot his sister's lover. He participated in the **exhumation** of the body of civil rights worker Medgar Evers when Mississippi decided to re-open the murder case thirty years after Evers' 1963 killing by a white supremacist. Baden's popular reputation has given him a second career as a media star. He has authored two popular books on pathology for a lay audience and regularly appears on **television shows** devoted to autopsies.

SEE ALSO Autopsy; Crime scene investigation; Expert witnesses; Kennedy assassination; Pathology.

Matthew Baillie

10/27/1761–9/23/1823
SCOTTISH
PHYSICIAN

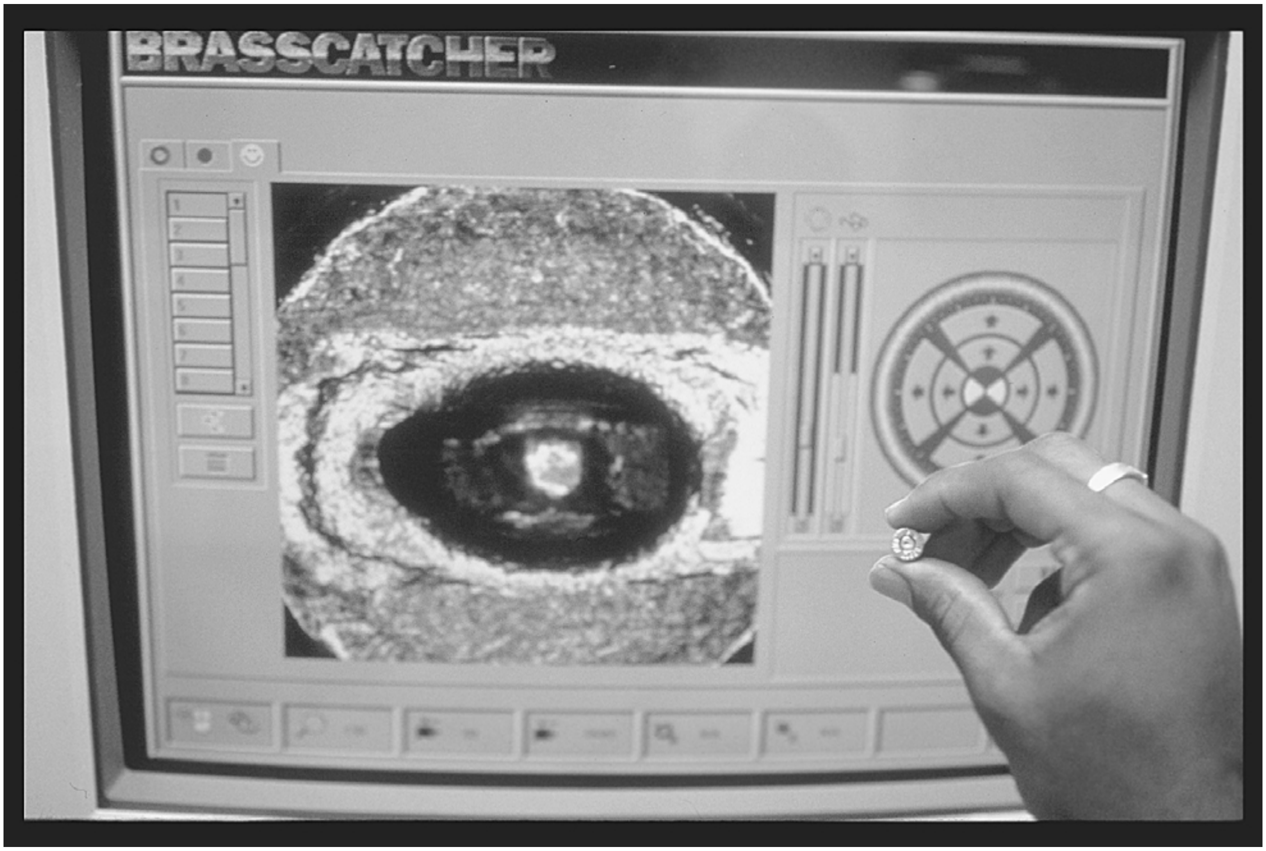
Over the course of his career, Matthew Baillie worked as a physician, lecturer, and author. While he worked at both St. George's Hospital and in his own private practice, he also served as the physician for many members of the royal family, including King George III.

Born in Lanarkshire in 1761, Baillie attended the University of Glasgow. In pursuit of a career in **medicine**, he moved to London to live with and study under his uncle William Hunter, the celebrated anatomist. At Hunter's home Baillie attended public lectures and was given private instruction by his uncle. In London he also attended Balliol College, Oxford, graduating in 1786. Three years later he received an M.D. from the school as well, and became a fellow of the Royal College of Physicians.

In 1787 Baillie was hired as a physician at St. George's Hospital, where he worked for a number of years. During this time, he also gave many lectures on various medical subjects. At the age of 36, Baillie left St. George's and devoted himself exclusively to his private medical practice. In this capacity, he became the physician of King George III, Princess Amelia, and Princess Charlotte. Baillie also continued to serve both wealthy and poor patients alike.

Baillie is perhaps best known as the author of *The Morbid Anatomy of Some of the Most Important Parts of the Human Body*, published in 1793. The book is credited with establishing morbid anatomy as an independent science. In it Baillie provides the first clinical descriptions of cirrhosis of the liver, gastric ulcers, and chronic obstructive pulmonary emphysema, and gives one of the clearest descriptions written about the pulmonary lesions of tuberculosis.

SEE ALSO Careers in forensic science.



A technician at the Bureau of Alcohol, Tobacco, and Firearms uses computer assisted technology to identify the patterns made by a particluar type of bullet. © STEVE LISS/CORBIS SYGMA

Ballistic fingerprints

A ballistic fingerprint is the unique pattern of markings left by a specific firearm on ammunition it has discharged. The technique has been used in **forensic science** to match a bullet obtained from a victim to a particular gun. This can help determine the **cause of death** as well as being instrumental in criminal prosecutions.

In 1997, the National Integrated Ballistics Identification Network, established by the Federal Bureau of Investigation and the Bureau of Alcohol, Tobacco, and Firearms, made 8,800 ballistic fingerprint matches, which resulted in the linking of 17,600 crimes. As of 2000, two states—Maryland and New York—had passed laws requiring the ballistic fingerprinting of weapons. Upon selling a firearm, a dealer was required to provide the state with a spent round from the gun, so as to establish a permanent record of the gun's ballistic fingerprint. Other states followed suit.

Despite this, the use of ballistic fingerprinting as a tool of forensics is controversial. On the one hand, many law-enforcement officials insist that ballistic fingerprints are as useful as ordinary fingerprints in linking a round of ammunition to a specific gun. Police used ballistic fingerprints, in part, to link the shootings of numerous people in the Washington, D.C., area during the fall of 2002 to the accused "Beltway snipers," John Muhammad and John Lee Malvo. The case brought ballistic fingerprinting to national attention.

On the other hand, many advocates of gun-owners' rights maintain that these fingerprints change so much over time that they are largely useless as a means of matching a spent round to a firearm.

Criminologist Daniel W. Webster, director of the Center for Gun Policy and Research at Johns Hopkins University in Baltimore, is an advocate of ballistic fingerprints as a tool of forensics. In *Comprehensive Ballistic Fingerprinting of New Guns*, Webster cited research suggesting that although ballistic fingerprints change over time, these changes do not prevent authorities from establishing a match between a firearm and a spent round.

However, technical factors may limit the current use of ballistic fingerprinting in forensic science. An independent study contracted by the California Department of Justice and conducted by the National Institute for Forensic Science reported in early 2003 that ballistic fingerprinting was impractical. Testing revealed that the computer software used to match the discharge pattern on a bullet with a specific firearm was too inaccurate to be reliable.

SEE ALSO Ballistics; Bomb damage, forensic assessment; Crime scene investigation; Firearms; Gunshot residue.

Ballistics

When a forensic investigation involves a shooting, ballistics becomes an important facet of the investigation. Ballistics is a term that refers to the science of the flight path of a bullet. The flight path includes the movement of the bullet down the barrel of the firearm following detonation and its path through both the air and the target.

Tracing the path of a bullet is important in a forensic examination. It can reveal from what direction the bullet was fired, which can be vital in corroborating the course of events in the crime or accident.

It is an obvious truism that the distance that a bullet can travel depends on its speed. A higher speed imparts more energy to the bullet. The frictional resistance of the air and the downward pull of gravity will take longer to slow the bullet's flight, as compared to a bullet moving at a lower initial velocity.

Generally, a bullet fired from a rifle will carry more energy than a bullet fired from a handgun. This is because the stronger firing chamber of a rifle is able to withstand the increased explosive power of a larger quantity of powder that would likely rupture the barrel of the handgun. Detonation of the powder in a rifle or handgun supplies the thrust to propel the bullet down the barrel.

Expansion of the exploding gunpowder generates pressure, which is measured as the force of the explosion that pushes on the area of the bullet's base. This area is essentially the diameter of the barrel of the firearm, which remains constant. Thus, the explosive energy that passes to the bullet depends on the mass of the bullet multiplied by the force of the explosion multiplied by the time that the force is applied (i.e., the time the bullet is in the barrel). A longer barrel will produce a faster moving bullet.

Once a bullet leaves the rifle or gun barrel, the aforementioned frictional and gravitational forces begin to slow its speed, producing a downward arc of flight. The frictional force is affected by the bullet's shape. A blunt shape will present more surface area to the air than will a very pointed bullet.

Another factor that affects the flight of a bullet is called yaw. As in an orbiting spacecraft or a football tossed through the air, yaw causes a bullet to turn sideways or tumble in flight. This behavior is decreased when the object spins as it moves forward (the spiraling motion of a football). The barrel of a rifle or gun contains grooves that cause the bullet to spin. More damage results from a bullet that is tumbling rather than moving in a tight spiral.

The shape of a typical bullet—much like a football with one end blunt instead of tapered—is a compromise that reduces air resistance while still retaining the explosive energy that allows the bullet to damage the target.

The composition of a bullet is also important. Lead is commonly used to form the core of bullets. However, because it tends to deform, the blending in of other metals (typically antimony and copper) produces a bullet that can withstand the pressure of flight and impart high energy to the target upon impact.

Copper is often used to jacket the inner lead core of a bullet. However, some bullets are deliberately made without this full metal jacket. Instead, the bullet has a tip made of lead or a tip that is hollow or very blunt. These bullets deform and break apart on impact, producing more damage to the target than is produced by a single piece of metal. This is because the bullet's energy is dissipated within a very short distance in the tissue.

Forensic and medical examiners are able to assess the nature of tissue damage in a victim and gain an understanding of the nature of the bullet used.

A bullet produces tissue damage in three ways. First, a bullet can shred (lacerate) or crush tissue or bone. Bullets moving at relatively low velocity do most of their damage this way. Fragmentation of bone can cause further damage, as the bone shards themselves become missiles.

The second form of damage is known as cavitation. This damage is produced by the forward movement of air or tissue in the wake of the bullet. The wound that is produced by the bullet is destructively broadened by the force of the moving air or tissue. In a tissue, this produces even more structural damage.

Third, the air at the front and sides of a very fast moving bullet can become compressed. The explosive relaxation of the compression generates a damaging shock wave that can be several hundred atmospheres in pressure. Fluid-filled organs such as the bladder, heart, and bowel can be burst by the pressure.

Recovery of bullets can be a very useful part of forensic ballistics. A variety of bullet designs exist, some that are specific to the firearm. Furthermore, the scouring of a bullet's surface as it encounters the grooves of the firearm barrel can produce a distinctive pattern that enables a bullet to be matched with the firearm. A weapon recovered from a suspect can be test fired and the bullet pattern compared with a bullet recovered from the scene to either implicate or dismiss involvement of the firearm in the crime.

This aspect of ballistics was crucial in convicting John Allen Muhammad and John Lee Malvo of the 10 sniper murders and the wounding of three others in the Washington, D.C. area that occurred during three weeks in October of 2002.

SEE ALSO Bullet lead analysis; Bullet track; Crime scene investigation; Gunshot residue; Firearms.

Victor Balthazard

1/1/1872–1950
FRENCH
PROFESSOR IN FORENSIC MEDICINE

In the early 1900s, Victor Balthazard worked as a professor in forensic **medicine** at the Sorbonne University in Paris, France. Together with the French physicist Pierre Curie (1859–1906) and his Sorbonne colleague Charles Bouchard (1831–1915), they collaborated on the physiological action of radium (radon) emanation on mice and guinea pigs.

At this time, the Canadian physician Wilfred Derome (1877–1931) worked as director of laboratories at the Notre Dame Hospital in Montreal, Quebec, in close proximity to the courthouse where he was frequently summoned to provide expert testimony. Recognizing his need for more **training**, Derome traveled to France in 1909 to obtain a diploma in forensic medicine at the Sorbonne under professor Balthazard. Because of Balthazard's interest in **firearms**, Derome also became competent in this discipline and, upon his return, he successfully lobbied the Attorney General of Quebec on the importance of the new specialty of forensics. In July 1914, the Premier announced the establishment of the Laboratoire de Recherches Medico-Légales (research laboratory for forensic medicine).

Body hair carries pieces of circumstantial forensic **evidence**. Examining hair under an optical or an electronic microscope can help identify the nature of a crime, and its condition reveals information on the circumstances of a crime. Thus, the **identification** of a person might eventually be possible through particular characteristics such as hair dyes or hair diseases. The first forensic hair studies are recorded by the German physician Rudolph Virchow (1821–1902). In 1910, however, Victor Balthazard and Marcelle Lambert published the first comprehensive hair study "Le poil de l'homme et des animaux" ("The hair of man and animals"), which includes numerous microscopic studies of hairs from most animals. As a result, during one of the first legal cases ever involving hairs, French citizen Rosella Rousseau was prompted to confess to **murder** in 1910.

Victor Balthazard is credited for his statistical model of **fingerprint** individuality, published in 1911. His model is simplistic and ignores relevant information, but is the foundation for later improved statistical models. Balthazard's work was the basis for Locard's Tripartite Rule, referring to statistical models supporting quantifiable thresholds for friction ridge individualization.

In 1912 Balthazard asserted that machine tools used to make gun barrels never leave exactly the same markings. After studying images of gun barrels and bullets, he reasoned that every gun barrel leaves a signature set of etched grooves on each bullet fired through it. Another milestone in firearms identification history occurred when Balthazard devised a number of procedures to match fired bullets to the firearms from which they were fired by taking an elaborate series of photographs of test fired bullets from the firearm as well as evidence bullets. The photographs were then carefully enlarged, and the observed markings compared. Balthazard applied these same specialized photographic techniques to the examination and identification of cartridge casings using firing pin, breech face, ejector, and extractor marks, too, and he was among the first to attempt to individualize a bullet to a weapon.

It took Balthazard another decade to advance **ballistics**, i.e. the study of the functioning of firearms, the flight of the bullet, and the effects of different types of ammunition. In the early 1920s, Balthazard's work had evolved so much that court cases and literature continued at a fast pace. In 1922 two articles were published in the recognized French *Comptes Rendus de l'Académie des Sciences* describing the perfected technique for determination of the identification of projectiles. One year later, other articles appeared in the French journal *Annales de Médicine Légale* investigating fissures of the **skull** by revolver bullets at short range, and the identification of fired bullets and shells. Eventually, ballistics was formally established in 1923 in crime investigation, and the United States Bureau of Forensic Ballistics was established in 1925.

SEE ALSO Ballistic fingerprints; Ballistics; Bullet track; Civil court, forensic evidence; Computer modeling; Fingerprint; Firearms; Hair analysis; Identification; Locard's exchange principle; Medicine; Photography.

Barbiturates

The term barbiturate is a name given to a group of drugs that function by depressing the activity of the central nervous system. Their principal effect is to reduce stress and bring the user a feeling of calm. Often, this sedation can help someone fall asleep. This is why barbiturates are often termed sleeping pills.

Barbiturates were first made over a century ago by the Bayer laboratories in Germany. They take their name from barbital, which was the first barbiturate used medically, in the first decade of the twentieth century.

Aside from their stress relief, the nervous system alteration induced by barbiturates can also be beneficial in the management of diseases like **epilepsy**.

Of the dozen or so barbiturates still in common medical use, the speed at which the effects are produced and the length of time the effects persist are the distinguishing features between the drugs.

Some barbiturates produce an effect within seconds of being taken. Others require more time to act but last longer. Finally, those used for sedation before an operation can last for hours.

Barbiturates are important to forensic scientists when they are present in **blood** samples in excess amounts. This can occur accidentally, since the effective dose of many of the drugs is not too different from a dose that causes harm. One well-known victim of an accidental overdose of sleeping pills was the musician Jimi Hendrix. As well, a barbiturate overdose can be deliberately administered. When present in excessive amounts, the drugs can cause debilitating changes. Sedation can even be so severe that coma and death result.

Forensic investigators can be interested in determining if barbiturates were a factor in someone's illness or death. Recollections of the victim's behavior can be helpful in determining the involvement of barbiturates. For example, side effects of an overdose include slurred speech and unsteady balance. Admittedly, these are also symptoms of excessive alcohol consumption.

More definitive evidence of barbiturate use comes from the chemical demonstration of the drug in tissue samples. Because most barbiturates tend to accumulate in fat deposits in the body, to be released at varying rates depending on the specific drug, a barbiturate may be detectable in tissue specimens recovered even some time after death.

SEE ALSO Amphetamines; Analytical instrumentation; Autopsy; Death, cause of; Narcotic; Psychotropic drugs.

John G. Bartlett

2/12/1937–
AMERICAN
PHYSICIAN

John G. Bartlett is known as one of the founding directors of the Center for Civilian Biodefense Strategies in 1997. Under the guidance of Bartlett and D.A. Henderson, the Center's objective is to stop the development and use of biological weapons and to minimize the consequences to victims if such weapons are used. Today, Bartlett is a Stanhope Bayne-Jones professor of **medicine** and chief of The Johns Hopkins University (Baltimore, Maryland) School of Medicine, Division of Infectious Diseases, Department of Medicine.

In 1959 Bartlett was awarded an undergraduate degree at Dartmouth University in Hanover, New Hampshire. From there, he received his doctor of medicine (M.D.) degree in 1965 from Upstate Medical Center School of Medicine in Syracuse, New York. For the next three years, Bartlett performed his residency **training** in internal medicine, first at the Peter Bent Brigham Hospital in Boston, Massachusetts (1966–1967) and then at the University of Alabama, Birmingham (1967–1968). He began, in 1968, his fellowship training in infectious diseases at UCLA (University of California, Los Angeles) School of

Medicine and the Wadsworth Veterans Administration Hospital (Los Angeles).

Bartlett became a faculty member at UCLA and the School of Medicine, Tufts University (Boston) in 1970. Ten years later, in 1980, Bartlett transferred to The Johns Hopkins University to assume the positions he presently holds: professor in the School of Medicine (and joint appointment in the Epidemiology Department) and chief of the Infectious Diseases Department. From 1980 to today, Bartlett has performed research within the areas of anaerobic infections, antibiotic-associated colitis, diarrhea, human immunodeficiency virus (HIV)/acquired immune deficiency syndrome (AIDS), pathogenic mechanisms of *Bacteroides fragilis*, and pneumonia, with clinical interests in infectious diseases, HIV primary/managed care, and HIV and hemophilia.

Members of the Center for Civilian Biodefense Strategies, with past affiliation to The Johns Hopkins University and current affiliation, as of November 1, 2003, to the University of Pittsburgh Medical Center, have used their expertise to: build a world network to improve biosecurity communications; provide independent research and analysis for the bioscience, government, national security, medicine, and public health sectors; propose, design, build, and promote systems to manage the consequences of biological attacks; promote responsible use of bioscience/biotechnology; and develop **bioterrorism** scenarios. In 2001, the Center co-sponsored the "Dark Winter" scenario at Andrews Air Force Base (Maryland), where participants responded to a hypothetical **smallpox** attack on the United States.

As the author of 41 editions of 13 books, more than 300 articles, and over 300 chapters, reviews, and letters, one of Bartlett's more recently authored books is *PDR Guide to Biological and Chemical Warfare Response*. Bartlett currently chairs the Antimicrobial Availability Task Force for the Infectious Diseases Society of America. He has been a member of such organizations as the American Society for Clinical Investigation, Anaerobe Society of America, Society of Critical Care Medicine, American College of Physicians, and Institute of Medicine. Bartlett has been on the editorial boards of such publications as *Infectious Diseases in Clinical Practice*, *Clinical Infectious Diseases*, *Medicine*, *American Journal of Medicine*, and *Journal of Clinical Illness*.

SEE ALSO Biological warfare, advanced diagnostics; Bioterrorism.

William Bass III

AMERICAN
FORENSIC ANTHROPOLOGIST

William ("Bill") Bass, professor emeritus of the University of Tennessee and one of the world's most renowned forensic anthropologists, is perhaps best known as the (former) custodian of "The Body Farm," also known as the University of Tennessee's Anthropology Research Facility. The **Body Farm**, as it is commonly known, is the world's only research facility dedicated solely to studying the **decomposition** of human bodies. Bill Bass started the research center with one corpse and a small piece of land in 1971.

Bass retained directorship of the University's Forensic Anthropology Center after achieving emeritus status. He has continued an active forensic consulting practice, with particular areas of expertise in estimating **time of death** and victim **identification**. He has remained a sought-after forensics public speaker well into his retirement from academia.

The Body Farm encompasses three barbed wire encircled acres not far from the University of Tennessee's Medical Center. At any given time, about forty bodies are being studied as they decompose under varying conditions; some hang from scaffolds; some are left in cage-like enclosures; some are in car trunks; some lie in the sun; some are in the shade; some are barely covered by leaves and forest debris; some are covered with brush; some are submerged in ponds; and some even occupy shallow graves.

Throughout the United States, law-enforcement agencies and graduate students of forensic anthropology have sent students and staff to the Anthropology Research Facility (informally called ARF, but publicly known as the Body Farm, particularly by readers of Patricia Cornwell's Kay Scarpetta series). The **FBI** conducts short-course trainings at the ARF each year, teaching Special Agents what to look for when they excavate areas to search for bodies. Agents learn which insects feed on human bodies, and how their activity can suggest time of death (or, more accurately, time since death).

Eventually, the skeletal remains of the Body Farm's inhabitants are collected and cleaned; sorted by age, gender, and race; numbered; and stored in boxes in an indoor lab, where they are used during student research.

Bass's work has been lauded in worldwide media; he has been profiled by CNN, featured in the *American Bar Association Journal*, the

Philadelphia Inquirer, and Reuter's News Service, among many others. Bass estimates that he has personally been involved in the **training** of at least 65% of the forensic scientists in the United States. William Bass continues to be intrigued by the study of decomposition of human bodies, and believes that much is yet to be learned. Bass views his life's work not as the study of death, but as an intriguing science experiment. Bass sees his job as marshalling all of his abilities and his knowledge, striving to see the corpse as an individual, and trying to determine exactly what happened to him or her.

SEE ALSO Ancient cases and mysteries; Anthropology; Decomposition.

Bathymetric maps

A bathymetric map represents ocean depths depending upon geographical coordinates, in much the same way a topographic map represents the altitude of the Earth's surface in given different geographic points. Bathymetric maps have provided useful forensic **evidence** in court when certain types of crimes involving the sea are committed, or disputes arise about fishing boundaries or national boundaries at sea. Bathymetric maps have also been used by treasure-seekers when investigating the sea floor to identify the most likely areas to seek sunken ships, and aided in the search for the H.M.S. *Titanic* in the 1980s.

The most common type of bathymetric map displays lines called isobaths that indicate ocean depths. Like geographical maps of the Earth's surface, bathymetric maps are usually constructed in Mercator projection. Mercator projection is a mathematical method for displaying the surface of the Earth on a flat sheet of paper or computer screen. Mercator projection maps have been used for centuries in constructing sea charts that are used for sailing in all latitudes except the polar regions. Mercator projections are not used at extreme northern and southern latitudes because of the increasing degree of map distortion (the difference between map depiction and geographical reality) as one nears the poles.

The creation of a bathymetric map for a given region depends on the amount of depth measurement data for that region. Since before the invention of the echo sounder (an instrument that uses sound waves to gauge the depth of a body of water or of objects below the surface) in the 1920s, ocean (sea) depth measurements were quite rare; these measurements were made only in isolated points, and the creation of a bathymetric map was practically impossible. Thus, the structure of the ocean floor was unknown. It should be noted, for example, that the most important structure in the Atlantic Ocean—the Middle-Atlantic ridge—was discovered and began to be studied only after World War II (1939–1945). Another important factor for creating bathymetric maps lies in the determination of the geographical coordinates of the point where the depth measurement is made. In order to produce precise maps, precise geographical determinations are needed. GPS (Global Positioning System) technology is usually used for determining the coordinates of measurement points in bathymetric mapping.

Bathymetric maps of a country's continental shelf (the gradually sloping seabed around a continental margin) are important due to the special legal status of sea areas. These maps are important not only for defining territorial waters; they are also important because the shelf is home for intensive mineral deposits and mineral output, such as oil from beneath the sea floor off the coasts of the United Kingdom, Norway, and Mexico.

The United Nations Convention on the Law of the Sea (1982) states that, "The fixed points comprising the line of the outer limits of the continental shelf on the seabed…either shall not exceed 350 nautical miles from the baselines from which the breadth of the territorial sea is measured or shall not exceed 100 nautical miles from the 2,500 meter isobath, which is a line connecting the depth of 2,500 meters." It is clear that this statement implies that bathymetric maps are essential to draw precise boundaries of continental shelves. The Law of the Sea also determines that the foot of a continental slope will be set as the point where the slope's gradient change at its base is the greatest. A gradient is the maximum angle of the surface of a slope at a given point, and on the sea floor, a gradient can only be determined with bathymetric mapping.

When constructing topographic land maps, one can always measure the altitude of any point of the surface precisely. However, when constructing bathymetric maps, it is practically impossible to determine the depth of any one point on the ocean bottom. Obviously, bathymetric maps are more precise when more depth measurements per surface area unit in the given region are available. The most precise and detailed bathymetric maps are constructed using data provided by multi-beam echo sounding. The multi-beam echo sounder is a special kind of sonar located on board the research vessel that measures the depth

Wreckage of the Russian nuclear submarine *Kursk* in dry dock at Murmansk, Russia, 2001. Explosions caused the submarine to sink in 2000 in 355 feet (108 meters) of water in the Barents Sea. © REUTERS/CORBIS

simultaneously in several points of the ocean bottom, creating a swath of data. Depth determination by this method is performed regularly every few seconds while the vessel is in motion.

Bathymetric maps are finding more and more use both for practical forensic and scientific purposes. They have documented evidence that has resulted in laws to protect the environment of a given area (for example, locating areas of the sea and estuaries stressed by pollution off South Florida in 1999). In 1997, also in South Florida, bathymetric maps served as evidence of environmental compliance violations when they illustrated detrimental changes in submerged wetlands after sea grass was removed by illegal dredging.

Bathymetric mapping is also important for projects conducted in port territories; in these cases, usually a very detailed bathymetric map is constructed. Besides their uses in international courts, bathymetric maps are important for scientists who study the development of the Earth, the formation of seas and oceans, and the changing sea floor.

SEE ALSO Accident investigations at sea; Remote sensing.

Henri-Louis Bayard

1812–10/12/1852
FRENCH
FORENSIC PATHOLOGIST

Henri-Louis Bayard was one of the earliest practitioners of legal **medicine**, known today as **forensic science**. Born in 1812 in Paris, Bayard received his medical degree in 1836, studying medicine under the well-known forensic scientist Charles Prosper Ollivier d'Angers. When d'Angers died in 1845, Bayard inherited much of his forensic practice.

Bayard's work in Paris in the years prior to 1848 was extensive, and he was highly respected as a "legal physician." In addition to his own practice of forensic science, Bayard also wrote extensively. His published works include an analysis of juvenile murders, volumes championing the importance of forensic medicine as a field of study, and a biography of his mentor. Bayard also served as co-editor of *The Annals of Public Health and Legal Medicine*, an early French professional journal in the field. Some of Bayard's publications are still valuable today; a first edition example of his 1845 work *Manuel Pratique Medicine Legale* (Manual of legal medical practices) was offered in early 2005 at an online antique book dealer for $150.00.

Bayard's most notable scientific achievements were in the realm of microscopy. While microscope pioneer Antony van Leeuwenhoek first observed and identified **sperm** cells in the seventeenth century, the use of sperm analysis in forensic science remained error-prone, with numerous techniques being practiced and no standard criteria for acceptance or rejection of findings. This led another forensic writer of the day to warn that numerous other items could resemble detached sperm heads, hence intact sperm should be considered the "gold standard" for evidentiary use. In the face of numerous, often unreliable methods, Bayard's research in microscopy led to the first reliable procedure for detecting sperm. Bayard also contributed substantially to the understanding of fiber characteristics and their use in criminal cases by documenting the distinct characteristics a wide variety of fabrics.

The overthrow of the monarchy in Paris and the accompanying unrest during 1848 spelled the end of Bayard's stay in the city, and he relocated to Chateau-Gontier, a regional capital in western France. While there he divided his time between practicing medicine and overseeing his mining interests. He died at the age of 40.

SEE ALSO Fibers; Microscopes.

Frank Bender

AMERICAN
FORENSIC SCULPTOR

Frank Bender is a man of many talents. He is a painter, a sculptor, and a forensic artist. Bender is expert at the evaluation and authentication of fine art paintings for insurance purposes. He also creates architectural models for government and agency use. In forensics, Bender is adept at traffic accident scene model reconstruction; he is an expert witness with local, state, and federal courtroom experience; he is an expert at facial reconstruction of homicide victims from **skull** to full three-dimensional face and head; he is the co-founder of The Vidocq Society, which is an international society of forensic experts dedicated to the solution of "cold cases"; he is expert at creating sculptures in order to facilitate **identification** of crime victims whose bodies are no longer recognizable; and he is perhaps best known for his age-progressed three-dimensional sculptural renderings of fugitives.

The most well known case in which Frank Bender was involved was that of John List. In November of 1971, List shot and killed his wife, his mother, and his three children. He made no effort to hide the crime, and left several notes stating that he felt a need to "free his family's souls." It took the police about a month to discover the bodies, and the only clue as to List's location was the discovery of his car in the parking lot of a nearby airport. Eventually, it was learned that List had lost his job and was feeling considerable anxiety and shame over financial pressures. Rather than choosing to deal with his difficulties and facing the consequences thereof, List opted to **murder** his entire family.

List successfully eluded capture until 1989, when the television show *America's Most Wanted* planned to air an episode about the List murder. The show's executives approached Frank Bender, and asked him to create a strong visual representation of what John List would look like 18 years after the crime. Although Bender had considerable experience in aging faces, he felt that this case also required psychological insight in order to estimate how List might look—how he might have chosen to alter his appearance after the crime; how his personality traits might have affected the aging process and his appearance across time; and, generally, how to make the sculpture "come alive." Bender enlisted the aid of criminal psychologist Richard Walter, and they collaborated on the creation of a "profile" to assist in the generation of List's age-progressed appearance.

Ultimately, they created a psychological portrait of a man who would alter his appearance very little, who would try to re-create his former life as much as possible (to include re-locating to an area less than 300 miles from his original home, although he might have traveled some distance immediately after the murders), and who would have opted not to hide a potentially identifying surgical scar behind his right ear. They decided that he would probably be a bit paunchier, have drooping jowls, deep worry lines, and a receding hairline, and they incorporated those features into the final List sculpture. The bust was completed and aired during the proposed television program. Within days of the broadcast, a call was received from a female former neighbor of a man named "Bob Clark," who felt that he might be List, and was able to offer a number of striking details. Less than two weeks after the call, **FBI** agents arrested "Clark" at his office, which was located less than 250 miles from the murder site. Bender learned that List largely resembled the bust that he had created, and was quite similar to the profile generated by he and Walter. Ultimately, List was convicted of five counts of first-degree murder and sentenced to life in prison.

SEE ALSO Ancient cases and mysteries; Art identification; Cold case; Composite drawing; Crime scene reconstruction.

Alphonse Bertillon

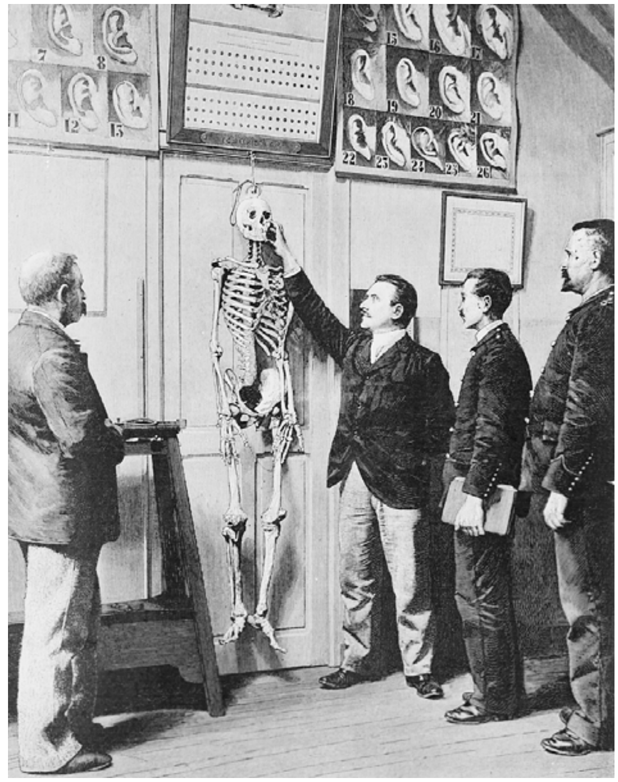
4/24/1853–2/13/1914
FRENCH
CRIMINOLOGIST

The French criminologist Alphonse Bertillon is often cited as a pioneer in the arena of **forensic science** and is known as the inventor of the first scientific method of identifying criminals.

Alphonse Bertillon was born in Paris, the son of Louis Adolphe Bertillon, a physician and statistician. Because of Alphonse's poor scholarship, his father sent him to Great Britain, where he was forced to rely on his own resources. Returning to France, he was inducted into the army.

In 1879, having completed his military service, Bertillon took a position as a minor clerk with the Paris Prefecture of Police. One of his duties was to copy onto small cards the recorded descriptions of the criminals apprehended each day. Bertillon realized that the short descriptions were practically useless for the purpose of identifying recidivists, or criminal repeaters. He had a general familiarity with anthropological statistics and anthropometric techniques because of the work of his father and his elder brother Jacques, also a doctor and statistician.

Bertillon devised a system of **identification** of criminals that relies on 11 bodily measurements and the color of the eyes, hair, and skin. He included standardized photographs of the criminals to his anthropometric data. He first described his system



1899 photograph of French criminologist Alphonse Bertillon demonstrating his system of identifying criminals based on anthropometric measurements at police headquarters, Paris, France. © BETTMANN/CORBIS.

in *Photography: With an Appendix on Anthropometrical Classification and Identification* (1890). The Bertillon system proved successful in distinguishing first-time offenders from recidivists, and it was adopted by all advanced countries.

It is commonly believed that Bertillon was the first to recognize the value of fingerprints. Actually, that achievement must be associated with Sir **Francis Galton**, Edward Henry, and **Juan Vucetich**. However, Bertillon was the first in Europe to use fingerprints to solve a crime.

In 1888, the Department of Judicial Identity was created for the Paris Prefecture of Police; Bertillon became its head. He invented many techniques useful to criminologists. His use of **photography** was especially effective, and he did much to improve photographic techniques in **criminology**. Around the turn of the century, fingerprinting began to replace the Bertillon system and has now superseded it throughout the world.

Bertillon died Paris at the age of 60. His anthropometric method of identifying recidivists represented a first step toward scientific criminology. It is said that his work played an important role in inspiring greater confidence in police authorities and in establishing a more favorable sense of justice toward the end of the nineteenth century.

SEE ALSO Anthropometry; Automated Fingerprint Identification System (AFIS); Criminology; Photography.

Marie François Xavier Bichat

11/11/1771–7/2/1802
FRENCH
ANATOMIST, PATHOLOGIST, PHYSIOLOGIST

The French anatomist, pathologist, and physiologist Marie François Xavier Bichat was a pioneer in the field of **forensic science**. He was the founder of animal histology, the microscopic study of animal tissues.

Bichat was born in Thoirett, France. His father, a physician, was his first teacher of anatomy. He studied anatomy and surgery at Montpellier and Lyons and later served as an assistant to P. J. Desault, a famous physician at the Hôtel-Dieu, a hospital in Paris. In 1799, Bichat, after the death of Desault, became physician at the Hôtel-Dieu. From 1800 onward, he abandoned surgery and did only research in anatomy, performing as many as 600 autopsies in a single year. He investigated the structure of the body generally, rather than studying particular organs as separate entities. He broke down the organs into their common elemental materials, for which he introduced the term "tissues."

Bichat rejected the notion of iatrochemistry, the assumption that disorders in human health were caused by an imbalance in the chemical relations of fluids in the body. He also rejected Stahl's animism, which maintained that there is a special spirit of life. Bichat was a follower of Albrecht von Haller's philosophy of vitalism, which states that the body possesses some truly vital functions such as motion, communication, and sensibility, while other characteristics of the body are not vital. In other words, he rejected the old theory that life is a collection of subtle fluids and maintained rather that life is a result of a combination of vitality and the vital functions of various tissues of the body. Bichat also rejected the reductionist philosophy, which states that all biological phenomena have to be reducible to the laws of physics and chemistry—an attitude prevalent in his own time. Bichat's definition was that life consists of the sum of functions by which death is resisted. One of his most interesting works is *Physiological Researches on Life and Death.*

Bichat's experimental work had great influence and was long quoted as a model of experimental exactitude and penetrating insight. In this context it is interesting to note that Bichat steadfastly refused to make use of the most advanced experimental tool for anatomy, namely, the microscope. His frenetic activity weakened him, and in 1802, after a fall from the Hôtel-Dieu's staircase, he contracted a fever and died on July 22; he was only 31 years old.

SEE ALSO Anatomical nomenclature; Autopsy; Pathology.

Bindle paper

Bindle paper is one of the tools that has long been used by forensic examiners to collect **evidence** and transport the evidence so that none of the contents are lost or contaminated. While many sophisticated techniques of forensic analysis and detection have emerged, the simple use of bindle paper remains an important part of an examiner's repertoire.

Typically, bindle paper is used for so-called **trace evidence** such as **fibers**, hair, paint chips, crystallized or dust-like material such as drugs, or other tiny particles. This material is light and can be difficult to see, which increases the chances that it can go missing if not carefully stored.

Bindle paper is nothing more than a clean sheet of paper that is folded in a defined manner in a series of steps. An 8 x 12 inch sheet of paper is a convenient size to use. And can be easily transported to the scene of the accident or crime.

In order to house (place) the evidence, the flat sheet of paper is first lightly folded in thirds horizontally and vertically to create nine similarly sized squares. Next, the vertical creases are folded, with the left hand side of the paper folded first, followed by the right hand side. The bottom square is folded upward. At this point the evidence is placed into the opening at the top edge of the paper. The top square is then folded down and the edge is inserted into the opening present in the lower folded square.

If done correctly, the evidence is secured inside the folded paper, which is then secured shut with tape. The package is never stapled shut, as this introduces holes through which the evidence might escape or contaminating air or moisture can enter.

At this point the bindle paper package can be put into an envelope for transport to the forensic laboratory. The folding design of bindle paper is preferred over an envelope. The manufactured corners, folds, and opening of the latter can all be places where evidence can be lost. Furthermore, the use of paper for trace evidence is preferred over plastic containers for evidence that can pick up an electrostatic charge, is moist, or which may require genetic analysis.

Biodetectors

Biodetectors, which are used to detect the presence of biological material, can be used in forensics to detect microorganisms or some of their components in material and tissue recovered after death (post-mortem samples).

More specifically, biodetectors are analytical devices that combine the precision and selectivity of biological systems with the processing power of microelectronics. These detectors typically consist of a biological recognition system, usually enzymes or binding proteins immobilized on a surface acting as a physico-chemical transducer. One typical example of a biodetector is the immunosensor, which uses antibodies as the biorecognition system. In addition to enzymes and antibodies, the recognition systems can consist of nucleic acids, whole bacteria and other single-celled organisms, and even tissues of higher organisms. Specific interactions between the target molecule or analyte and the complementary biorecognition layer produce a detectable physicochemical change, which can then be measured by the detector.

The detection system can take many forms, depending upon the parameters being measured. Electrochemical, optical, mass, or thermal changes are the most common parameters providing both qualitative or quantitative data.

In recent years, the emphasis on measures to combat terrorism has led to the development of techniques that could be useful in **forensic science**. For example, a microarray of fluorescent labeled nucleic acids immobilized on a support has been developed by researchers at Argonne National Laboratory. The intended application for the "bacillus microchip" is the detection of *Bacillus anthracis* (the **anthrax** agent). It would distinguish *B. anthracis* from other related bacteria, such as *B. thuringiensis*, *B. subtilis*, and *B. cereus* and also indicate whether the organism is alive or dead by detecting **DNA** when there are no RNA matches. However, the same technique could be applied to the detection of other microorganisms in post-mortem samples.

A number of new fast, reliable, and portable DNA detection devices have been developed that can prepare and test samples within a very short time. Devices consisting of cell disruptors, capable of breaking bacterial **spores** and extracting DNA that is then used to identify the species of organism, are being tried. Some companies have incorporated an automated sample preparation scheme and coupled it with a microfluidic "lab on a chip" device for detecting microorganisms on the basis of their DNA sequence. The system can reduce a laboratory preparation procedure that can take six hours to just 30 minutes. The chip contains tiny channels, valves, and chambers through which milliliters of sample can be pumped and concentrated into a microliter volume. Any bacterial cells are broken ultrasonically and their DNA is extracted, amplified by **PCR (polymerase chain reaction)** and sequenced.

A DNA-based biochip designed by Northwestern University detects DNA sequences that are specific for pathogenic microorganisms. The chip initially contains very short single strands of DNA between two small electrodes. The DNA strands are complementary to DNA sequences from a specific pathogen. When DNA from that pathogen comes into contact with the chip, it hybridizes with the DNA on the chip. To detect the hybridization, further pieces of DNA are added to the system and these are complementary to the sections of pathogen DNA that have not hybridized. The additional DNA pieces contain gold particles that, on successful hybridization, form a bridge of conducting metal linking the two electrodes. The bridge completes an electrical circuit and triggers a signal.

SEE ALSO Anthrax, investigation of the 2001 murders; Bacterial biology; Biosensor technologies; Pathogens; RFLP (restriction fragment length polymorphism).

Biohazard bag

A biohazard bag is a specially designed plastic or paper bag that is used to collect and transport **evidence** from a crime or accident scene to another site, such as the laboratory, where subsequent analyses can be done.

Samples such as **blood**, fabric, bullets, and other pieces of evidence cannot be analyzed at the scene. But if the transport to the laboratory alters the

Military personnel in hazmat suits handle a biohazard bag between the Longworth and Rayburn House Office Buildings on Capitol Hill in Washington, 2001, after the buildings were swept for anthrax. © REUTERS/CORBIS

sample composition (i.e., contamination, **decomposition**) then the value of the sample as a legally admissible piece of evidence is destroyed.

The use of a biohazard bag prevents such contamination of a sample. As well, in the case of a potentially contaminated or poisonous sample, the handler is kept safe.

Biohazard bags vary in their dimensions and capacity. Typical dimensions are 6 x 9, 8 x 10, and 12 x 15 inches. However, several features are often preserved. They are similar to the kitchen-variety sandwich bag, in having a "zip-lock" type of closure. This eliminates the need for an external enclosure and allows a bag to be closed when a handler is wearing gloves.

Similar to some household plastic sealable bags, biohazard bags can have plastic strips positioned above the zip-lock. They provide material that the user can grasp when opening the bag, without having to handle the actual storage area. This allows a bag to be easily and repeatedly opened, especially when the user is wearing gloves, and lessens ripping of the bag.

A common feature of biohazard bags is their rugged construction. In contrast to the single layered sandwich bags, biohazard bags can have three layers of polypropylene or other plastic polymer. This reduces the chance of leakage and puncture.

Most biohazard bags will have a roughened portion on the surface that allows for writing on the surface. Written **identification** of all retrieved evidence is essential. Bags can also have an external pouch to house related paperwork.

Sharp objects that could puncture plastic will typically be stored first in a paper bag or other receptacle instead of a plastic bag. Biohazard bags made of Kraft paper are commercially available.

The choice of paper instead of plastic can be advantageous in other ways. Paper allows a sample to remain dry during transport. In contrast, condensation that can form in a plastic bag transported at a warm temperature can be deleterious to, for example, blood-stained fabric.

SEE ALSO Crime scene investigation; Evidence.

Biological warfare, advanced diagnostics

Forensic analysis techniques are often used for other applications. For example, various chromatographic techniques can be used to examine an array of materials, including **blood** and other forensically-relevant samples.

Technologies that are used to detect biological warfare agents can be relevant to forensic analyses. These include the detection of living bacteria, based on the metabolic conversion of one compound to another by the organisms. Indeed, one novel technology can detect the distinctive aromas emitted by bacteria when they metabolize certain compounds.

Toxins that are produced by bacteria including *Bacillus anthracis* (the agent of **anthrax**) and *Clostridium botulinum* (which causes the food-borne illness of botulism) can be detected using antibodies targeted specifically for the particular toxin protein. Other poisons (such as **ricin**) are likewise detectable.

In the United States, the development of diagnostic capabilities for biological warfare is a government concern. The Advanced Diagnostics Program is funded by the Defense Advanced Research Projects Agency of the United States government (DARPA). Its objective is to develop tools and medicines to detect and treat biological and chemical weapons in the field at concentrations low enough to prevent illness. Challenges to this task include minimizing the labor, equipment, and time for identifying biological and chemical agents.

One area of interest includes development of field tools that can identify many different agents. To accomplish this goal, several groups funded under the advanced diagnostics program have developed field-based biosensors that can detect a variety of analytes, including fragments of **DNA**, various hormones and proteins, bacteria, salts, and antibodies. These biosensors are portable, run on external power sources, and require very little time to complete analyses.

A second focus of the advanced diagnostics project is the **identification** of known and unknown or bioengineered **pathogens** and development of early responses to infections. Many viruses act by destroying the ability of cells to replicate properly. One group funded under the advanced diagnostics program is studying the enzyme inosine 5′-monophosphate dehydrogenase (IMPDH), which produces products that are required for synthesizing nucleic acids, such as RNA and DNA, both of which are essential for proper cell replication. This group seeks to develop novel drugs based on IMPDH, which can cross into cells and thwart viral infection.

A final goal is to develop the ability to continuously monitor the body for **evidence** of infection. Researchers are addressing this goal in two ways. The first involves engineering monitoring mechanisms that are internal to the body. In particular, groups funded under the initiative are developing bioengineered white blood cells to detect infection from within the body. Often genetic responses to infection occur within minutes of infection, so analysis of blood cells provides a very quick indication of the presence of a biological threat. The second method involves the development of a wearable, non-invasive diagnostic device that detects a broad-spectrum of biological and chemical agents.

SEE ALSO Aflatoxin; Bacterial biology; Bioterrorism.

Biological weapons, genetic identification

The ability to use microorganisms and their components as weapons has been a reality for decades. Individual countries and organizations such as the United Nations have mounted efforts to detect the use and presence of microbial weapons. A recent example is the effort by United Nations and United States inspectors to detect **evidence** of microbial weapons in Iraq in the aftermath of the two Gulf Wars.

Initiatives like the aforementioned represent the use of **forensic science**. Traditional forensic investigations relied on the use of techniques that required the growth of the target microorganism. This approach has limitations. For example, the growth conditions selected might not be suitable to permit the growth of the target microbe. Furthermore, the laboratory facilities required, especially for the **culture** of highly infectious organisms, may not be widely available.

The use of genetic techniques of **identification** represents a promising forensic approach. Genetic technologies can be useful in the detection of biological weapons. Of particular note is the **polymerase chain reaction**, or **PCR**, which uses select enzymes to make copies of genetic material. Within a working day, a target sequence of genetic material can be amplified to numbers that are detectable by laboratory tests such as gel **electrophoresis**. If the target sequence of nucleotides is unique to the microorganism (e.g., a **gene** encoding a toxin), then PCR can be used to detect a specific microorganism from among the other organisms present in the sample.

Hand-held PCR detectors that have been used by United Nations inspectors in Iraq during their weapons inspections efforts of 2002–2003 purportedly can detect a single living *Bacillus anthracis* bacterium (the agent of **anthrax**) in an average kitchen-sized room.

The sequence of components that comprise the genetic material (genome) of a microorganism can also be deduced using techniques such as electrophoresis. Once a sequence is known, it can be compared to the many bacterial, viral, protozoan, and other microbial sequences in databases in order to determine if the deduced sequence resembles a catalogued sequence.

SEE ALSO Anthrax, investigation of the 2001 murders; Biosensor technologies; Chemical and biological detection technologies; Nucleic Acid Analyzer (HANAA); PCR (polymerase chain reaction); RFLP (restriction fragment length polymorphism); STR (short tandem repeat) analysis; Toxins.

A steer receives a retinal scan used by a meat company to better track the cow's life history to assure consumers that the beef the company processes is safe to eat. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

Biometric eye scans

The **identification** of a victim or suspect of a crime can result from comparison of information collected during a forensic examination with information residing in various data bases. One example includes fingerprints. The **Integrated Automated Fingerprint Identification System** that is maintained by the Federal Bureau of Investigation is a repository for millions of **fingerprint** patterns and other information. Another example is the pattern obtained from a scan of the retina and iris, both parts of the eye.

The retina is the neural part of the eye responsible for vision. The pattern of blood vessels serving the retina is unique to an individual, and is as unique as fingerprints. The chance that two people will have the same iris pattern is estimated to be one in 10^{78}.

The technology that scans the retina is known as retinal scanning. The true target for the scan is the capillary pattern in the retina. The process relies on generating images of the retina using a low intensity light source. In 1930s retinal capillary patterns were suggested to be unique, but the technology to use this information was developed much later. Although military and high-security use of photographic retinal scans began decades earlier, by 1985, retinal scan technology became available for computerized biometric identification and commercial security use.

Retinal scans are just one of the biometric methods using the eye for personal identification. Two years after the first retinal scanner was developed, in 1987, Leonard Flom and Aram Safir patented the use of iris patterns as a personal identifier. However, it was not until 1994 when John Daugman developed the technology for iris scanning. Since then iris scanning technology began to challenge the retinal scans. Currently a number of companies claiming that they perform retinal scanning, in reality are performing iris scans.

Retinal scans are based on the presence of the fine network of capillaries supplying retina with oxygen and nutrients. These vessels absorb light and can be easily visualized with proper illumination. Retinal scans require close contact of user and scanner, a perfect alignment of the eye with a scanner, and no movement of the eye. The examiner is required keep the subject's eye within half an inch (1 cm) of the instrument. The subject must focus on a little green light (to properly align the eye) and avoid blinking. A low intensity coherent light is then transmitted through the eye and the reflected image of the retinal capillary pattern is recorded by the computer.

A frequent flyer has his iris scanned at Boston's Logan Airport in a 2004 trial program allowing frequent fliers to cut down on their airplane boarding times, after submitting to fingerprinting, iris scanning, and a background check. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

Although retinal patterns are generally thought to be constant during a person's life, they can change in case of diabetes, glaucoma, retinal degenerative disorders or cataracts. Therefore, although retinal scans are nearly 100% accurate, they cannot be used as a universal security measure without making allowances for normal age-related physiological changes.

An initial scan (enrollment) takes a minimum of five scans and lasts approximately 45 seconds; subsequent authentication scans are faster and take only 10–15 seconds. An acquired image containing 320–400 reference points is converted to a map of the retina and used to identify a match from the templates encoded in the scanner's software. Retinal images captured are extremely small, only 35 bytes in size.

The technology for retinal scans has changed in recent years. The initial large devices are being followed now by smaller and more accurate instruments. The first commercial retinal scanner was developed in 1984. One of the most recent developments in the area is a small mobile and easy to use retinal scanner. Although it was initially developed for diagnostic purposes, it will be available as a security tool as well.

Fooling the retinal scanner is very difficult, as it requires intact retina to complete a scan. Following death, the retina degrades very quickly and thus cannot be used in most cases for accurate post-mortem identification. Although often a popular movie special effect, using a retina detached from a cadaver would fail with modern scanning equipment. Likewise, surgical alteration of the retinal pattern would be not only a dangerous and extremely expensive process, but futile, as the changes introduced would be readily detected by modern scanning equipment.

Iris scans use characteristics more similar to fingerprints than to retinal vein pattern. The colored part of the eye appears to be as unique as fingerprints and retinas. Scanning technology takes advantage of crypts, furrows, ridges, striations, ligaments, and collarette. While 240 points are recorded, the image size is 512 bytes, over ten times larger than a retinal scan. The main advantage of the iris scans is the ability to perform them from a distance of up to three feet and short time of scan of only 20 seconds initially, with subsequent identification requiring only two seconds. Glasses and contact lenses do not interfere with the scanning process and identification.

In contrast to the retinal scanners, iris scanners are of two main types: active and passive. The active system works from 3–14 inches (7.5–35 cm) and also requires the user to move forward and backward so the camera is adjusted properly. In contrast the passive system can work over longer distance from one to three feet (0.3–1 m).

Biometric techniques are used in identification and authentication. The features used for the two processes can overlap, or can be different. Authentication requires high accuracy to ensure restricted access. Retinal and iris scans offer high accuracy, and the primary users of retinal scans are military and government facilities, such as CIA, **FBI**, and NASA. Scans are used to control access to high security areas.

An acceptance is growing for the iris recognition systems and they are now used by government agencies, commercial companies, and also in the public sector. Among the government users are the U.S. Congress, and Departments of Defense, State, and Treasury. Some of the commercial companies that protect themselves by using iris recognition are Bank United, GTE, Hewlett Packard, Lockheed Martin, and British Telecom.

Scanning is also being implemented at airports as an added security feature. For example, as of 2005, eight of the largest Canadian airports (Toronto, Vancouver, Ottawa, Montreal, Halifax, Winnipeg, Calgary, and Edmonton) have, or are planning to install, systems that will be part of the U.S. Customs inspection process.

SEE ALSO Fingerprint; Identification.

Biometrics

Biometrics refers to the measurement of specific physical or behavioral characteristics and the use of that data in identifying subjects. With wide application, biometric-based **identification** techniques are increasingly an important part of **forensic science** investigations because biometric data is difficult, if not impossible, to duplicate or otherwise falsify. Examples of such data include retinal or iris scans, fingerprints, hand geometry, and facial features. Accordingly, biometric systems offer highly accurate means of comparison of measured characteristics to those in a preassembled database.

Biometric identification points include gross morphological appearance that is most often subjectively interpreted upon superficial examination (e.g., gender, race or color of skin, hair, and eye color). Other gross biometric data can include more quantifiable—and therefore less subjective—data (e.g., weight, height, location of scars or other visible physical markings). Some biometric data is easily changeable and therefore not reliable (e.g. presence of facial hair, wearing of glasses, etc.).

Because even objective features such as weight can change over time, systems of identification that rely on changeable or gross features are not as reliable as biometric systems that measure more stable anatomical and physiological characteristics such as fingerprints, retinal blood vessel patterns, specific **skull** dimensions, dental and skeletal x rays, earlobe capillary patterns, and hand geometry.

The most specific and reliable of biometric data is obtained from **DNA sequencing**.

More controversial and, at present, less reliable biometric studies seek to enhance quantification of social behaviors, voice characteristics—including language use patterns and accents—handwriting, and even keystroke inputs patterns.

Biometric data can be encoded into magnetic stripes, bar codes, and integrated circuit “smart” cards.

On a global scale, biometric data interchange and interoperability standards are at present fragmented into different measurement and input format schemes. The Common Biometric Exchange File Format (CBEFF), in development by the International Biometric Industry Association (IBIA), seeks to integrate such measurement schemes to enhance reliability and use of biometric data. Other integration efforts include the Biometric Application Programming Interface (BioAPI) specification program used by the United States Department of Defense. The Department of Defense has also established a Biometrics Management Office (BMO). BioAPI protocols are also being used by other governmental agencies and the financial service industry in the development of smart cards.

Britain's Prime Minister Tony Blair's demonstration biometric card is displayed at the Passport Office in central London during a biometrics enrollment trial, where records were taken of volunteers' facial identity, iris recognition, and fingerprints.
© CHRIS YOUNG/POOL/REUTERS/CORBIS

The National Institute of Standards and Technology (NIST) also dedicates programs to biometric research and exchange. NIST developed the initial data protocols used in the Face Recognition Vendor Test (FRVT) and established the format for data collection used by most face recognition technologies.

Finally, reflecting the power of biometrics in forensic science, police forces are increasingly equipping themselves with the technical and personnel expertise to undertaken biometric examinations. These efforts are aided by the Internet, which allows police forces to access databases and share information on a global scale.

SEE ALSO Automated Fingerprint Identification System (AFIS); Digital imaging; DNA fingerprint; Fingerprint; Hair analysis; Handwriting analysis; Integrated Ballistics Identification System (IBIS).

Biosensor technologies

The detection of biological agents that pose a threat of disease has become an important facet of forensic investigations. A well-known example was the effort of United Nations inspectors to detect microbiological weapons before and following the 2003 Gulf War between Iraq and coalition forces headed by the United States.

Part of these detection efforts involved the use of hand-held devices that could identify the presence of certain bacteria with great precision and sensitivity. These devices represent the cutting-edge application of what are known as biosensors.

Biosensor technology is also used more routinely, for example, in forensic investigations of an illness outbreak or death. The systems currently available for sensing biological analytes rely on two technologies: reporter molecules that attach to antibodies and give off fluorescent signals and the **polymerase chain reaction** (**PCR**) that amplifies suspect **DNA**. Because two steps are required to identify biological weapons, the procedure is both labor and time intensive. The Defense Advanced Research Projects Agency (DARPA) initiated the Biosensor Technologies program in 2002 to develop fast, sensitive, automatic technologies for the detection and **identification** of biological warfare agents. The program focuses on a variety of technologies, including surface receptor properties, nucleic acid sequences, identification of molecules found on the breath, and mass spectrometry.

A major thrust of the surface receptor research is to enhance or replace the chemical signal given off by antibodies to biological analytes. One such project has developed short polypeptides (4–5 amino acids long) that can bind to **anthrax spores**. A separate group has engineered aptamers, short strands of nucleic acid that specifically bind to the DNA of the bacteria that cause anthrax. Another research area involves using ion channels for amplifying the signal of a reporter molecule. This work includes the engineering of an artificial ion channel that is triggered by the binding of an **antibody** or other small molecules. Such engineered ion channels are sensitive to a single binding event, require no external energy, and can greatly amplify the chemical signal. Finally, converting phosphors as a replacement for fluorescent reporter molecules is being investigated.

The focus of the nucleic acid sequence technology is the development of a biochip that contains an array of engineered molecules that react with the genome of biological warfare agents or disease causing organisms of public health importance. The biochip is embedded in a platform that is portable, automated, and allows for direct sampling of the environment. A biochip platform to identify the anthrax bacteria is in the testing stages and additional biochips for identifying other harmful bacteria and viruses are in development.

SEE ALSO Antibody; Antigen; Anthrax; Bacterial biology; Biodetectors; Biological weapons, genetic identification; Fluorescence; PCR (polymerase chain reaction).

Bioterrorism

Bioterrorism is the use of a biological weapon against a civilian or military population by a government, organization, or individual. As with any form of terrorism, its purposes include the undermining of morale, creating chaos, or achieving political goals. Biological weapons use microorganisms and **toxins** to produce disease and death in humans, livestock, and crops.

Bioterrorism is viewed as a serious threat to national security and a range of experts, including forensic investigation teams, would be called on to deal with an incident involving biological weapons. For example, disaster scenarios created by United States government agencies predict that the release of a few hundred pounds of the **spores** of *Bacillus anthracis* (the bacterium that cause the disease called **anthrax**) upwind of Washington, D.C., could sicken or kill hundreds of thousands to millions of people within 24 hours. Forensic scientists would likely respond by identifying the bacterium, tracing its source, and gathering and analyzing other **evidence** from the biocrime scene and the victims.

Bioterrorism can also be used as a weapon to damage or destroy the economy of the target nation. A report from the **Centers for Disease Control and Prevention (CDC)** estimates the cost of dealing with a large-scale anthrax incident is at least $26 billion per 100,000 people. Only a few such incidents would cripple the economy of any nation. Indeed, the few anthrax incidents that occurred following the September 11, 2001, terrorist attacks cost the United States government hundreds of millions of dollars in treatment, investigation, and other response measures.

Biological, chemical, and nuclear weapons can all be used to achieve similar destructive goals (i.e., massive loss of life). Relative to chemical and nuclear weapons, biological weapons are inexpensive to make. A sophisticated biological production facility can be set up in a warehouse or even a small house. Biological weapons are relatively easy to transport and can resist detection by standard security systems.

In general, chemical weapons act immediately, causing illness in minutes. For example, the release of **sarin gas** in the Tokyo subway in 1995 by the religious sect Aum Shinrikyo almost immediately killed 12 and hospitalized 5,000 people. In contrast, the illness and death from biological weapons can occur more slowly, with evidence of exposure and illness appearing over time. Thus, a bioterrorist attack may at first be indistinguishable from a natural outbreak of an infectious disease. By the time the deliberate nature of the attack is realized, the health care system may be unable to cope with the large number of victims.

The deliberate production and stockpiling of biological weapons is prohibited by the 1972 Biological Weapons Convention. The United States ceased offensive production of biological weapons in 1969, on orders from President Richard Nixon. The U.S. stockpiles were destroyed in 1971–1972. This measure has not stopped bioterrorists from acquiring the materials and expertise needed to produce biological weapons.

Genetic engineering can produce a wide variety of bioweapons including bacteria or viruses that produce toxins. More conventional laboratory technologies can also produce bacteria that are resistant to **antibiotics**.

A young child tries on a gas mask designed especially for small children in Tel-Aviv, Israel. © JEFFREY L. ROTMAN/CORBIS

Examples of the bioterrorist weapons most likely to be used include **smallpox** (caused by the **variola virus**), anthrax (caused by *Bacillus anthracis*), and plague (caused by *Yersinia pestis*).

The last recorded case of smallpox was in Somalia in 1977. Today, only two facilities—one in the United States and one in Russia—are authorized to store the virus. In spite of international prohibitions, security experts suspect that smallpox viruses may be under development as biological weapons in other laboratories of many nations. As recently as 1992, Russia had the ability to launch missiles containing weapons-grade smallpox. A number of terrorist organizations, including Al Qaeda, have explored the use of biological weapons.

Bioterrorism may ultimately prove to be more destructive than conventional warfare because of the mobility of the weapons and their ability to spread infection through an entire population. An epidemic can spread a disease far from the point of origin of the illness.

Preparing a strategy to defend against biological warfare is challenging. Traditional identification of microorganisms such as bacteria and viruses relies on assays that detect growth of the microbes. Newer technologies detect microbes based on sequences of genetic material. The genetic technologies can detect microbes in minutes. However, these technologies are not available to any but the most sophisticated field investigative units.

Researchers are also working to counter bioterrorist attacks using several other technological strategies. For example, robots equipped with sensors or microchip-mechanized insects (with computerized circuitry that can mimic biological processes such as neural networks) are being refined. Bees, beetles, and other insects outfitted with sensors are used to collect real-time information about the presence of toxins or similar threats. These technologies could be used to examine a suspected biological weapon and spare exposing investigators to potential hazards. The robotics program of the Defense Advanced Research Project (DARPA) works to rapidly identify bio-responses to **pathogens**, and to effectively and rapidly treat them.

Research is also underway to find genetic similarities between the microbes that could be used by bioterrorists. A vaccine made to act on a protein that is common to several bacteria could potentially offer protection to the exposure any bacterium in the group, for example.

SEE ALSO Anthrax, investigation of the 2001 murders; Biological warfare, advanced diagnostics; Biological weapons, genetic identification; Chemical Biological Incident Response Force, United States; Pathogen transmission; Pathogens; Sarin gas; September 11, 2001, terrorist attacks (forensic investigations of); Smallpox; Vaccines.

Bite analysis

Bite marks may be found at the scene of a crime and their analysis has been used for many years as an aid in forensic investigation. Bite marks can occur on the skin of a victim or on other objects, including foods such as cheese, chocolate, or apples. Non-food items that may bear bite marks and are therefore worthy of investigation include chewing gum, bottle tops, masking tape, and pencils. The bite mark itself may be matched to the bite mark of a suspect. There is also the possibility of gathering **saliva** from the bite mark, which can then be used to identify a suspect through **DNA** analysis.

Bite marks tend to have a double horseshoe pattern showing the six central teeth of the upper jaw and the corresponding six teeth in the lower jaw. Those made in food are usually well defined; bite marks made in flesh are usually less defined. The analysis of a bite mark begins with photographing the **evidence** in both black and white and in color, and from several angles. It is important to take these photographs within eight hours of the injury being inflicted in the case of a victim. Inflammation tends to blur the pattern after this time if the victim is alive. If the mark is deep enough, then a cast can be made using dental processes similar to those used for making a tooth crown or a bridge. The next step is to make an image that can be overlaid on the bite mark of a suspect for comparison. The image can be made by manual tracing or by scanning into a computer and using a program that makes a picture on a transparent overlay sheet.

Bite marks reveal features such as gaps between the teeth, ridges on the biting surfaces of the teeth, rough fillings, as well as missing, broken, chipped, or distorted teeth. In fact, human teeth patterns are individual and careful expert analysis of a bite should be able to tie the mark to a suspect. **Identification** through bite mark analysis is given over to a forensic odontologist, who is a specialist in dental anatomy and its interpretation.

Flesh is elastic and stretches when it is bitten. A bite mark on a body, therefore, is somewhat different from a bite mark on an inanimate surface. A forensic pathologist will note a bruising pattern in the shape of two curved lines facing one another if the bite has been inflicted antemortem (before death). Bites inflicted on muscular tissue make a more distinct pattern than bites found on fatty tissue. Postmortem bites do not produce bruising. Particularly ferocious bites will produce lacerations. Bite marks on a victim tend to be specific to the nature of the attack. For example, bite marks on the neck, breasts, and shoulders are seen in some rapes, sexual assaults, or incidents of domestic violence. Multiple bites on the arms or buttocks are sometimes a feature of child abuse. Sometimes a victim may bite the suspect as a means of the defense using the teeth as a weapon; this tends to produce multiple bites, rather than single bites.

It is also important to take sterile swabs of the bite to collect traces of saliva. The presence of the enzyme amylase in the swab shows that saliva is present and the injury is indeed a bite. Microbiological evidence from the swab can also be informative if it corresponds to the microbial flora (microorganisms present) from the mouth of a suspect. It may also be possible to determine the **blood** group of the suspect from saliva analysis. This kind of evidence is useful for excluding a suspect, taken with the bite pattern analysis. If DNA can be extracted from the saliva as well, then the bite mark evidence for or against the suspect becomes even stronger.

One of the most famous cases involving bite analysis is that of serial murderer Ted Bundy. In 1978, a brutal attack at the Chi Omega sorority house at Florida State University left two young women dead and two others seriously injured. A fifth woman, who escaped, was able to describe her attacker. Bundy, an escaped prisoner, was caught and put on trial for the Chi Omega murders. A crucial piece of evidence for the prosecution was an enlarged photograph of a bite mark found on the left buttock of one of the victims. An image of the outline of Bundy's front teeth was created on a transparent overlay. Bundy's teeth were misaligned and chipped. According to the forensic odontologist, this matched perfectly with the photograph of the bite mark found at the scene. This helped identify Bundy as the attacker and he was found guilty and executed in 1989. Bundy confessed to up to 50 other murders.

SEE ALSO Body marks; Bundy (serial murderer) case; Odontology.

Edward T. Blake

7/31/1945–
AMERICAN
FORENSIC SCIENTIST

For more than thirty years, forensic scientist Edward T. Blake has been considered an expert in **DNA** analysis. He was the first to use **polymerase chain reaction** (**PCR**) based DNA testing in the United States, during the civil court case *People v. Pestinikas* in 1986. Since that time, he has worked as a consultant to analyze biological **evidence** in countless criminal cases, including work that has led to the exoneration of approximately fifty people wrongly accused of crimes.

Born in Honolulu, Hawaii, Blake early on was interested in the field of **forensic science**. He attended University of California, Berkeley (UCB), earning a bachelor's degree in **criminalistics** in 1968 and a doctorate of **criminology** in 1976. While in school, Blake worked at the Contra Costa County Sheriff's Office Criminalistics Laboratory, and served as a teaching assistant in the Forensic Science Program at UCB. After graduation, he immediately began his work as a consultant in forensic biology, and eventually opened his own consulting firm, Forensic Science Associates, in 1978.

With Forensic Science Associates, Blake conducts independent analysis of DNA and crime scenes, analyzing biological evidence such as **saliva**, **blood**, and **semen**. This analysis can take months, if not years, to perform. But through the use of PCR-based DNA testing, analysts can identify a genetic profile with incredible accuracy. While much of the work is conducted before or during a criminal trial, Blake's firm has earned national recognition as a source of post-conviction testing as well. As an advisor and consultant, Blake has taken part in hundreds of court cases, including such high-profile cases as the O.J. Simpson trial in California.

Since the 1970s, Blake has also been a regular contributor to many trade publications, including the *American Journal of Human Genetics*, the *New England Journal of Medicine*, the *Journal of Forensic Science*, and the *Banbury Report.* He has often written about the topics of genetic markers, DNA analysis, and PCR-based testing. He has also frequently spoken at conferences and seminars held by key professional societies and organizations, including the California Association of Criminologists, the **American Academy of Forensic Sciences**, and the Federal Bureau of Investigation.

SEE ALSO DNA evidence, cases of exoneration; PCR (polymerase chain reaction).

Blood

Frequently, the forensic analysis of a crime or accident scene will involve the analysis of blood. Whether in the form of fresh liquid, dried blood, jelly-like coagulated blood, or patchy drops or stains, blood can be a treasure trove of information. As one example, the pattern of a bloodstain can tell a forensic investigator much about the nature of the accident or crime. Just as important is the composition of the blood.

A typical human body contains approximately ten pints (4.7 liters) of blood. Depending on the severity of a wound, blood can be lost slowly or, as in the case of a severed artery, can spurt quickly out of the body. A forensic examiner can tell a great deal about the nature of the accident or crime from the pattern of the blood residue. Additionally, knowledge of the composition of blood and properties of these components is also valuable in identifying a victim or implicating an assailant.

Human blood is made up of several different types of cells. Each has a distinctive appearance and function.

Red blood cells are absolutely vital for life. Each drop of blood contains millions of these cells. In the body, the circulating red blood cells deliver oxygen to cells and transport waste material from the cells.

Red blood cells are round, smooth-edged, and saucer-like in shape, typically having a slightly depressed center. In a disease like anemia or sickle cell anemia, the cells can be present in reduced numbers or can adopt an abnormal sickle shape. This reduces the oxygen carrying capacity of the blood. The presence of such abnormalities can alert a forensic investigator or **medical examiner** to the presence of disease or poison, or lack of constituents, including iron, vitamin B_{12}, or folic acid, or other maladies.

The bright red color of a healthy red blood cell comes from the presence of an iron-containing compound called **hemoglobin**. The presence of iron makes hemoglobin an excellent molecule for the binding and transport of oxygen and carbon dioxide. As blood passes through the tiny channels that permeate the lung, the oxygen molecules that diffuse across the channel membrane bind to the hemoglobin. The oxygen is subsequently released to cells all through the body during the circulation of the red blood cells.

Once vacant, the binding site in the hemoglobin is able to accommodate the binding of carbon dioxides and other waste products of cellular metabolism. These products, which would become toxic to the cells if allowed to accumulate, are then transported away. As the red blood cells pass back through the lung, the carbon dioxide and other waste molecules are released from the hemoglobin and are exhaled.

Red blood cells are long-lived, but not immortal. The average lifetime is approximately 120 days. Although cells are continually dying and being replenished, the number of red blood cells remains constant in a properly-operating body.

In contrast to the smooth, plate-like red blood cells, white blood cells are spheres that have numerous knob-like projections sticking out from their surface.

White blood cells are part of the body's defense system against infection. When a microbial threat is recognized by the **immune system**, white blood cells are signaled and directed to the site of the threat. There, they attack the invading microorganisms, by producing antibodies directed against components of the microbe or by physically engulfing, ingesting, and dissolving the invader.

White blood cells are primed and ready for their defensive duties by means of a short life span. They live only a few days to several weeks.

Under normal conditions there are 7,000–25,000 white blood cells per drop of blood. The determination of this number can provide an indication of the presence of disease. For example, if a bacterial, viral, or parasitic infection proves resistant to eradication, an increased number of white blood cells will be recruited to do battle with the invader, reducing the white blood cell count in the blood. Conversely, cancer of the blood (leukemia) causes the numbers of white blood cells to increase markedly. A leukemia patient can display upwards of 50,000 white blood cells per drop of blood.

The bloodstain that confronts a forensic investigator at the site of an accident or crime may be the result of a catastrophic injury that the body was unable to repair. Normally, the cuts and scrapes that occur during the normal course of life can be addressed by sealing up the wound.

The patching of a wound is the task of the colorless blood cells called platelets. Platelets do not have a uniform shape. Rather, they are reminiscent of an amoeba, being blob-like, with long and thin surface projections.

Platelets are recruited to the site of a cut or wound. Their shape and sticky surface facilitates their clumping together, along with calcium, vitamin K, and a protein called fibrinogen. The clump is known as a clot.

Clot formation is a complicated process that involves a cascade of biochemical reactions. Without platelets, clotting would not occur. When in the vicinity of the open wound, and so in the presence of an increased concentration of oxygen, the platelets dissolve. A consequence of the dissolution is the conversion of fibrinogen to fibrin. The tiny thread-like fibrin molecules collect to form a mesh that entraps intact and dissolved blood cells and other constituents. As this mass hardens, the clot forms. A hardened clot is also called a scab.

This effective wound patching system does have its limits, however. In the case of a catastrophic injury such as a knife or bullet wound, bleeding may continue unabated. If not treated, such a wound can be fatal.

The various blood cells are suspended in a straw-colored liquid called plasma. Plasma is composed mainly of water. Physiologically-important ions including calcium, sodium, potassium and magnesium also comprise plasma.

Plasma provides the medium in which the blood cells are suspended and transported around the body. As well, the disease-fighting antibodies produced by the immune system are also ferried to where they are needed via the plasma.

Blood, specifically the red blood cells, are also a valuable resource for a forensic investigator, as the cells can be used to determine what is known as the blood type of the victim or assailant.

The chemical residues present on the surface of red blood cells are the basis of blood typing. These were first described early in the twentieth century by the Austrian-born American immunologist **Karl Landsteiner** (1868–1943), who subsequently developed the typing criteria. For his achievements, Landsteiner was awarded the 1930 Nobel Prize in Medicine.

Landsteiner noted the presence of two distinct molecules—protein antigens A and B—on the surface of red blood cells. Type A blood is comprised of red blood cells that have only the A molecule, whereas the red blood cells of type B blood have only the B molecule. The presence of both molecules occurs in type AB blood. Finally, red blood cells can be devoid of both molecules. This occurs in type O blood.

The determination of blood type can be easily done by mixing a sample of blood with antibodies to the A or B components. In the presence of the correct **antibody**, the blood cells will clump together, forming a visible precipitate.

Blood typing remains a powerful forensic tool in linking someone to the crime or accident scene. In addition, because blood type is a genetically acquired trait, blood typing can be useful in establishing familial relationships. However, because a great many people have the same blood type, this test alone is not a definitive **identification**.

Another very useful aspect of blood in forensic examinations involves a factor known as the Rh (for Rhesus) factor. The factor, which was also discovered by Landsteiner, derives its name from the Rhesus monkey, a species similar to us and so one that is used in medical studies. The Rh factor of human blood was discovered in blood comparisons between humans and the Rhesus monkey.

Rh factor is a protein that is present in the blood of some people (who are described as Rh positive, or Rh^+. Some people lack the blood protein, and so are described as being Rh negative (Rh^-).

The determination of the Rh status of a blood sample provides another piece of **evidence** that can help determine the identify of the victim or link someone to the crime or accident.

In addition to the A and B antigens and Rh factor, modern day blood typing includes over 150 blood-borne proteins and 250 enzymes located in blood cells.

This extensive form of blood typing, while still useful, is laborious and has been largely replaced by the molecular precision of genetic analysis.

As with every other cell in the body, blood cells contain genetic material in the form of deoxyribonucleic acid (**DNA**). DNA can be isolated and subjected to a variety of sophisticated analyses to determine the sequence of the nucleotide building blocks that comprise the structure. As well, small sequences that tend to vary from person to person can be quickly copied over and over again, using the **polymerase chain reaction** (**PCR**), to produce sufficient quantities for the sequence analysis. In this way, the pattern of DNA that is unique to an individual can be revealed.

Recovering the same DNA pattern in a blood sample of a suspect and from blood recovered at a crime scene is very powerful evidence tying the person to the crime scene. As seen in the trial of O.J. Simpson, however, even this evidence can fail to sway a jury if not convincingly presented or defended.

SEE ALSO Blood spatter; Bloodstain evidence; Blood volume test; Blood, presumptive test; Cast-off blood; DNA; Toxins; Wound assessment.

Blood, presumptive test

A forensic investigator can be confronted with a variety of **fluids** at a crime or accident scene. It is critical to determine the nature of each fluid.

While a detailed examination of a suspect bloodstain requires the equipment and technical expertise of an analysis laboratory, a fluid suspected of being blood can be examined at the scene to determine if it indeed could be blood. This examination is called a blood presumptive test.

Properly done, a blood presumptive test rules out the possibility that a fluid is blood. A blood presumptive test relies on the use of chemicals that will change color when in the presence of blood. As one common example, a solution of phenolphthalein, which is colorless, will turn an intense pink when added to a blood stain in the presence of hydrogen peroxide. The formation of a pink color indicates that the fluid could be, and indeed, likely may be, blood. However, confirmation requires the more detailed lab analyses.

Another chemical called o-tolidine can also be used in conjunction with hydrogen peroxide instead of phenolphthalein. Again, the formation of the characteristic color must be followed up by a more detailed and confirmatory examination of the sample.

When a blood presumptive test is done at a crime or accident scene, an investigator must include the use of controls to ensure the accuracy of the result. This is because a blood presumptive test can be subject to what is known as a false positive result. This is when the characteristic color reaction is produced by

An FBI pathologist in a laboratory at the FBI Academy in Quantico, Virginia, inspects dried material on a jacket before performing a presumptive blood test. © ANNA CLOPET/CORBIS

a sample that is in fact not blood. As well, a false negative reaction is possible, where for some reason a blood sample does not produce the characteristic color change in the indicator chemical.

Standard procedures can rule out the possibility of a false positive or negative result. However, if these controls are not run, then the accuracy of the presumptive test can be questioned. In that case, the results would not be admissible in a court of law.

Presumptive blood tests are commercially available in a convenient form that is easily transportable to the crime or accident scene. Typically, a sample is placed in a sterile plastic bag or box to which are added the chemicals. Upon mixing, the solution is visually observed for the development of the target color. Other containers contain the positive and negative controls.

SEE ALSO Blood; Blood spatter; Bloodstain evidence; Blood volume test; Indicator, acid-base.

Blood spatter

Blood spatter, or bloodstain pattern interpretation, is a technique that seeks to piece together the events that caused bleeding. Knowing how the blood got on the wall or other surface can be helpful in determining if a crime was committed and if the blood is **evidence** in that crime.

The blood spatter pattern can tell a trained investigator much about what crime may have been committed and rule out other types of crime. Together with other evidence, blood spatter can be very useful in piecing together what took place, identifying the victim, and determining who was responsible.

One of the first things that a forensic investigator needs to do when examining a blood spatter is to verify that the material is indeed blood. This can be determined by using tests that are portable enough to be used right at the scene. Later, tests will be done to determine if the blood is animal or human in origin and even to narrow down the people from whom the blood may have come.

In the actual spatter analysis, a forensic investigator determines the **trajectory** of the blood (where the blood came from and how it spread over the surface). By measuring the shape of the bloodstain on a surface, the direction of movement can be determined. As well, the speed at which the blood contacted the surface can be approximated. This can help distinguish, for example, between the rapid movement of blood that can be produced by a gunshot or the severing of an artery in opposition to the slower movement of blood from a minor cut.

If blood originated some distance away from a surface, the force of impact will cause the blood to break up into smaller drops. Thus, a blood spatter consisting of larger drops with a trail of smaller drops can tell an investigator much about how the blood got there and where the blood came from (i.e., near the floor, higher up in a room, near or far away from the surface).

The trained eyes of an experienced investigator remain one of the most powerful tools in blood spatter analysis. Specialized analytical computer programs are also available. Such detailed analysis can be important if the blood spatter is presented as evidence in a legal case.

SEE ALSO Bloodstain evidence; Cast-off blood; Crime scene investigation.

Blood volume test

The forensic investigation of a crime or accident scene involves the collection and analysis of **evidence**, including any **blood** present at the crime scene. One facet of a forensic examination that concerns blood is known as the blood volume test.

A blood volume test is designed to determine the quantity of blood that has been shed in a particular area. As well, the test seeks to relate the shed blood to a blood stain on a surface such as a rug or floor, or a **blood spatter** pattern on a surface such as a wall. Finally, the blood volume test can provide information concerning the length of time that was needed to create the stain or spatter pattern.

The volume of blood that is present at a crime or accident scene can tell a forensic examiner a great deal about the origin of the blood. For example, a small quantity of blood is typically produced by a relatively insubstantial cut, whereas a copious quantity of blood is more characteristic of a severe cut such as a deep stab wound, bullet impact or the severing of an artery.

Blood is sometimes collected directly from a person. As in a hospital, this collection involves drawing the blood from the person into a sterile container (Vacutainer) that is specifically designed to hold blood.

Blood that has collected on surfaces can be collected in a clean unused plastic container. It is likely that not all the blood will be collected. But, enough can be retrieved to discriminate between a small or copious blood spill. Once collected, the blood volume test should be refrigerated, transported to the laboratory, and analyzed as soon as possible, to prevent contamination of the specimen or destruction of blood cells.

The retrieval of dried blood is more complicated. The area containing the dried blood can be scrapped or cut free of the surrounding fabric. Sometimes, dried blood can be lifted off a surface by applying sticky tape (fingerprint tape is typically used), or absorbing the blood onto a pre-moistened thread or cotton square.

The collected dried blood can subsequently be reconstituted into a known volume of liquid for the determination of the blood volume.

Determination of the volume of the sample occupied by blood cells is not complicated. Each sample is spun in a centrifuge, which causes the heavier blood cells to move to the bottom of the tube. The tubes have gradations that allow the packed volume of the blood cells to be measured, relative to the total volume of the cells and liquid (plasma).

SEE ALSO Blood; Blood, presumptive test; Blood spatter; Crime scene investigation.

Bloodstain evidence

Bloodstains are an important piece of **evidence** in a forensic examination. The pattern of a stain and the quantity of **blood** present can be important clues to the nature of the accident or crime. Moreover, detailed analysis of the blood obtained from a stain can reveal genetic and other information that can help identify a victim or implicate the person responsible.

Analysis of bloodstains can also help reveal the nature of the injury and even the order that the wounds were received. The pattern of the bloodstain, which is also referred to as **blood spatter**, can be important in identifying the weapon used to inflict the injury, and help determine if the victim was moving or motionless when injured.

When initially dealing with a bloodstain, a forensic investigator will seek to obtain as much information as possible without disturbing the scene. This can involve recording the bloodstain by means of a sketch, video camera, or digital camera. As well, a chemical called **luminol** can be sprayed over the area of the bloodstain. Under ultraviolet illumination, the luminol that has bound to blood will fluoresce, which can reveal small quantities of blood that might otherwise escape detection.

When establishing the extent and pattern of a bloodstain, the use of sufficient illumination is important, to avoid shadows that might contribute to misleading shapes to blood drops, since the shape of a drop can indicate the direction and speed of impact of the drop with the surface.

The pattern of a bloodstain can tell a lot about the origin of the blood. For example, blood can drip or ooze out of a cut or bullet wound, spurt out at much higher speed from a severed artery, or be flung off a weapon as a blow is delivered. The resulting patterns will differ. Indeed, the pattern of **cast-off blood** from a weapon can even be used to determine if the assailant was right- or left-handed.

A drop of blood falling from 5–6 feet (1.5–2 m) above a floor will splash upon impact, while a drop falling several feet straight down will tend to be

Bloodstains on lyrics of a song about peace carried by former Israeli Premier Yitzhak Rabin on the day he was assassinated in 1995.

somewhat circular but with a wavy edge. A drop oozing out of a cut that is just a few inches above a floor likely will be circular.

In another example, the high impact of a gunshot wound can send blood away from a body at high speed. If the blood impacts a wall at an angle, the blood drop will assume more of a teardrop shape than if the blood impacts the wall straight on. Moreover, the orientation of several of the teardrop-shaped bloodstains will allow a forensic investigator to apply trigonometric functions to produce a three-dimensional recreation of the area that the blood came from.

A smeared bloodstain around a body can be evidence that the body was dragged to that position. Similarly, a trail of blood drops leading to a body can be evidence that the person was moving while bleeding, or was being carried by someone else.

A skilled forensic investigator is often able to trace these patterns back to their origin; literally, to the scene of the crime.

Bloodstains can also be a treasure trove of other information. If someone walked through a bloodstain on the floor, an impression of the sole of the shoe may have been left. This piece of evidence can help match someone to the scene of the crime or accident. The blood may also have carried bits of skin, hair, or clothing with it. All these materials can be recovered and analyzed to provide more information about the victim or the assailant.

Blood naturally carries the genetic information of the person from which it originated. Blood cells will contain deoxyribonucleic acid (**DNA**). The DNA can be enzymatically digested into many differently sized fragments and the fragments can be analyzed to deduce the sequence of building blocks (bases) that comprise the DNA. Small stretches of DNA that are of particular interest can be obtained in large quantities using a procedure known as the **polymerase chain reaction** (**PCR**). Essentially, PCR makes a copy of the target region, uses those copies to make more copies, and so on. The number of copies grows at a logarithmic rate to quickly generate millions of copies of the target region. The unique region can then be studied.

In this way, an individual's DNA sequence can be found. This sequence, like a fingerprint, can be almost unique to the individual. DNA sequence analysis, if properly done, can be a powerful piece of evidence.

Such was the case in the O. J. Simpson murder trial. The DNA pattern obtained from blood at the scene of the double **murder** matched the patterns obtained from blood found in Simpson's vehicle and from a blood sample obtained from Simpson himself. The odds that the blood was Simpson's and not someone else's were astronomically high. However, Simpson's lawyers were able to create doubt in the juror's minds concerning the way the blood samples were collected. The result, despite this overwhelming evidence, was an acquittal.

A bloodstain can also be tested to determine the blood type. There are four possible blood types: A, B, AB, and O. These various types can be distinguished from one another by virtue of the different proteins (antigens) on the surface of the blood cells. The different antigens can be recognized by specific antibodies.

Blood typing can be another powerful means of linking someone to a crime or accident scene, or exonerating them. For example, if a bloodstain at a crime scene contains Type A blood and a suspect has Type O blood, then the blood did not come from the suspect. However, because many people have the same blood type, blood typing alone cannot implicate someone.

Blood also can possess another **antigen** group called the Rh factor. Individuals who produce the Rh antigen have Rh positive blood. Those who do not produce Rh antigen have Rh negative blood.

Bloodstain analysis is now recognized as a vital facet of a forensic examination. This importance is exemplified by the Royal Canadian Mounted Police (RCMP), who maintain a Crime Scene Bloodstain Section in their Forensic Support Services. This section is one of the most advanced in the world, and is the only agency that specifically trains investigators to do bloodstain analyses at a crime scene.

SEE ALSO Blood, presumptive test; Blood spatter; Blood volume test; DNA fingerprint; Indicator, acid-base; Simpson (O. J.) murder trial.

Bloody Sunday inquiry in Northern Ireland

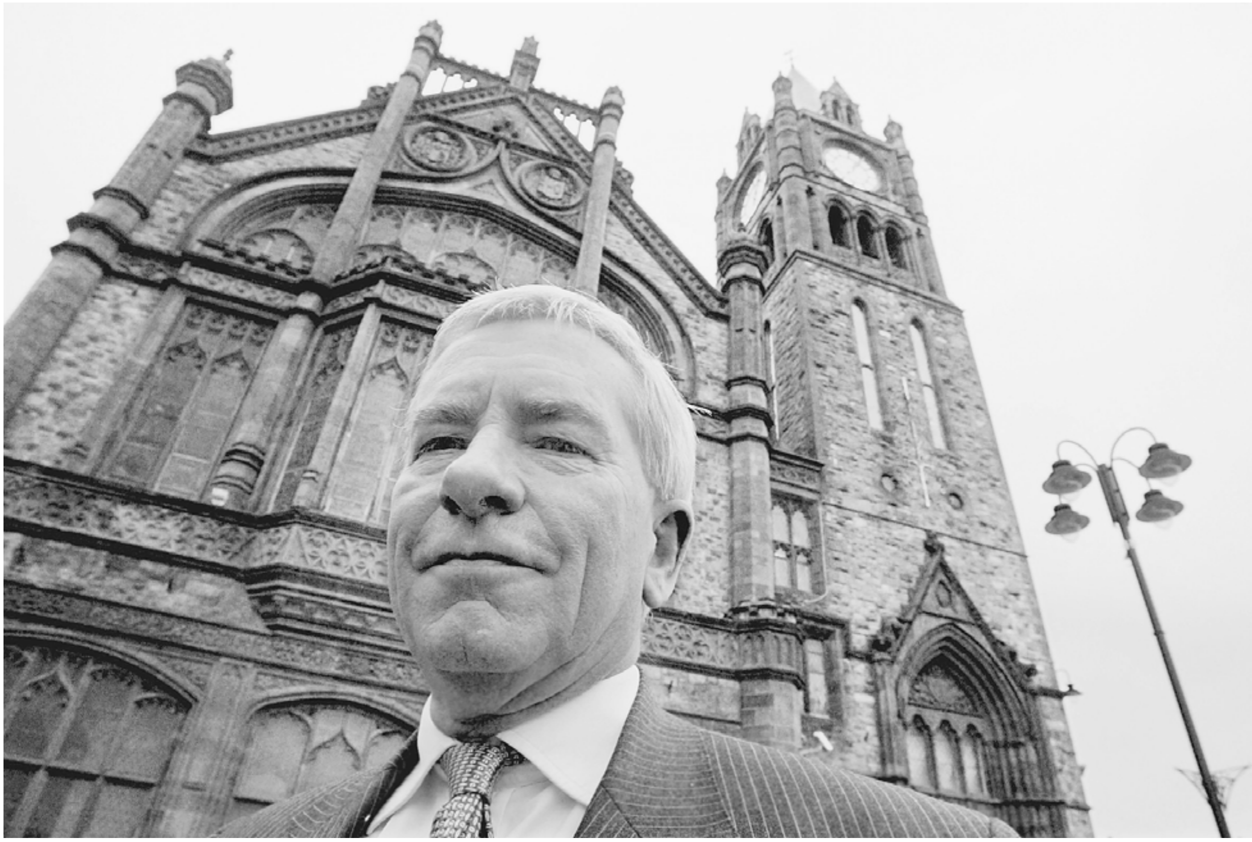
The Bloody Sunday inquiry in Northern Ireland examined the events surrounding the killing and wounding of Catholic civil rights protesters by British soldiers on January 30, 1972. The violence that day formed the latest episode of a decades-long resistance by Catholics against Protestants supported by the British government. The turbulent atmosphere demanded an impartial investigation. The refusal of the investigators to consider all forensic **evidence** led many Catholics to conclude that they could not obtain justice from the British government.

The Northern Ireland city of Derry, known to Protestants as Londonderry, was one of the centers of the Catholic civil rights movement. In the winter of 1972, the Northern Ireland Civil Rights Association (NICRA) informed British authorities that it intended to stage a protest march in Derry. Scheduled for Sunday, January 30, the march protested against the policy of the internment without trial instituted the previous year.

A crowd estimated to be between 10,000–25,000 strong turned out on the sunny January day. The atmosphere was relaxed and jovial, but the history of sudden violence in the region prompted the British government to expect trouble. The 1st Battalion of the British Parachute Regiment was assigned to conduct scoop-up operations against rioters. The regiment, trained to shoot to kill when confronted with a threat to life or personal safety, had the reputation of being among the toughest in the British Army. To later critics, this particular regiment had supposedly been chosen specifically to kill Catholics.

Initially, the marchers, many of whom were children with their parents, seemed intent on avoiding a direct confrontation with the army. When the march reached army barricades, the protesters turned and walked away. At this point, the army proceeded through one barricade in a convoy of ten vehicles, while soldiers walked through another barricade. The protesters began to jeer and throw stones. The soldiers responded, as was typical in past erupting protests, with spray from water cannons and rubber bullets. Much of the crowd dispersed.

The commander in charge of the British forces, defying a specific instruction not to conduct a running battle with Catholic protesters, deployed a unit to arrest and disperse the remaining rioters. In the space of about ten minutes, thirteen civilians were shot dead and another thirteen were wounded. No



Chairman of the Bloody Sunday Inquiry, Lord Saville, at the Inquiry in Londonderry, Northern Ireland in 2004, after Britain's Prime Minister Tony Blair ordered a fresh probe into the killing of 13 civilians by paratroopers in Northern Ireland in 1972.

guns were recovered from any of the victims. Four nail bombs were recovered on one body in circumstances that suggested that they could have been planted. Forensic tests conducted on all of the deceased proved negative for handling bombs or carrying explosive residue. Five of the dead also tested negative for **firearms** handling with the tests on the remaining suspects proving inconclusive.

The British government appointed an inquiry commission on January 31, headed by the Lord Chief Justice of England, Baron John Widgery. The tribunal conducted seventeen public sessions between February 21 and March 14, 1972, in which it heard 117 witnesses. Three further sessions were held from March 16 to March 20 to hear closing speeches. The tribunal's report, issued on April 10, 1972, blamed those who had organized the illegal march for creating a highly dangerous situation in which a clash between the demonstrators and the British forces was almost inevitable. Catholics condemned the report as a biased and unabashed attempt to protect the army against any claims of serious wrongdoing.

The problems with the Widgery Inquiry began with Lord Widgery. As a former officer in the British Army, he had an interest in maintaining the reputation of the army. Widgery did not interview the wounded that were still hospitalized, and he refused to accept over 700 eyewitness statements made to NICRA on the grounds that the statements were an attempt to embarrass him. Widgery also refused to consider some evidence damaging to the army because it did not satisfy the technical rules governing the admission of evidence in a court of law, although the inquiry was not a court of law. He did not visit the scene of any of the shootings and did not commission diagrams of the shootings.

The evidence that Widgery did accept included over two hundred statements and a large number of photographs. The soldiers stated that they had been attacked by gunfire, nail bombs, acid bombs, gasoline bombs, and various other missiles. No photographs showed gunmen or bombers. Civilians and journalists claimed that the soldiers fired at unarmed civilians.

Given the tense political situation in Northern Ireland, it is unlikely that the Widgery inquiry would have satisfied everyone. However, Widgery's refusal to consider all forensic evidence injured Northern Ireland Catholic faith in the British justice system. The release of the Widgery report was marked by rioting and a jump in the membership of the Irish Republican Army.

SEE ALSO Explosives; Firearms; Gunshot residue; Trace evidence.

Blunt injuries, signs of

The signs of blunt injuries (also called blunt trauma or blunt force trauma injuries) include lesions such as abrasions (scrapes), contusions (bruises), and lacerations (cuts), but can also include bone fractures and organ ruptures. Blunt injury lesions occur when the skin of the human body makes contact with a blunted object in the form of a crushing impact or penetrating blow. For the investigations performed by forensic scientists, lesions are usually found to result from assaults and beatings of a victim often in the form of hitting, kicking, punching, or clubbing; but they can also occur from accidents such as falls. The general form of such lesions usually assumes the pattern or characteristic of the impacting blunt object. For the most part, blunt injuries to the human body cause pain and discomfort. If severe enough, however, blunt injuries sustained to the head can cause death primarily due to blood clots in the lungs that cause blockage of the major pulmonary arteries or foreign objects that flow to the brain.

Abrasions normally include only external injuries. These injuries result when the skin is rubbed away by contact with a blunt object (such as a block of wood) or rough surface (such as being dragged across a concrete floor). The signs of abrasions usually appear as lines of scraped skin with small areas of bleeding.

Contusions usually include either external or internal injuries. These injuries are the result of powerful trauma that injures an internal bodily structure (such as the rib cage) without actually breaking the skin. Contusions can be caused by blows to the abdomen, chest, or head with a blunt object such as a fist. The signs of contusions appear as a bruise beneath the skin or may not appear at all, only showing up through the use of **imaging** examinations. The injury occurs when the small blood vessels located beneath the skin are damaged. As a result, the unbroken skin surrounding the fragmented blood vessels swells and turns dark shades of blue, red, and purple as blood runs into neighboring tissues. The amount and degree of such discolorations can vary by the victim's weight, where obese people show color more than lean people. Initially, victims may feel weakness and pain, and show signs of perspiration. Signs of brain contusions are less noticeable and, thus, more difficult to analyze. The severity of brain trauma is usually more obvious on the opposite side of impact because, upon contact with a blunt object, the brain will slide to the opposite side of the **skull**.

Lacerations (or open wounds), such as tears, generally include either external or internal injuries. The injury results in an irregular break or opening in the skin, sometimes called a separating wound. The edges of the wound may be dirty, jagged, or bleeding. These injuries are caused by a large force against the body. Lacerations usually affect only the skin, but may damage deeper tissues of the body such as bones, fat, muscles, and tendons.

SEE ALSO Pattern evidence; Puncture wound.

Body Farm

The Body Farm is more correctly known as the University of Tennessee Forensic Anthropology Research Facility. It was established in 1980 by the pioneering forensic anthropologist William Bass and is dedicated to the study of the rate of **decomposition** of the human corpse under various conditions that are relevant to crime investigation. Many hallmark scientific papers have come out of the research at the Body Farm and this new knowledge has been crucial in driving forensic investigation into unsolved deaths.

Bass had long experience as a "bone detective," as forensic anthropologists were previously known, and knew that there were many unsolved scientific problems in this area. A major issue was estimating the **time of death** of a body that is discovered, and this remains a challenge today in difficult cases. The human body undergoes many changes after death. It is colonized by bacteria and insects, the skin falls off, decomposition occurs, and all of this is dependent upon both the circumstances of any crime that has been committed and on the environment into which the body has been placed.

Research at the Body Farm has increased scientific understanding of what happens to the human body after death and this new knowledge has been used in court to convict the guilty in many of the cases that Bass describes. The Body Farm is a research facility close to the forensic labs at the University of Tennessee, where human bodies are allowed to decompose under various different environmental conditions that are relevant to the investigation of crime. The work involves the smell of decomposing bodies and dealing with maggots and flies, but the scientists who work at the Body Farm are dedicated to science and solving crime.

The facility began as a piece of waste ground close to the University of Tennessee in Knoxville. From 1980, Bass and his team began to prepare the site and, in 1981, received their first body for examination. There are two kinds of bodies donated to the Body Farm, with the consent of their next of kin. The first are bodies donated to medical research and the second are corpses that have been involved in crime of some kind. Whatever the cause and circumstances of the death, the mere presence of a corpse at the Body Farm allowed the researchers the first opportunity to study what happens to the human body after death in a controlled fashion. As Bass describes, it took only two weeks for the first body received by the facility to undergo dramatic change. The **skull** had become bone. The hair slid off in a mat that lay in a greasy pool, while the initially bloated abdomen had collapsed to leave a shrunken belly clinging to the rib cage. This marked a clear transition that was already known; a dead body does initially swell up with gas because of bacterial action, but afterwards it starts to shrink and decompose. At the Body Farm, these changes were observed, documented, and categorized in a scientific manner.

One of the main research aims of the Body Farm is to make it easier for pathologists to determine the time since death when a corpse is discovered. When someone dies, their body starts to decompose and eventually it will become a skeleton. However, the rate at which a body decomposes varies widely. A thin person, especially a child, decomposes more slowly than an obese or older person. Much also depends on climate, geography, and season. In the summer heat of Tennessee, where the Body Farm is situated, a body can become a skeleton in as little as two weeks.

Researchers who have worked at the Body Farm have begun to contribute information that aids in determining time of death with precision. For example, the role of insects in corpse decomposition has been investigated by Bill Rodriquez. His observations back in the early days of the Body Farm showed that blowflies come to a body within minutes of death and feed on bloody areas, where wounds have been inflicted, or on moist areas like the mouth. After this, they go through their life cycle, feeding on the body, and producing eggs and maggots. This kind of **evidence** can be used in a forensic investigation, but had not been much researched before the advent of the Body Farm. A paper on this work published by Rodriguez in the *Journal of Forensic Sciences* in 1982, went on to become one of the most cited articles in the field.

Decomposing corpses are consumed by bacteria as well as flies and other predators. Other research carried out by Arpad Vass and colleagues at the Body Farm has shown how bacterial action on a corpse could be used as a forensic clock. As a body decays, a succession of different bacteria preys upon it. Different species have their own feeding requirements. A fresh corpse may not appeal to one bacterial species, but once it is three weeks old, they may start to invade. Bacteria, like all other living things, excrete waste products to the environment. In the case of bacteria feeding on a corpse, this means that analysis of the surrounding soil can be revealing.

Bacteria work inside the body, and more recent research has focused on examining their products in tissues from the decomposing brain, liver, and kidneys. This can help pinpoint the time of death in an even more accurate way, within hours if the corpse is a few weeks old. This type of research is now looking at ways of measuring the distinctive odor of death, that is, the molecules that signify death and decay. It may be possible in the future to transfer this knowledge to portable systems that forensic investigators could use when investigating a burial ground.

It is well known that a body kept in cold conditions is going to decompose slower than one kept at a higher temperature. This makes estimating time of death rather tricky. However, the Body Farm research has come up with a way of controlling for this. A measure called the accumulated degree days, or ADDs, is a method of accounting for the number of days of decomposition at a particular temperature. A measure of 700 would give a specific set of signs of decomposition, but it would have occurred at a certain number of days at one temperature and fewer days at a higher temperature, where the rate of decay would be accelerated. In Body Farm experiments, ADDs were measured from the moment of death, which was known, of the bodies donated to the facility. When a body was being investigated, this knowledge was applied using local climate data and the state of the body. This kind of data helps reveal time of death in the circumstances of the crime.

Despite the unique scientific work it accomplishes, a facility like the Body Farm does not exist without some controversy. Some are concerned that the work does not show proper respect to the dead, although the bodies have always been given to the research with full consent, and are solemnly buried after the conclusion of observations. In the early days, it was local residents who objected to the existence of the Body Farm. If they got close, they could see the bodies decomposing. However, the local community came round when the scientific importance of the work was publicized.

In 1993, novelist **Patricia Cornwell**, who has a background in **forensic science**, came to the Body Farm with the intent of trying to have experiments carried out that would help in her latest book. *The Body Farm* was, by 1996, one of the best-selling detective stories of all time. This meant massive publicity for the Body Farm, which was featured in the book. It helped raise awareness of the importance of forensic anthropology and the emerging science of **taphonomy**, which is concerned with what happens to a person's body when they die.

The work at the Body Farm is immensely important to forensic investigations. The research that has been done there helps establish time of death more accurately, although it is still hard to be exact. With a time of death, witness and suspect alibis and statements have much more meaning. Further work at the Body Farm, and elsewhere if the facilities can be established, can help set the forensic clock for any body that is discovered under suspicious circumstances.

SEE ALSO Adipocere; Decomposition; Entomology; Taphonomy.

Body marks

External examination of either a corpse, injured victim, or suspect includes a careful verbal and visual record of any body marks. These include features such as birthmarks, moles, body piercings, tattoos, and scars. Body marks can be characteristic of an individual and can be used to support an **identification**, in conjunction with medical or police records and with identification given by family members.

Tattoos are patterns on the skin formed by injection of dyes into a pattern of prick marks. The presence of tattoos can signify a number of meanings—sometimes people are tattooed with the name of a loved one, or it may be a sign of belonging to a gang. There are even a few remaining instances of tattoos from World War II (1939–1945) concentration camps among elderly victims or suspects. Semi-permanent make-up is another form of tattoo that might be used for identification purposes. It is sometimes possible to link a tattoo to a particular tattoo artist by analyzing the materials used in creating the tattoo. The chemical composition of the dyes can be determined by extracting a small amount from the tattoo and subjecting it to **thin layer chromatography** or high performance liquid **chromatography**. Generally, a tattoo is a permanent feature and it might be possible to identify a suspect by looking for a record of the tattoo in police records. A tattoo might also be mentioned in a missing person's record that could help identify a victim or suspect. Tattoos survive partial **decomposition** of the body; they can still be seen even if the outer layer of the skin has been sloughed off.

Body piercing is fashionable and related items of jewelry like earrings can be used as **evidence**, possibly aiding identification via the evidence from relatives. The site and number of piercings may be matched to existing records if they have been present for some time. Birthmarks are another important body mark. Birthmarks are benign tumors involving the blood vessels just under the skin. They are often present at birth, as the name suggests, although they may fade with time. They are sometimes known as strawberry marks or port wine stains and these names are very characteristic of their appearance. The shape and positioning of a birthmark can be important in helping identify an individual involved in a crime. Moles and warts are other important skin features, although they are more common and less individual than a birthmark.

Scars are another important type of body mark. A scar is a healed wound and it may arise from surgery, accident, or assault. Needle tracks in drug users make characteristic scars that may be informative in the context of many crimes. Severe acne during adolescence may leave scars that persist into adult life and may be a useful identification aid. Many people have scars from common operations such as appendix or gall bladder removal. The dates of such operations should be in the person's medical records and the **medical examiner** will try to relate this to the age of the scar. The internal examination will relate the scar to the operation because the relevant organ will be missing. Operation scars are an aid to identification, but are not usually sufficient alone for identification as they are fairly similar and common. It is also possible to remove some scars with modern

laser surgery, so expected scars may no longer be present.

Any wound, however it was acquired, follows the same course of healing. Serious **knife wounds**, deep or jagged accidental cuts, and surgical wounds need stitches to repair them. For several months after the wound was inflicted, a telltale pattern from the stitches will be apparent and this can help age the wound. The healing process involves tiny blood vessels supplying the wounded area with blood and this gives a characteristic pink to reddish brown color to the wound. Later, the body will create scar tissue by laying down collagen, a protein found in connective tissue. This makes the scar fade and shrink. Four to six months after the wound occurred, it will have the appearance of a faint white line. After this, the appearance of the scar won't change much, although it will still be present. This means it is possible to be precise about recent surgery, accidents, or assaults. However, older wounds cannot be dated with much precision although the presence of a scar can still be a useful aid to the identification of an individual.

It is important that the pathologist distinguishes between body marks and injuries that have been sustained during the crime. Often the difference between new and old injuries is obvious. If a body is partially decomposed, dating body marks and assessing their significance may be more of a challenge.

SEE ALSO Autopsy; Wound assessment.

Bomb damage, forensic assessment

Fires and explosions are closely related phenomena in physical and chemical terms. Appropriately, bomb-damage assessment is an aspect of **forensic science** closely related to **arson** investigation.

Explosions can be accidental, such as the rupture and ignition of a propane tank, yet they can also be the deliberate result of the detonation of a bomb. In assessing a crime scene, forensic scientists look for the telltale signs of the cause of the bomb damage.

Such forensic investigations can take place at the municipal and state level, if the involved agencies have the capability to conduct the investigations. Certainly, such capability exists at the national level. In the United States, the two agencies most concerned with bomb-damage assessment at the federal level are the Bureau of Alcohol, Tobacco, and Firearms (**ATF**), and the Explosives Unit of the Federal Bureau of Investigation (**FBI**).

Explosions involve a physical change in materials. A solid or a liquid is converted into a gas or, given the tremendous force of some bombs, directly into energy. Both processes must take place in the presence of oxygen, which is among the most reactive of the chemical elements, meaning that it is highly likely to bond with atoms of other elements.

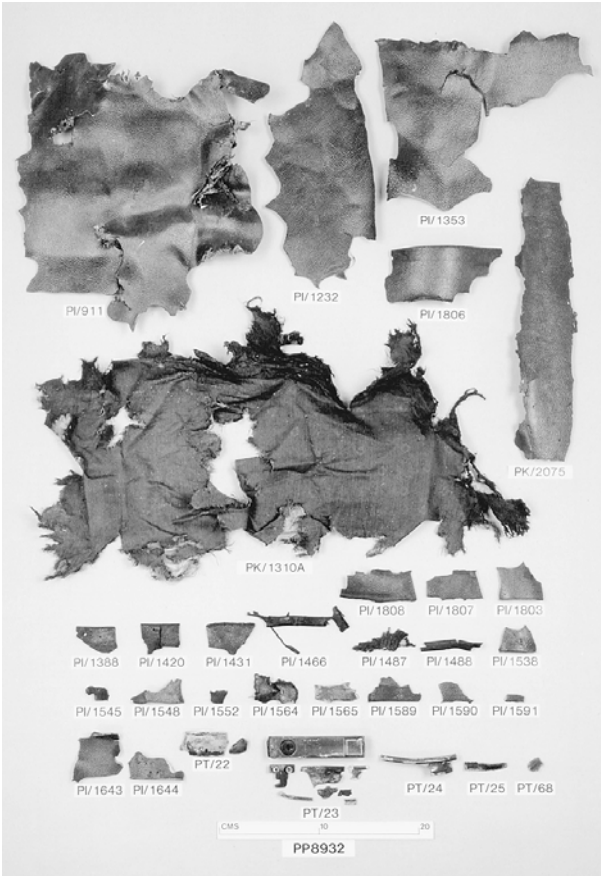
During the process of oxidation, an element bonding with oxygen loses electrons, while the oxygen gains electrons, a process chemically known as reduction. The world is full of oxidation-reduction reactions, some of which include the rusting or corrosion of metals, the metabolism of food and other biological processes, and combustion. The last of these is commonly known as the process by which materials catch fire, and explosion is simply a fast form of combustion. In the combustion process, chemical bonds are broken quickly, releasing energy that is experienced in the form of heat. In the case of explosion, these bonds are broken even more quickly, producing even more heat and more kinetic energy, which propels objects outward from the center of the blast with greater force.

The investigator of a scene where a bombing has taken place must be schooled in basic physics and chemistry and in forensic science. An initial concern is to ascertain how the explosion occurred and what caused the explosion.

Some bombs are relatively unsophisticated. One example is a pipe bomb, which is typically little more than a metal pipe containing shotgun powder.

Much more complex are explosives using trinitrotoluene (TNT) or nitroglycerin. The latter is a component of dynamite, which combines sodium nitrate and inert compounds to generate the explosive punch. One notorious variety of an explosive is ammonium nitrate. This common ingredient found in fertilizer was used in the 1993 World Trade Center bombing and the 1995 Oklahoma City bombing. Combined with fuel oil, it produces a foul smelling and lethal ammonium nitrate and fuel oil (ANFO) sludge.

One difference between lower-level explosives and their more sophisticated cousins is the fact that the latter requires a detonator or blasting cap, a device to make it active. Investigators will, therefore, seek not only the telltale physical and chemical residue that will lead to a determination of the type of bomb used, but also for **evidence** of detonators



A forensic explosives laboratory photograph shows recovered fragments of a suitcase containing a bomb that exploded aboard the Pan Am airliner above Lockerbie in December, 1988. © REUTERS/CORBIS

and other components such as tapes, wires, timers, switches, and batteries.

ATF agents investigating the first World Trade Center bombing, which killed six people, found a great deal of chemical evidence in the aftermath, ranging from a lingering acrid and acidic aroma to the presence of specific types of molecular residues. There was also **physical evidence** that identified the perpetrators' van as the site from which the blast originated: among the items noted were "feathering," blast-related stretching; "bluing," exposure to welding-torch-like heat; and "dimpling," whereby the metal close to the blast liquefied and shot out, colliding with nearby objects and leaving tiny craters on their surfaces.

In addition to the ATF, the FBI operates a laboratory to which other law-enforcement agencies submit materials for investigation. At the international level, bomb damage assessment may be performed by security services of various nations, or even by international teams, which may include civilians. Such was the case in the investigation of the scene in Bali, Indonesia, where Islamist terrorists detonated a bomb that killed several hundred people in October 2002.

SEE ALSO Accelerant; Architecture and structural analysis; Bomb detection devices; Bomb (explosion) investigations; Explosives.

Bomb detection devices

Forensic investigations often involve determining the nature of damage caused to property and people. Various means of destruction impart telltale signs that an expert forensic scientist can unearth.

A related part of forensics can be the detection of the destructive device before it can do its damage. Various bomb detection devices are part of **forensic science**.

Bombs are capable of enormous power and devastating damage. When detonated in strategic, population-dense, or confined spaces, bombs are especially destructive. For example, a bomb planted by political terrorists in a suitcase was responsible for the explosion of Pan Am Flight 103 over Lockerbie, Scotland, on December 21, 1988, that claimed 270 lives. Given the devastation that bombs can cause, and the risk they pose to national security, the detection of bombs is a important priority in airports and elsewhere.

Despite the fact that x-ray examination may not detect some bombs, the technique is still a mainstay in bomb detection. For example, x rays are the best way to reveal the presence in luggage of suspicious shapes. A drawback is that plastic **explosives** can be molded to resemble common objects. Also, explosives are not metallic, and so will escape metal detection. A well-trained operator is a key part of this bomb detection strategy. A newer version of the x-ray examination places a reflector on the opposite side of an object from the x-ray beam. As the rays are scattered back, they are analyzed by a sophisticated computer program, which can reveal differences in the outgoing and incoming beams that were caused by passage of the beams through suspicious material.

Another version of the x ray—dual energy technology—sends two x-ray beams through the object at the same time. One of the beams distinguishes organic material (i.e., food, leather objects, paper) and displays them as red. The other beam distinguishes inorganic objects (i.e., metal clips, umbrellas, metal pens) as green or blue. The color difference helps the operator quickly scan packages and baggage for objects that are suspicious by their shape or chemistry. A similar method, which uses radio waves instead of x rays, is called quadrupole resonance technology.

Another optical device is computer tomography, a technique that has been adapted from the CAT scan x-ray technology used in the medical operating room. In tomography, an object is scanned and then a computer analyzes the x-ray image. If areas of the package have not been adequately revealed, the x-ray source can be rotated so as to produce a detailed view of the specific area. In this way packages and baggage can be examined in great detail.

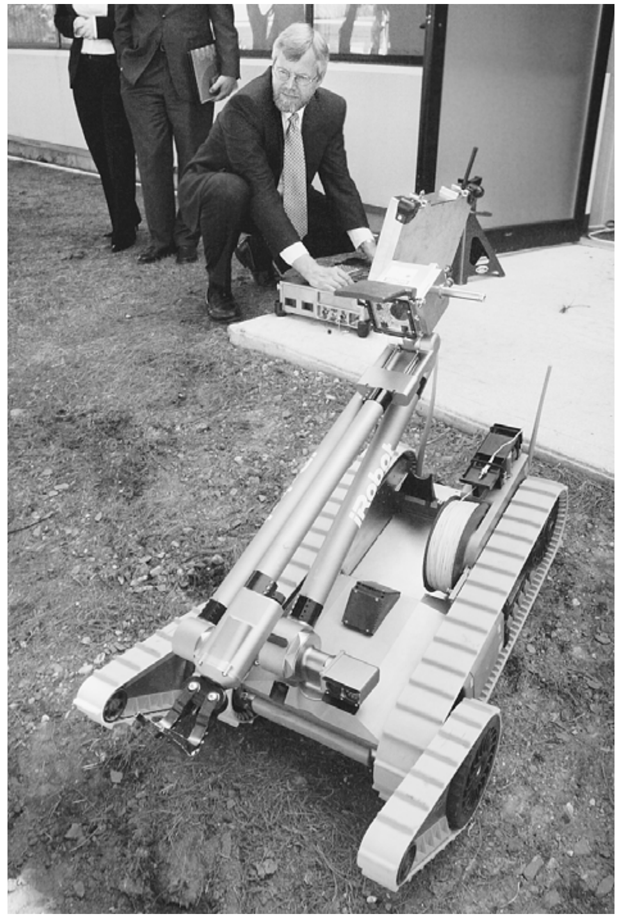
Some bomb components can leave a scent. Until a few decades ago, specially trained dogs were a mainstay of bomb detection squads. Specially trained dogs are still used today to check out packages or locations that are difficult to examine using a machine. A dog's nose is actually a bit more sensitive than the sensitivity of detection machinery that is currently available. However, a dog and handler team costs approximately $50,000 a year, whereas a piece of detection equipment represents a one-time cost of $20,000 to $40,000. Thus, machines are becoming more prevalent.

One such technology utilizes gas **chromatography** and a property called chemiluminescence. In gas chromatography, chemicals of different composition can be separated from each other based on their differing speeds in a stream of gas (selection of the gas can determine the rate of movement of different compounds). A compound in the gas, which will then glow, will recognize an isolated compound that has a certain chemical group in its structure. The glowing (chemiluminescence) registers on an optical detector, revealing the presence of the explosive chemical.

Devices known as sniffers detect vapor given off by certain explosives. Chemicals such as nitroglycerin are readily detected. But, a sniffer can miss explosives such as plastic explosives that do not readily vaporize. Thus, a sniffer should be used only as part of a bomb detection forensic regimen that involves other detection techniques.

Another forensic device detects chemicals present in bombs by concentrating the air collected from a target location. The air is drawn through a filter, where explosive chemicals collect, due to their tendency to be heavier than the air molecules around them. The filter is analyzed using ion mobility spectrometry.

The spectrometric technique is very sensitive. Less than a nanogram (10^{-9} gram) of explosives residue can be detected. To put this into perspective, a **fingerprint** on a luggage handle left by someone who had been handling explosives will typically contain 100,000 times more of the residue.



PackBots like this one, demonstrated by an iRobot executive in 2004, are currently being used by the U.S. military in Iraq and Afghanistan for reconnaissance and bomb detection and detonation. © BRIAN SNYDER/REUTERS/CORBIS

SEE ALSO Accelerant; Architecture and structural analysis; Bomb (explosion) investigations; Explosives.

Bomb (explosion) investigations

The investigation of explosions has a long history in **forensic science** and covers incidents ranging from accidents in the home or workplace to major terrorist attacks. An explosion is a sudden release of physical or chemical energy, carried on a high-pressure wave, and generally accompanied by an emission of heat, light, and sound. An explosion may result from a criminal act involving a bomb, but it can also occur by accident—if a spark ignites a leak of domestic gas, for example. Establishing the nature of an explosion can be a significant challenge to the forensic investigator. The high-pressure wave of an explosion can be extremely destructive, both to bystanders and any objects of materials in the vicinity. Analyzing this kind of **evidence** can be a very difficult task, particularly as an explosion is often followed by a fire. This causes complications for the investigators as much valuable evidence is then destroyed. There are also potential hazards to the investigators themselves in investigating a bomb site. There may be structures in danger of imminent collapse as well as exposure to dangerous materials such as broken **glass**, flammable or toxic vapors, or asbestos. In the case of a bombing, there is always a possibility that a second device has been placed to kill or maim those who respond to the explosion.

Explosions are an example of the Law of Conservation of Energy, which states that energy can neither be created nor destroyed, but it can be converted from one form into another. The two main classes of explosions are chemical and physical. When a bomb explodes, for instance, the chemical energy stored in the molecules of the explosive making up the device is converted into kinetic (movement) energy, heat, light, and sound. This is an example of a chemical explosion—probably the class of most interest to the forensic scientist. Physical explosions are the other main class requiring investigation. A typical example of a physical explosion is the sudden release of gas from a container of pressurized gas or liquid if it becomes overheated.

An explosive is a substance that can produce an explosion through a chemical reaction. When it is used illegally and to cause harm it is generally known as a bomb. Legitimate **explosives** include fireworks and blasting materials used in quarrying. Explosives generally contain fuel and an oxidant and it is the chemical reaction between them which releases stored chemical energy.

There are two types of explosions due to chemical reactions, which is reflected in the type of damage they cause at the scene. In a detonation, the speed at which the chemical reaction moves though the explosive is greater than the speed of sound in that material. The resulting pressure wave may move at up to 8,500 meters per second (9,296 yards per second). High explosives, such as dynamite, generally undergo detonation and have a characteristic shattering effect on their surroundings. A deflagration occurs when the speed of the chemical reaction of the explosion travels through the explosive slower than the speed of sound in the material. This creates a pressure wave moving at 1,000 meters (1094 yards) per second or less. The impact of low explosives, such as a mixture of air and gasoline vapor or sugar and potassium chlorate, is best described as pushing, rather than shattering, although they can still produce an enormous amount of damage. Depending on their nature, explosives may or may not need an initiating material, called a detonator, to set them off. A useful distinction can also be made between condensed explosives, which are solid or liquid, and dispersed explosives, consisting of aerosol or gas.

Investigation of the scene of an explosion aims to discover whether an explosion actually took place and, if so, whether it was an accident or a bomb. The forensic scientist will then try to find out what kind of explosion occurred, the materials involved and, in the case of a criminal act, they will work with the police to find out who was responsible. Examination of the scene and witness reports can establish whether an explosion has happened. Loud bangs, flashes, violent eruption of debris, shattering of nearby objects and formation of a crater where the event occurred are all indicative of an explosion. The investigator will look for evidence of a possible accident, such as a gas leak or creation of a cloud of flammable gas at the scene. If it looks as if a bomb caused the explosion, then the explosive device must found. This involves searching for the device itself and any detonator fragments which may be scattered among the debris. There may have been a timing device to allow the bomber time to get away, which would consist of electronic circuitry, wires, and batteries. The remains of the device will probably contain some residue from the explosive and may even bear fingerprints from the perpetrators. The construction of the device and how it was triggered may also be deduced from examination of these fragments.

The investigator will probably have to search far and wide at the scene of the explosion to recover bomb fragments. Some may be embedded in the bodies of victims, and here medical staff will need to carry out x rays to identify any evidence and, if possible, recover it for forensic investigation. A suicide bomber is, of course, an important source of such evidence. Suspect surfaces must be swabbed with various solvents to extract invisible chemical traces of explosive residue. There is nearly always a part of the bomb that did not explode and these residues can be very informative. Small items that

Rescue workers and crash investigators search the area around the cockpit of Pan Am flight 103 that crashed east of Lockerbie, Scotland in 1988, killing 270 people. Investigators found the aircraft was downed by a Libyan planted bomb exploding in mid-air.

may bear explosive residue can be placed in a beaker and agitated with a suitable solvent. The solvent has to be chosen to match the explosive—diethyl ether may be used for organic materials, while water dissolves inorganic materials such as potassium chlorate.

Once the samples are back in the laboratory, there are many sensitive analytical techniques, such as high performance liquid **chromatography** and **thin layer chromatography**, that can be used to assess the chemical nature of explosives and identify the **trace evidence**, comparing it with reference samples of explosives. Similar techniques can be used to sample for traces of explosives on suspects' hands and clothing. Comparison may be sufficient to link a suspect with a crime scene. The analysis of traces of explosives has to be done with great care and expertise because there is ample opportunity for **cross contamination** to occur. This means taking scrupulous care with the collection of the trace evidence and then using **control samples** throughout the analysis. If the explosive can be identified, the police investigation will look for buyers and sellers of that particular material.

Explosions often cause characteristic damage to nearby surfaces through a combination of the high temperature generated and the high pressure wave. A mottled irregular appearance, known as gas wash, results from a combination of melting and erosion of the surface material. Textiles may undergo characteristic clubbing damage as the polymer melts and then re-solidifies. On metal surfaces, microcraters may be visible on microscopic examination. Soot deposits on more distant surfaces, such as window frames, are also characteristic of an explosion.

The pattern of damage at the scene of an explosion will help the forensic scientist to determine what happened. The location and depth of any crater or the nature of structural damage such as broken windows can all help to locate the actual seat of explosion, for instance. The scene can also be very informative about the nature of the explosion too, as different combinations of explosive and explosion can give rise to characteristic types of damage. Detonation of a condensed explosive tends to produce a huge crater and very severe damage that involves pulverizing and shattering of nearby objects, even if they are made of tough materials like steel. A deflagration in a condensed explosive produces intense heat and could bend or melt objects rather than cutting them. Detonation is rare with dispersed explosives, but deflagration gives a pattern in which most of the damage may occur some way from the explosion itself owing to a pushing out effect. In one example, a natural gas explosion caused only superficial burns to two people in the basement underneath the room where it occurred, yet the incident was violent enough to blow furniture out of the building.

Some explosions are of a mixed type. Petrol (gasoline) bombs are often used by terrorists and typically involve using a small charge of high explosive to disperse and ignite petrol, which is a flammable liquid. This event involves detonation of a high explosive and deflagration of a dispersed explosive. The detonation will produce damage close to the point where the bomb was set off, while the deflagration will produce damage further away.

SEE ALSO Accelerant; Bomb damage, forensic assessment; Bomb detection devices.

Robert Borkenstein

8/31/1912–8/10/2002
AMERICAN
ALCOHOL/DRUG RESEARCHER, TRAFFIC SAFETY INVENTOR

Known for contributions in the area of chemical tests for blood and breath alcohol, Robert F. Borkenstein was the scientist who invented in 1954 the first practical, hand-held breath-alcohol-measuring device called the **Breathalyzer®**. Based on Borkenstein's groundbreaking invention, police officers use such devices today as a simple but accurate way to determine a driver's level of intoxication. By taking a sample of expelled breath when a driver is stopped, police officers are able to calculate the amount of alcohol as a percentage of blood. Borkenstein was also instrumental in founding and developing the International Council on Alcohol, Drugs and Traffic Safety (ICADTS), an independent, nonprofit organization whose purpose is to reduce injury and death caused by the abuse of drugs and alcohol while operating motor vehicles.

Borkenstein was born in Fort Wayne, Indiana. With an early interest in criminal justice and traffic safety, Borkenstein began his career in 1936 as a police photographer. He advanced quickly to criminal justice technician for the Indiana State Police, and completed his 22-year career as captain in charge of the Indiana State Police Forensics Laboratory. Borkenstein completed a bachelor's of arts degree in 1958 from Indiana University (IU) in Bloomington. Upon graduation, he became an IU professor and the chairman of the university's newly created Department of Police Administration, a position he held until his retirement in 1983. During his tenure, Borkenstein expanded the department so that today it offers masters and doctor of philosophy (Ph.D.) degrees. In 1963, Borkenstein received an honorary doctor of science degree from Wittenberg University in Springfield, Ohio. Then, in 1971, Borkenstein became the director of the IU Center for Studies of Law in Action. Today, the Center offers a one-week course (twice a year)—the "Robert F. Borkenstein Course on Alcohol and Highway Safety: Testing, Research, and Litigation"—for professionals in criminal justice, **forensic science**, law, and law enforcement. Indiana University bestowed Borkenstein with a honorary doctor of laws degree in 1987.

Because Borkenstein felt so strongly about reducing drunk driving, the use of breath samples for the enforcement of blood alcohol concentration (BAC) limits has been adopted in many countries around the world. Borkenstein's invention also allows for a larger percentage of impaired driving arrests by police officers because it eliminates the need to call a specially trained technician to take blood samples and the consequential delays for laboratory results. It also enables a greater number of convictions by prosecutors because the accurate breath samples are allowed as forensic **evidence** in court.

In 1950 Borkenstein attended the first meeting for the organization that would eventually become the ICADTS. Largely due to his early organizing efforts and his monetary contributions, the ICADTS became an international organization of professionals from such fields as economics, law, law enforcement, government, **medicine**, and public health. Borkenstein also helped to establish the Widmark Award, which is presented to individuals and organizations—such as the U.S. National Safety Council and Mothers Against Drunk Drivers—who have made outstanding contributions to reducing impaired driving.

During the 1960s, Borkenstein led a research team in the "Grand Rapids" study, which determined the relative risk of motored vehicle crashes due to BAC levels. The study was one of the earliest and largest studies of its kind and had a strong influence on strengthening the impaired driving laws around the world.

SEE ALSO Automobile accidents; Breathalyzer®; Chemical and biological detection technologies; Sobriety testing.

Botany

Soil, plant fragments, and pollen, maybe in trace amounts, are often left behind at the scene of a crime. Most people entering a house will bring in some soil or mud from outside. Even if they take off their shoes, their clothing may contain tiny smears of mud where they have been splashed or come into contact with a surface. Tools like shovels might also contain significant traces of mud. An expert in botany, the science of plants, can often help unravel the identity and significance of such **trace evidence**. Soil and mud, in particular, are often present in footprints or **tire tracks** and can help link a suspect to the scene of a crime. The pattern of mud on clothing can also be significant.

Soil is a mixture of mineral, plant, and animal matter that is often characteristic of a particular area and may reveal something about a suspect's movements. Often soil also contains some man-made products such as **glass** or paint. The forensic scientist is interested in the patterning of soil and mud staining and how it might relate to the circumstances of a crime. For instance, if an assault takes place out-of-doors, then the mud staining of a suspect's clothes could naturally be revealing.

The visual and chemical analysis of a soil trace can often link it to a particular geographical region. This, in turn, can help to track the movements of a suspect if he or she has traveled to the area where the crime was committed. If a body has been moved for burial, then soil or plant material in a vehicle could be important.

The forensic botanist, first with the naked eye, looks at any soil or mud and assesses its color and texture. Microscopic examination reveals more about the content of the soil and the range of particle sizes it contains. Large samples might be sieved to separate them into different portions, depending upon particle sizes. Then these can be further examined to give more information.

Chemical analysis using advanced techniques like atomic absorption **spectroscopy** will give the mineral composition of a soil sample, such as chalk or clay, which is often characteristic of the area it came from. The acidity of the soil is also measured, as this varies greatly with place of origin. Thermal analysis of the soil, heating it in an oven till it decomposes, is also often characteristic of its origin. There may be dramatic color change or the soil may absorb heat in a characteristic way.

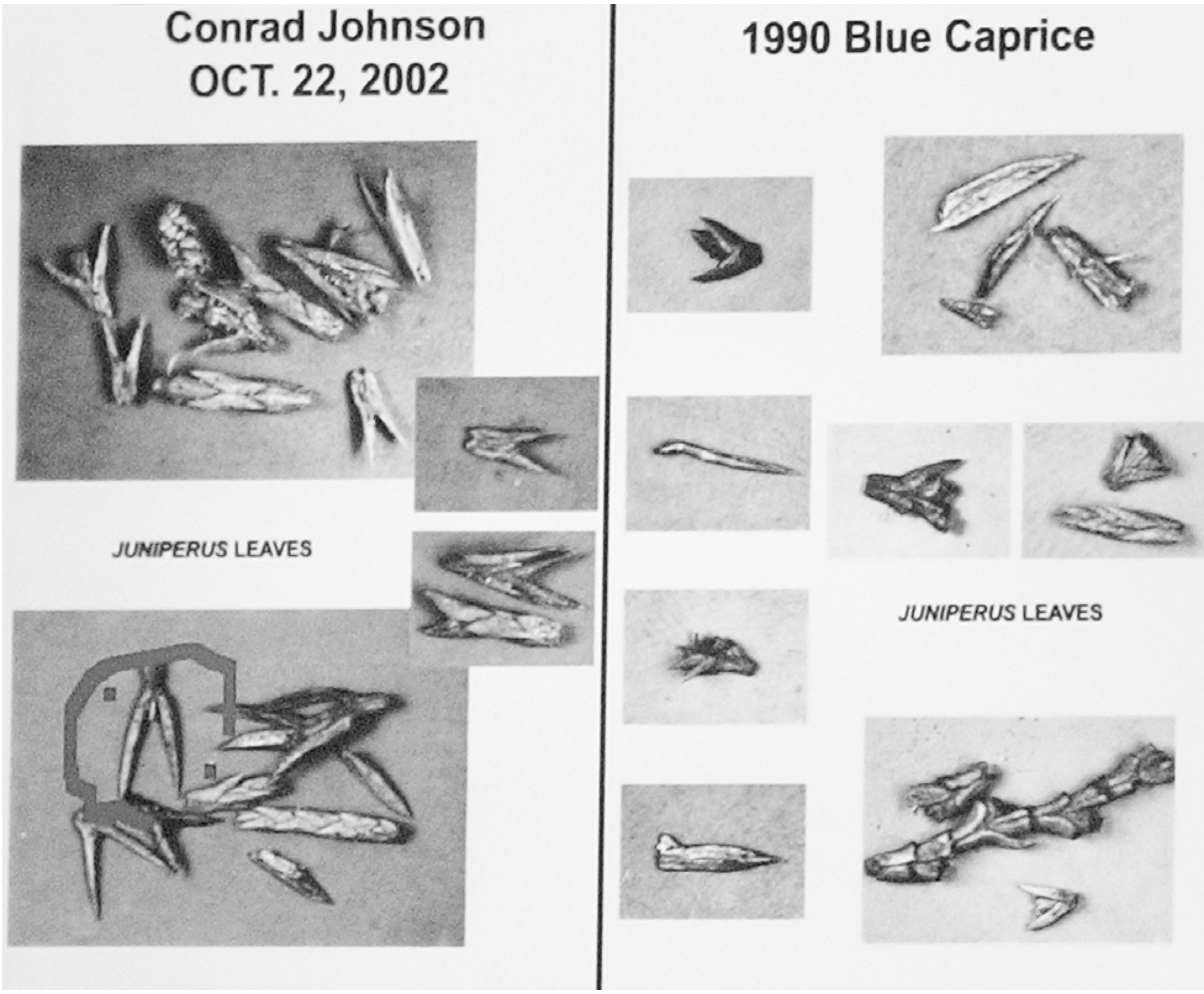
Suspects and victims also, often unknowingly, carry various items of plant debris on their bodies and clothes such as flower petals, seeds, and pollen. These are often native to a specific area. For instance, if pine needles are found around a victim who seems to have perished in an area where there are no evergreens, it may tell the investigators something important and specific about the suspect and his or her movements. The botanist can investigate what species carries these particular needles and so help link the perpetrator to a specific source.

Pollen grains are tiny and are not usually noticed by those involved in a crime. Pollen is often found almost everywhere—in hair, on surfaces, and on paper. If pollen is found on the envelope of a threatening letter or a ransom note, for instance, it may provide a valuable link to the suspect. There are pollen databases which can show the investigators where a particular pollen sample may have come from.

When a body is left out in the open or in a shallow grave, plant debris, including leaves and needles, may cover the remains. Analysis of this growth can often help establish the time and season of death and burial.

In one British case from 1887, a 15-year-old boy was found drowned in a ditch. Footprints led down the bank of the ditch. Sand grains were found on the suspect's trousers and matched to the ditch. Mud on the clothing of the suspect's daughter, who turned out to be an accomplice, was examined microscopically. Hairs from the seeds of the groundsel plant were found. This mud matched samples taken from the part of the ditch where the body was found, but not mud found from other areas. If botany helped solve a case so long ago, it can be even more powerful today with modern analytical techniques.

SEE ALSO Geology; Geographic profiling; Minerals; Pollen and pollen rain; Soils; Spores.



Magnified plant material was displayed on a screen during the testimony of Bureau of Alcohol, Tobacco, and Firearms (ATF) forensic chemist Edward C. Bender during the trial of convicted sniper suspect John Allen Muhammad in 2003. © DAVE ELLIS/POOL/CORBIS

Botulinum toxin

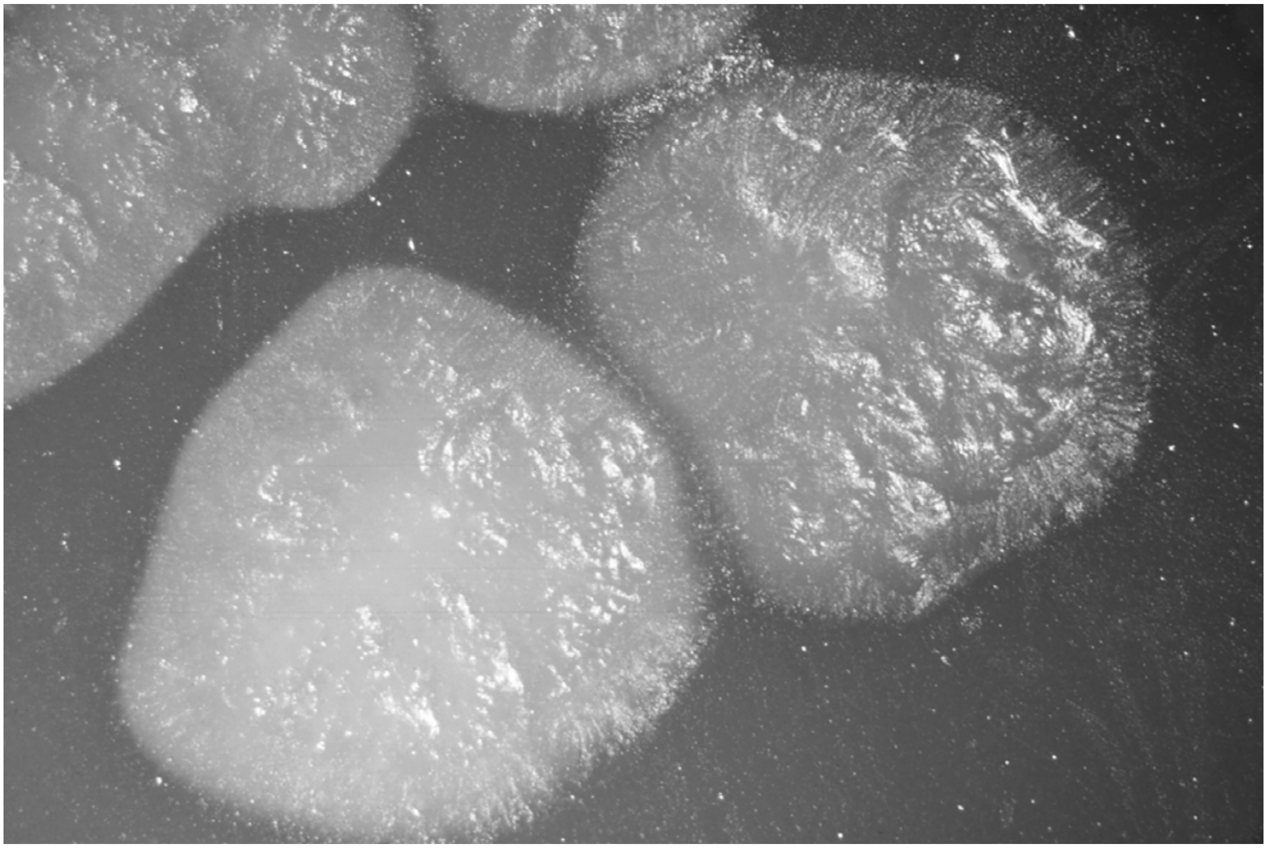
Clostridium botulinum is a spore-forming bacterium. Like the well-known **anthrax** bacillus, the **spores** of *Clostridium botulinum* can persist in the environment for many years and, when conditions become more favorable (i.e., in a wound, food, and the lungs) the spore can germinate and free the toxin.

There are at least seven structurally different versions of botulinum toxin. The type designated as type A is responsible for some botulism food-borne outbreaks in the United States and elsewhere. Improperly canned foods are a particular threat.

Botulinum toxin is among the most poisonous substances known in the natural world. The toxin, which can be ingested or inhaled, and which disrupts transmission of nerve impulses to muscles, is naturally produced by the bacterium *Clostridium botulinum*. Certain strains of *C. baratii* and *C. butyricum* can also be capable of producing the toxin.

Botulinum toxin acts by preventing the transmission of nerve signals between the nerves that connect with muscle cells. Progressive functional deterioration of the affected muscles occurs. Symptoms of botulism intoxication include dizziness, blurred or double vision, nausea, vomiting, diarrhea, and weakness of muscles in various areas of the body. The muscle failure can be so severe as to lead to coma and respiratory arrest. Even in those who survive exposure to the toxin, complete recovery can take months.

The damage and lethality that can be inflicted by the toxin makes this agent important in **forensic science**. If botulism toxin poisoning is suspected, a



Clostridium botulinum (Type E) colonies grown on a 48-hour egg yolk agar plate. © CDC/PHIL/CORBIS

forensic scientist can check for the presence of the bacterial spores.

The sometimes deliberate use of the toxin is also forensically relevant. Contamination of food is one route for infection with the toxin. This can occur naturally, via the bacterial contamination of the food. On the other hand, food can be deliberately contaminated. As well, the toxin can also be released into the air. The latter is invariably deliberate. For example, on at least three occasions between 1990 and 1995, while experimenting with biological warfare agents, the Japanese cult Aum Shinrikyo released botulinum **toxins**, but failed in attempts to spread them.

SEE ALSO Biodetectors; Bioterrorism; Nervous system overview; Pathogens; Toxins.

Bovine spongiform encephalopathy SEE Mad cow disease investigation

Brain wave scanners

The term brain wave scanners, in the context of law enforcement, particularly concerning forensic investigations, encompasses an array of research and technological developments that seek to electronically determine whether a statement is true or false.

It has been demonstrated that brain patterns are altered when a lie is being told. Moreover, using a technique called magnetic resonance **imaging** (MRI), the alteration can be visualized as a lie occurs (commonly referred to as "real-time"). Simply put, a lie can be seen.

The concept of a brain wave scanner is not unlike that of a polygraph. Whereas a polygraph measures fluctuations in heart rate and breathing, a scanner measures brain responses to stimuli. It could be more effective, because a person adept a telling a lie may experience little excitement in the circulatory system. However, even this individual would be required to expend extra energy on the thought necessary to tell a lie, and it is this energy that a brain wave scanner may be able to measure.

When one is asked a question to which one knows the true answer, that answer comes first to mind automatically. Even if the individual has already prepared and rehearsed a lie, it is still necessary to think past the true answer and access the lie. This extra activity is easily measured on a brain scan.

After the September 11, 2001, terrorist attacks, a number of government agencies began to take a new look at brain scanning technology as a means of security screening. In 2002, officials of the National Aeronautics and Space Administration reportedly informed airline officials that they were developing brain-monitoring technology for use in screening airline passengers. Such activity, along with an increase of interest in brain-wave scanning by the Federal Bureau of Investigation, has raised concerns among civil-libertarians, who view brain-wave scanning as a particularly objectionable invasion of privacy in the service of public security.

SEE ALSO Epilepsy; Neurotransmitters; Polygraphs; Radiation, electromagnetic radiation injury.

Breathalyzer®

Accidents or crimes can occur when one or more of those involved are intoxicated. Impaired driving is the obvious example. In the United States, at least 25,000 people die in alcohol related traffic accidents each year, representing about 500 people each week. In fact, alcohol-related traffic accidents are the leading **cause of death** among Americans aged 16–24.

Alcohol can also fuel domestic disturbances and other altercations between people that result in injury and death.

Traffic accidents and violent incidents can lead to a forensic investigation. Thus, alcohol is closely tied to **forensic science**.

The determination of alcohol level can be an important part of an ongoing investigation. Returning to the example of a traffic accident, one of the early facets of an investigation can be the determination of the alcohol level of a driver. Often a police officer needs to ascertain whether a person is legally impaired. Several tests of coordination (i.e., walking a straight line, touching the tip of the nose with a finger) can be helpful indicators. But, determination of blood alcohol levels via a Breathalyzer® test is a critical part of the assessment of sobriety.

An initial Breathalyzer® measurement is often conducted at the scene of the accident, since normal metabolic processes in the body will reduce the alcohol level within hours.

Measurements of alcohol level are most conveniently taken by monitoring expired air. The Breathalyzer® is one of three different devices that can be used. It is the most popular device for portable, at-the-scene use. The instrument uses a color reaction to detect alcohol; the degree of color change is related to the alcohol level in the breath.

The result is typically expressed as the blood-alcohol concentration (BAC), which represents the grams of alcohol per 100 milliters of blood. The legal BAC limit can vary between jurisdictions; 0.08% is a typical limit. So, for example, if a suspect's breathalyzer reading was 0.15%, they would be legally impaired. If they were driving a vehicle, they would be charged with driving while impaired (DWI) or driving under the influence (DUI).

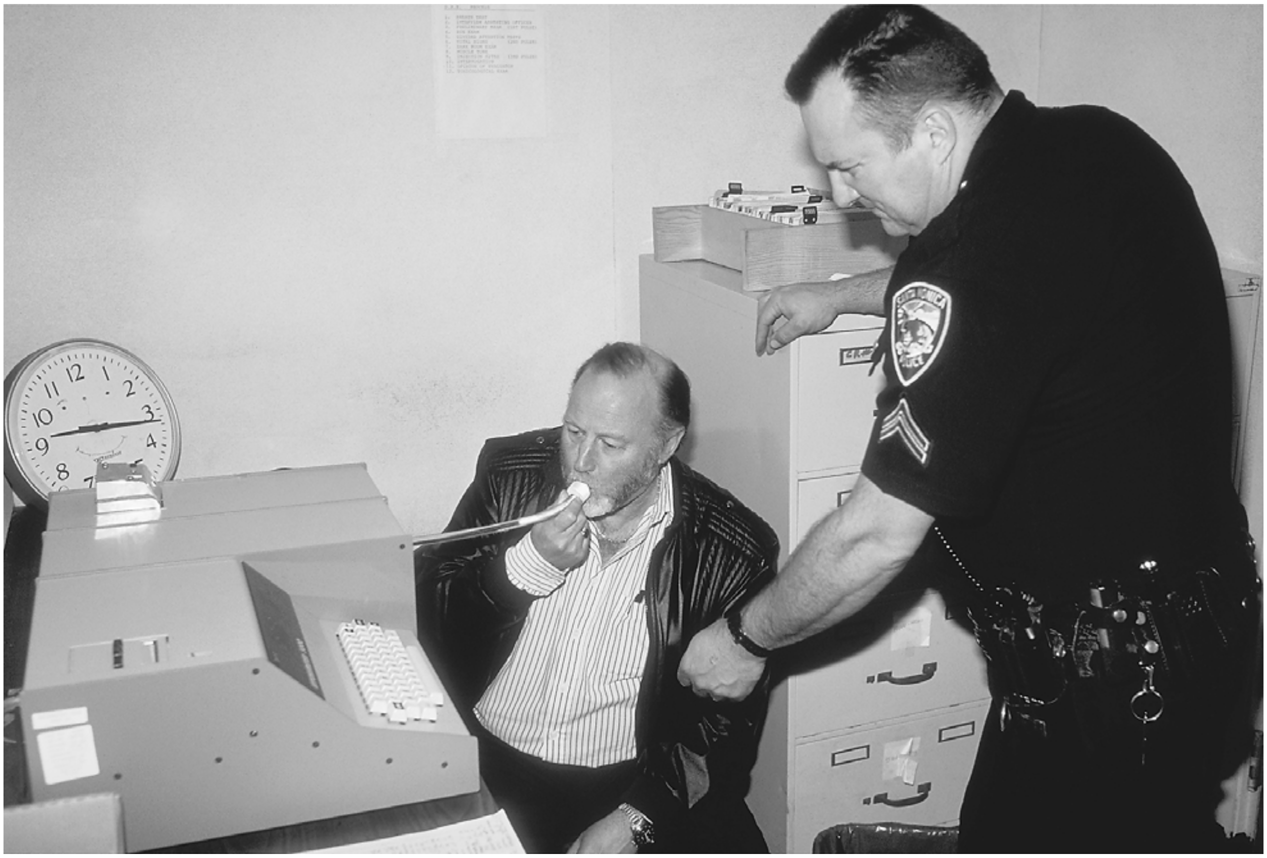
The development of the devices that could monitor alcohol in the breath dates back to the 1940s. In 1954, Dr. Robert F. Borkenstein of the Indiana State Police invented the modern-day Breathalyzer®.

The Breathalyzer® relies on the fact that, when consumed, alcohol is not altered in the bloodstream and on the volatility of the compound (the tendency of the compound to evaporate from solution). The latter is important when alcohol-laden blood passes through the tiny channels in the air sacs of the lungs. There, alcohol's volatility encourages its passage across the channel membranes into the lung, where it can be exhaled.

A Breathalyzer® detects this expired alcohol. When someone blows into a Breathalyzer®, the device detects both the volume of air expired and, as described below, the amount of alcohol present. The ratio of the amount of alcohol in the breath to the blood alcohol level is 2,100:1. By determining the amount of alcohol in the volume of expired air, a calculation of blood alcohol concentration can be made. This calculation is done as described below.

When air is blown into a Breathalyzer®, it bubbles through a mixture of potassium dichromate, sulfuric acid, silver nitrate, and water. The sulfuric acid acts to remove the alcohol from the air into the aqueous solution. In the solution, the silver nitrate acts as a catalyst (a compound that speeds up the rate of reaction without directly participating in the reaction) in the reaction that follows.

In this reaction, the alcohol (ethanol) reacts with the reddish-orange potassium dichromate to produce



A Santa Monica police officer tests a man on a breath analyzing machine to determine alcohol levels in his bloodstream.

the greenish-colored chromium sulfate, potassium sulfate, and acetic acid. The degree of the color change corresponds to the amount of alcohol that is present.

To determine the degree of the color change, and so calculate the alcohol level, it is necessary to compare the test solution to an unreacted solution. The latter control solution is contained in another compartment in the Breathalyzer®. The control solution is in a photocell; an electric current that is produced causes a needle in the device to move from its resting place. The operator then turns a knob to move the needle back to its resting place and then records the alcohol level from the position of an indicator on the knob relative to a scale.

Other versions of Breathalyzers® can perform the calculations automatically and display the alcohol level as a digital read-out. With improvements in technology, the Breathalyzer® has become smaller. Some models are so small that they can be attached to a key chain. Forensically-approved versions are larger, but are still portable enough to be taken to the scene of an investigation.

Two other alcohol detection devices can be used. They do not detect ethanol in the color-dependent fashion of a Breathalyzer®. An Intoxilyzer® detects alcohol using infrared **spectroscopy**, while an AlcoSensor® detects alcohol based on its use as fuel in another type of chemical reaction.

SEE ALSO Crime scene investigation; Evidence; Indicator, acid-base.

Pat Brown

AMERICAN
INVESTIGATIVE CRIMINAL PROFILER

Pat Brown is a prominent investigative criminal profiler whose company, the Pat Brown Criminal Profiling Agency, specializes in providing scene analyses and behavioral **profiling** to defense attorneys, prosecutors, the judicial system, and to international clients. She is also the C.E.O. of The Sexual Homicide Exchange (SHE), which was created in 1996 in an effort to provide a broadened approach to police **training**, homicide investigation, criminal justice, advocacy, and community involvement. SHE provides *pro bono* (at no cost) investigative and criminal profiling services to the families of homicide victims, as well as to law enforcement agencies. A central focus of SHE is the investigation and profiling of **cold case** homicides.

Through SHE, Pat Brown is piloting the CAPTURE (Coalition for Apprehending Predators through Utilizing Resources Effectively) Program, a serial homicide investigation methodology and training program for law enforcement personnel, the goal of which is to increase the efficiency of homicide investigations and thereby increase the rate of serial killer arrests (and significantly decrease the number of **serial killers** at large).

As an investigative criminal profiler, Pat Brown makes herself (and her team of profilers) available to assist law enforcement agencies without charge. Although their profiling work may sometimes serve merely to validate the work of the ongoing homicide investigation and to provide reassurance to the families of victims that the criminal justice system is doing all it can to solve the crime, they can sometimes offer new ideas and provide alternative directions for the investigation to take. In suspected serial homicides, investigative profiling may be used to narrow investigative focus or, alternatively, to broaden the base of possible leads; it may be used as a tool for linking crimes together.

Brown views investigative criminal profiling as a dynamic process that does not conclude until a suspect is arrested and convicted. She deems it a support process for the criminal investigative team, made up of a combination of four skills: investigation, forensic analysis, psychological assessment, and the application of cultural anthropology. Brown considers this type of profiling to be a real-time, speculative process requiring ongoing checking to avoid missing any significant data, and should never be done in isolation, but rather as one piece of the entire criminal investigative process.

Pat Brown, through her commonsense, straightforward law enforcement training programs, her media commentary work, her development of the CAPTURE program, and the evolution of SHE, has done much to contribute both to the solution of cold cases and ongoing investigations.

SEE ALSO Anthropology; Cold case; Crime scene reconstruction; Crime scene staging; Serial killers.

Richard L. Brunelle

AMERICAN
FORENSIC CHEMIST

Richard L. Brunelle worked for both the government and the private sector as a forensic chemist for almost forty years, specializing in document authentication and **ink analysis**. Brunelle's expertise led him to write two successful books on the subject. He also served as a consultant on many criminal cases. In addition, Brunelle is responsible for founding the Society of Forensic Ink Analysts.

Brunelle began his career as a forensic chemist for the Forensic Science Laboratory at the U.S. Bureau of Alcohol, Tobacco, and Firearms (**ATF**). He worked with the ATF for twenty-eight years, holding various positions including the chief of the Forensic Science Laboratory. During this time Brunelle conducted extensive research in the area of ink analysis, including work with chemist Antonio Cantu to develop new methods for chemically determining the relative age of ballpoint pens. Additionally, Brunelle was consulted on document fraud cases across the country and wrote articles for a number of **professional publications**.

Brunelle is perhaps best known for the two major books he co-wrote on the subject of ink analysis. The first was the 1984 *Forensic Examination of Ink and Paper*, written with Robert W. Reed. The text details the history, properties, and composition of writing inks and paper, as well as the forensic examination and court acceptability of said products. In 2003, Brunelle and fellow forensic scientist Kenneth R. Crawford wrote *Advances in the Forensic Analysis and Dating of Writing Ink*. In this book, the authors outline laboratory procedures used in examining and dating inks, and discuss the techniques' applications in civil and criminal cases. They focus on advances made within the last twenty years, including relative age comparisons and accelerated aging of inks.

After his retirement from the ATF, Brunelle started his own forensic science firm, Brunelle Forensic Laboratories. There he specialized in dating inks on **questioned documents**. He also was responsible for establishing the Society of Forensic Ink Analysts. It was the first professional association for forensic ink chemists, created to advance the science of forensic ink analysis such as ink comparisons, ink **identification**, and ink dating. Brunelle was awarded the 1972 John A. Dondero Award from the **International Association for Identification**, given in recognition of outstanding contributions in the field of scientific identification.

SEE ALSO Careers in forensic science; Document forgery.

Bubonic plague

Bubonic plague is an infectious disease. Thus, it is a concern in **forensic science** as a possible **cause of death** during an occurrence or outbreak featuring an unknown pathogen (illness-causing agent).

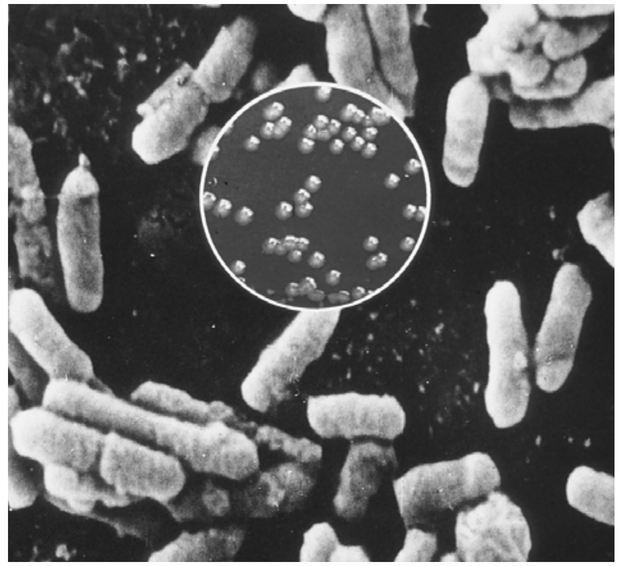
The bacterium that is responsible for bubonic plague is *Yersinia pestis*, named after one of its co-discoverers, Alexandre Yersin, and is also known as *Pasteurella pestis*. Typically, the bacterium is passed from rodents to other animals and humans via the bite of a flea. The flea acquires the bacterium as it lives on the skin of the rodent. Humans can also acquire the disease by direct contact with infected tissue or **fluids**.

Pneumonic plague (infection with *Yersinia pestis* bacteria in the lungs) results from inhaling minute droplets of moisture in the air that are contaminated with the bacteria, usually from being near another person with pneumonic plague who is coughing.

With bubonic plague, *Yersinia pestis* invades the lymphatic system. Bubonic plague is named because of the symptoms. The bacterial infection produces a painful swelling of the lymph nodes. These are called buboes. Often, the first swelling is evident in the groin. During the Middle Ages, a large epidemic of bubonic plague was referred to as the Black Death, because of the blackening of the skin due to the dried blood that accumulated under the skin's surface.

The bubonic plague has been a significant cause of misery and death throughout recorded history. The Black Death was only one of many epidemics of plague that extend back to the beginning of recorded history. The first recorded outbreak of bubonic plague was in 542–543. This plague destroyed the attempts of the Roman emperor of the day to re-establish a Roman empire in Europe. This is only one example of how bubonic plague has changed the course of history.

The plague of London in 1665 killed over 17,000 people (almost twenty percent of the city's population). This outbreak was quelled by a huge fire that destroyed most of the city.



Microscopic section showing plague bacteria. © CORBIS SYGMA

The disease remains present to this day. In North America, the last large epidemic occurred in Los Angeles in 1925. With the advent of the antibiotic era, bubonic plague has been controlled in the developed world. However, sporadic cases (e.g., 10–15 cases each year) still occur in the western United States. In less developed countries (e.g., in Africa, Bolivia, Peru, Ecuador, Brazil), thousands of cases are reported each year.

The infrequent outbreaks of bubonic plague do not mean the disease disappears altogether. Rather, the disease normally exists in what is called an enzootic state. That is, a few individuals of a certain community (e.g., rodents) harbor the disease. Sometimes, however, environmental conditions cause the disease to spread through the carrier population, causing loss of life. As the rodent populations dies, the fleas that live on them need to find other food sources. This is when the interaction with humans and non-rodent animals can occur. Between outbreaks, *Yersinia pestis* infects rodents without causing much illness. Thus, the rodents become a reservoir of the infection.

Symptoms of infection in humans begin within days after contamination with the plague bacterium. The bacteria enter the bloodstream and travel to various organs (e.g., kidney, liver, spleen, lungs) as well as to the brain. Symptoms include shivering, nausea with vomiting, headache, intolerance to light, and a whitish-appearing tongue. Buboes then appear, followed by rupture of blood vessels. The released blood can coagulate and turn black.

If the infection is untreated, the death rate from plague in humans approaches 75%. Prompt treatment most often leads to full recovery and a life-long immunity from further infection. Prevention is possible, since a vaccine is available. Unfortunately, the vaccine is protective for only a few months. Use of the vaccine is usually reserved for those who will be at high risk for acquiring the bacterial infection (e.g., soldiers, travelers to an outbreak region). **Antibiotics** such as tetracycline or sulfonamide are used more commonly as a precaution for those who might be exposed to the bacterium. Such use of antibiotics should be stopped once the risk of infection is gone, to avoid the development of resistance in other bacteria resident in the body.

The most effective way to prevent bubonic plague is the maintenance of adequate sanitary conditions. This acts to control the rodent population, especially in urban centers.

SEE ALSO Biodetectors; Bioterrorism; Nervous system overview; Pathogens; Toxins.

Bugs (microphones) and bug detectors

A forensic investigation typically involves the examination of items at the scene of the crime or accident. Fabric, bloodstains, and food are examples. In addition, an investigator will make use of recording devices that were in place prior to the incident. One example is a security camera. Another example involves the various forms of technology that allow voice conversations to be recorded. Microphones (bugs) can be installed in a room or even within a telephone.

Hand-in-hand with the development of bugs came technologies designed to detect the devices (bug detectors). Bug detectors are a very useful forensic tool, enabling a crime or accident scene to be scanned for the presence of recording bugs.

A typical electronic bug consists of a microphone and a radio transmitter. The microphone receives sound waves and either vibrates a thin membrane called a diaphragm (a dynamic microphone) or a thin metal ribbon suspended in a magnetic field (a ribbon microphone). Vibration of the diaphragm produces an electrical signal. Vibration of the metal ribbon produces a voltage change, which can be converted to an electrical signal.

The electric signals are then beamed out of the transmitter portion of the bug to a receiver. The conversation transmitted by the bug to the receiver can be recorded or listened to directly. Other types of bugs exist. For example, radio frequencies passing through the electrical wiring of a building can be intercepted. Bugs can also intercept the electrical transmissions from portable phones, wireless computers linked to a network, and even from a computer monitor.

The designation of secret listening devices as bugs is entirely suitable, given their small size. Modern bugs can be concealed in pens, calculators, and even buttons (although the latter need to be replaced frequently, as their power supply is so small).

The miniaturization of electronics has made it possible to pack more devices into the small package. For example, video equipment can be contained in a bug, enabling sight as well as sound surveillance.

Up to the 1980s, bugs operated using very high frequency, or VHF, radio waves. However, the development of mobile communications technology, particularly digital telephones, paved the way for the development of bugs that operate using ultrahigh frequency wavelength or microwaves. This has made the detection of bugs more difficult than simply detecting the output of radio waves. Some modern bugging devices can also disguise the output signal or vary the frequency of the signal, which can thwart detection.

Some bugs contain voice-activated recorders that are capable of storing up to 12 hours of conversation. The information can then be rapidly sent to a receiver in a "burst" transmission. Because detection of the bug is geared toward the frequencies emitted during transmission, the detection of these bugs is difficult. Counter systems are designed to try and activate the bug and then detect it. The transmission range of bugs has improved from mere yards to miles. Some bugs can even transmit to satellites, making monitoring from thousands of miles away feasible.

Another surveillance option is the use of a microphone. Conventional microphones operate electronically; the electrical signals representing the converted sound waves are passed through a wire to a receiving device located elsewhere. Microphones that operate using magnetic fields also exist.

Shotgun microphones equipped with a parabolic reflector can record conversation outside at a distance. Electronic filters screen out extraneous background noise in order to enhance the sensitivity of the microphone.

Laser microphones bounce a laser beam off of an object that is near the conversation. The object must be something that resonates, or is able to move as pressure waves created by noise in the room encounter it. As the object vibrates back and forth due to the sound waves from the conversation in the room, the distance traveled by the laser beam will become slightly shorter and longer. These length differences can be measured over time, and the pattern of the vibrations translated into the text of the conversation.

Microphones are extremely hard to detect, especially when used in a room where other electrical appliances (i.e., computers, telephones) are operating.

Bugs are detected by virtue of the frequencies they emit. Essentially, a bug detector is a receiver. When brought near an operating bug, the detector will collect and amplify the bug's transmission. Bug detectors are now portable enough to be carried in a "sweep" of a room.

Bugs and microphones have moved from the arena of political espionage to the boardrooms of corporate offices and police surveillance operations. Recognizing the prevalence of electronic eavesdropping devices and their threat to privacy, the United States Congress passed the Electronic Communication Privacy Act in 1986, which made bugging illegal. Nonetheless, the use of eavesdropping devices and detectors is widespread in the intelligence and business communities. One estimate places the annual sales of such devices in the United States alone at $888 million.

SEE ALSO Crime scene investigation; Evidence; Telephone recording system; Telephone tap detector.

Building analysis SEE Architecture and structural analysis

Building materials

Sometimes a burglar or assailant enters or leaves premises through a window, via a roof or ceiling, or by breaking down or forcing a door. This can produce a range of wide range of **trace evidence** derived from the building materials used in that particular dwelling. Trace **evidence** is often invisible and will adhere to the clothing, hair, skin, and footwear of a suspect without the person being aware of it. Forensic examination of the suspect may produce evidence that can link the person to the scene of the crime through the presence of tiny amounts of building materials.

Forensic analysis of building materials covers a wide range of substances, such as brick, plaster, slate, loft insulation, **glass**, and wood. The broad principles for collecting and examining such materials are the same. The evidence has to be collected from around the site of entry or escape from the scene of the crime, by brushing, taping, picking with tweezers, or vacuuming. The samples need to be stored in a separate unused container and transferred to the forensic laboratory through a careful **chain of custody**. Examination of the suspect and his or her clothes for matching trace evidence of building materials has to be done with great care and preferably not by the same investigator who was at the scene of the crime. Otherwise, fragments of brick dust or glass, for instance, could be unknowingly transferred to the suspect.

Most building material trace evidence is in the form of **fibers** or dust. For instance, loft insulation is composed of glass fibers. The first step is to examine the material by eye, in good lighting, and then under a microscope. Various microscopic techniques are used to establish the nature of the material. In comparison microscopy, the sample is compared to known reference samples of various types of brick or plaster. The exact color of the sample can be established by microspectrophotometry.

There are various analytical techniques that can determine the chemical composition of a building material. Forensic scientists may use infrared **spectroscopy**, neutron activation analysis, or x-ray diffraction as appropriate. The analysis of building material evidence may tell the investigators a great deal about how an entry or exit to a building was made by a suspect. This provides a vital link in reconstructing the events before and after the crime took place.

SEE ALSO Crime scene investigation; Crime scene reconstruction; Glass; Paint analysis; Physical evidence.

Bullet lead analysis

Crime scene bullets are sometimes too mutilated or fragmented to be useful for normal **ballistics** analysis—that is, the bullet has no markings that investigators can compare with those produced by a gun connected to a suspect. Bullet lead analysis, sometimes called compositional bullet lead comparison or comparative bullet lead analysis (CBLA), allows forensic investigators to identify the elemental composition and characteristics of a bullet. This information can show if the bullet matches that of a bullet whose source is known, whether two bullets likely came from the same source (a single manufacturer's lot), or possibly even the same box. CBLA is widely accepted in the courts to show that a bullet recovered from a crime scene matches other bullets found in the possession of a suspect, strongly suggesting that the suspect fired the bullet in question. CBLA can also be used to exclude suspects.

The procedure, which is generally carried out by the Federal Bureau of Investigation (**FBI**), was developed in the 1960s by researchers under a federal grant to develop uses for neutron activation analysis (NAA). With the aid of a nuclear reactor, these researchers were able to show that a billet, or ingot, of lead poured from a pot of molten lead was homogenous in its elemental composition. Thus, any bullets manufactured from that ingot were analytically indistinguishable. Conversely, bullets manufactured from billets poured from different pots of molten lead were analytically distinguishable because the concentrations of elements in them were different. Since about 1995, researchers have replaced NAA with a process called inductively coupled plasma-optical emission **spectroscopy** (ICP-OES). This process enables researchers to measure the concentrations of up to 70 elements simultaneously. The relevant elements in bullet lead are antimony, arsenic, copper, bismuth, silver, tin, and cadmium.

Bullets are generally manufactured from lead obtained from secondary lead smelters, which obtain most of their lead from recycled automobile batteries. The smelter separates the lead and melts it in kettles with a capacity of up to 100 tons, often supplementing the recycled lead with virgin lead. Elements such as antimony may be added to produce hardened lead, which is generally used in non-jacketed bullets. Soft lead, generally used in jacketed bullets, contains little or no antimony. Other elements are likely to be present in varying trace amounts. The lead is then processed into ingots ranging in weight from 65–80 pounds (29.5–36.2 kilograms); billets, from 100–300 pounds (45.3–136 kilograms); or sows, which weigh a ton. The bullet manufacturer then re-melts the lead, often adding scrap lead. The lead is then poured into a mold, where it is allowed to cool and harden before being extruded into "wires" that are cut into slugs, which are then formed into bullets by a process called swaging, then tumbled to make them smooth, and

Bullet fragments found on the front seat of John F. Kennedy's presidential limousine. Included as an exhibit for the House Assassinations Committee formed in 1976. © CORBIS

loaded into cartridges with gunpowder. The cartridges are then placed into boxes, which are stamped with a packing code or lot number.

CBLA is regarded as reliable forensically because each batch of lead that comes from secondary smelters is unique in its elemental composition. Differences in composition are tolerated as long as they are with in acceptable quality limits. At the bullet manufacturer, rejected bullets, rejected lead from previous runs, trimmings, and any other source of lead may be recycled into a particular batch, creating similar variances that give each batch a unique elemental fingerprint. The result is that each batch, and the bullets manufactured from it, is homogeneous, while elementally distinguishable from all other batches. The FBI states that ICP-OES technology is able to detect narrow compositional ranges of 0.01–0.05 percent of each of the seven relevant elements. The result is that ICP-OES can detect millions of distinguishable lead compositions.

The scientific validity of CBLA has been challenged in the courts. Specifically, defense attorneys have challenged the "same composition, same molten lead" theory of CBLA under Rule 702 of the **Federal Rules of Evidence**, claiming that the premises of CBLA—that lead and bullet samples are representative and that lead sources are compositionally uniform and unique—have not been sufficiently tested. CBLA has withstood these challenges, notably in *United States v. Jenkins* (1997) and in a 1998 New York case, *People v. McIntosh*. CBLA is likely to come under increased scrutiny as a result of a 2004 report released by the National Research Council of the National Academies of Science (NAS). The report was the result of a 12-month study conducted by the Committee on Scientific Assessment of Bullet Lead Elemental Composition Comparison, which found weaknesses in the research base that underpins CBLA. Following release of the report, though, the FBI maintained that CBLA "will still be useful in linking individuals to a crime as well as to exclude others."

SEE ALSO Ballistics; FBI crime laboratory; Federal Rules of Evidence; Laser ablation-inductively coupled plasma mass spectrometry; Spectroscopy.

Bullet track

When a bullet is fired from a gun, its **trajectory** or journey to its final destination is divided into three parts. The internal part of the trajectory concerns what happens from pulling the trigger to the bullet leaving the gun. The external trajectory involves the journey from the gun to the target. The final part of bullet's journey, from the target to the place where it comes to rest, is called the terminal trajectory. When a human being is the target, the forensic investigator gets involved. In such cases, the terminal trajectory leaves a bullet track inside the victim.

When someone is hit by a bullet, there will always be an entry wound. There may or may not be an exit wound, depending upon the track taken by the bullet and the way it is fired. Whether a bullet actually passes through the body depends on many factors such as the range of firing, whether it was with the gun in direct contact with the skin or from a distance. It also depends on the type of gun and bullet used. The forensic pathologist will examine the entry wound and note its shape and edges. Sometimes the edges are blackened and there may be some degree of ballooning if the gases from the bullet explosion enter the body. A shooting at close range will burn the skin on entry.

The exit wound of a bullet is generally somewhat bigger than the entry wound. However, if the victim is wearing tight clothing this may provide a constraint that makes the entry and exit wound look similar. Certainly no assumptions should be made by the investigator until he or she has all the information possible about the incident.

The internal effects of a bullet in the body, whether it exits or is left there, depend upon the kinetic energy it carries. Low velocity, low-energy bullets, as those fired from air rifles and some

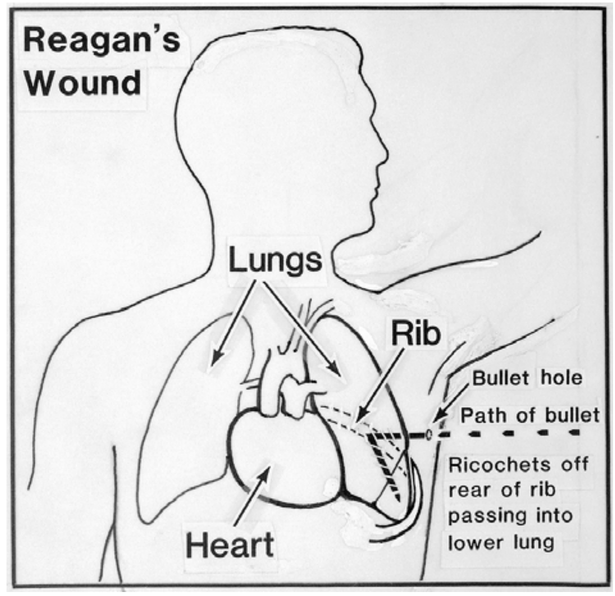


Diagram of the path of a bullet fired at close range at President Ronald Reagan during an assassination attempt in 1981.

revolvers, just cause a mechanical disruption, pushing tissue aside. A high-velocity bullet from a shotgun or machine gun would transfer large amounts of energy to tissues or organs. This typically forms large and destructive cavities within organs such as the liver or brain that may prove lethal.

SEE ALSO Ballistics; Gunshot residue.

Bundy (serial murderer) case

Ted Bundy was responsible for a series of brutal sex murders in the Pacific Northwest, Utah, and Colorado between 1969 and 1975. The law graduate was a handsome, charming young man who did charity work and volunteered for political candidates. In his early years, however, he had been unsettled and insecure. He had a history of repeated petty theft and found it difficult to make friends, suggestive of psychopathic tendencies.

Bundy's trick was to feign injury and ask for help to lure women to his car, an old Volkswagen Beetle. He had already claimed several victims in Seattle when, on November 8, 1974, he approached Carol DaRonch in Salt Lake City, posing as a policeman. He managed to persuade her into his car, despite her suspicions. Bundy then tried to handcuff her and pulled a gun, but she managed to escape.

Theodore Bundy (center) confers with his defense attorneys during his murder trial in 1979. Bundy was later convicted, then executed in 1989. © BETTMANN/CORBIS

Seventeen-year-old Debbie Kent wasn't so lucky; Bundy killed her later that night.

Eventually, in August 1975, Bundy was caught, but not before he had committed more brutal murders. Carol DaRonch picked him out in an identity parade (line-up) and he was convicted of kidnapping her and jailed for 15 years. The Colorado authorities also wanted him for the **murder** of Caryn Campbell. However, Bundy escaped from prison twice, once only briefly before recapture. The second time he adopted a false name and lived by theft. On January 15, 1978, in the dead of night, he traveled to Florida, where he broke into the Chi Omega sorority house at Florida State University. Here Bundy attacked four students, raping Lisa Levy, 20, and then killing her by beating her about the head with a log. Margaret Brown 21, was strangled, but not sexually assaulted. Another student, Nita Neary, saw him fleeing the scene and was later able to identify him.

A month later, Bundy sexually assaulted and strangled his last victim, 12-year-old Kimberley Leach. Bundy was finally caught driving a stolen car, by which time he was wanted for murder in several states. In the car was telling evidence—handcuffs and a crowbar. At the trial, Bundy insisted on conducting his own defense. No **fingerprint evidence** was found at the scene of the Chi Omega murders. However, there was a bite mark on the buttocks of Lisa Levy and another on the nipple, a common finding in violent rape. The first mark was photographed and a transparent overlay created. Bundy was forced by court order to give a dental impression. Forensic dentist Richard Souviron declared the outline of Bundy's front teeth, which were chipped and misaligned, an exact match to the pattern on the transparent overlay. This proved to be a major piece of evidence for the prosecution.

Bundy was found guilty of the murder of the two Chi Omega students and sentenced to death. He spent ten years on Florida's Death Row, using legal tactics to gain a reprieve. At first he insisted on his innocence. Later, though, he admitted to the murders of up to 50 women. Those who have studied this case suggest he could have been responsible for as many as 100 deaths. The true number will probably never be known. In these confessions, he always referred to himself in the third person, claiming an entity inside drove him to kill.

Bundy admitted to becoming obsessed with hard-core pornography involving sadomasochism, a tendency completely at odds with his clean-cut appearance and demeanor. Psychologists who had examined him during his first stay in prison suggested he was neither psychotic nor a sexual deviant. However, he was very dependent on women and feared humiliation in his relationships. He admitted enjoyment of the power he had over his victims. The primary motive in his crimes was, he said, always rape. He then felt compelled to murder his victims to prevent them giving evidence against him. It is interesting that all the victims bore a striking resemblance to one another, having dark hair parted in the middle. This suggests a female fantasy figure that was central to his sexual crimes. Bundy was finally executed in the electric chair on January 24, 1989.

SEE ALSO Bite analysis; Odontology; Serial killers.

Bureau of Alcohol, Tobacco, and Firearms SEE ATF (United States Bureau of Alcohol, Tobacco, and Firearms)

Ann Wolbert Burgess

AMERICAN
FORENSIC PSYCHIATRIC NURSE

Ann Wolbert Burgess is one of the foremost experts in **forensic nursing** in the continent of North America. She is a respected author, educator, advanced practice psychiatric nurse, and researcher who has been a pioneer in the rapidly expanding field of forensic nursing. She earned her bachelor's and doctoral degrees in nursing from Boston University, and her master's degree from the University of Maryland. In the mid-1970s, Lynda Lytle Holmstrom and Ann Burgess were the co-founders, at Boston City Hospital, of one of the first hospital-based crisis intervention programs for victims of rape. In 1974, the early results of their research at that program resulted in establishment of the validity of the rape trauma syndrome, which has since gained admissibility in more than 300 appellate court decisions.

Since 1972, Burgess has been actively involved in research on issues of child and adult sexual assault, battering, stalking, identifying markers for elder sexual abuse, and rape. Her forensic and other clinical research interests have expanded through the years to include heart attack victims and return to work, the use of children in pornography, sexual homicide, crime scene patterning, crime scene investigations, the use of children as witnesses in child sexual abuse trials, AIDS, infant kidnapping, and forensic markers in elder sexual abuse. With the **FBI**, she has studied serial perpetrators of sexual homicide, rape, and child sexual offenses, as well as the possible relationship between child sexual abuse and exploitation, juvenile delinquency, and eventual expression of criminal behavior.

Burgess has written or co-authored numerous textbooks in the fields of psychiatric nursing and crisis intervention. Her works have included books on the assessment and treatment of child, adolescent, and adult survivors of sexual assault, and texts concerning serial offenders: rapists, abductors, child molesters, and murderers. Among her best-known works in this area is the award-winning *Crime Classification Manual.* She has co-authored nearly 150 articles, book chapters, and monographs on rape victimology, child sex rings, adolescent victims of rape, adolescent runaways, child abductors and molesters, infant abduction, and juvenile prostitution.

Burgess continues to play a pivotal role in the advancement of **forensic science** through her continuing research, her prolific writings, and her prominence as an expert courtroom witness.

SEE ALSO Contact crimes; Criminal profiling; Expert witnesses; Forensic nursing; Pattern evidence.

John J. Buturla

AMERICAN
TERRORISM AND SECURITY EXPERT

Over the course of his career, John J. Buturla turned his interest in and experience with **forensic science** and law enforcement into one of the highest ranking roles in state security, as Director of Homeland Security for the state of Connecticut. Under his leadership, the state took part in one of the largest terrorism drills ever attempted.

Buturla pursued a career in law enforcement by becoming a police officer in the town of Trumbull, Connecticut, in 1979. During that time, he also attended Sacred Heart University, where he earned a bachelor's degree in criminal justice. In 1982 Buturla joined the Connecticut State Police. While working on the state level, he rose to the rank of Major and held numerous posts, including Chief of Staff for the State Police and Commanding Officer of Major Crime. He also returned to school, and in 1988 he earned a master's degree in forensic science from the University of New Haven.

In 1999, Buturla graduated from the **FBI** National Academy Program in Quantico, Virgina. Two years later, he moved into the position of Deputy Director of Homeland Security for the state of Connecticut. In this role he worked directly with the Federal Department of Homeland Security, developing a unified security plan for the state. In 2004, he took over the role of Director. That same year, Buturla led Connecticut in the execution of an international terrorism drill, in conjunction with the state of New Jersey and the United Kingdom. It involved a fictional terrorist organization, volunteers posing as victims at local hospitals, and federal officials tracking down leads regarding the fictional attack.

Buturla has also contributed to the literature of forensic science, as a contributing author of *Forensic Aspects of Chemical and Biological Terrorism.* Written for public health and safety workers, the book addresses the roles and responsibilities of these officials in the event of a terrorist attack.

In 2005 Buturla returned to the Connecticut State Police, overseeing the operations of its forensic lab. He also continued to work as an adjunct professor at the University of New Haven, instructing students in the Graduate Program in National Security.

SEE ALSO September 11, 2001, terrorist attacks (forensic investigations of).

C

Caliber

There are two recognized definitions of caliber that differ slightly. First, there is the factual term caliber that is defined as the internal diameter of the barrel of a firearm. Second, the nominal caliber of a bullet refers to its nominal diameter and the characteristics of the cartridge. In many instances, the numerical value of the nominal caliber corresponds to the factual caliber, but this is not always the case, as some variations might appear.

The caliber of a cartridge can usually be determined from the size, weight, and shape of the bullet. Once the caliber of a cartridge is known, it is possible to obtain a list of **firearms** capable of firing such a caliber. In addition, by looking at other characteristics imprinted on the bullet, it is possible to further narrow the possibilities. This is extremely important **evidence** in a forensic investigation. With one bullet found at a crime scene it is possible to determine which firearms could have fired the bullet, and therefore, enhance the search for a suspect.

Calibers are usually expressed in hundredths of an inch or thousandths of an inch in the United States and in Great Britain. In many other countries, these are expressed in millimeters. For example, the .25 Auto is equivalent to the 6.35 Browning, the .32 Auto is equivalent to the 7.65 Browning, and the .30 Luger is equivalent to the 7.65 Para. This can be confusing if the conversion is unknown.

Calibers range from very small to very large. Among the commonly known calibers, one of the smallest is the .117 or 4.5 mm and one of the largest is the .700 Nitro Express. Some well-known calibers are the .22 LR (long-rifle), 9 mm Para, .38 Special, .357 Magnum, 10 mm Auto, and .45 ACP (automatic Colt pistol).

The term gauge instead of caliber is used with smooth-bore firearms such as shotguns. In this case, the gauge number corresponds to the number of identical spherical balls of pure lead fitting the gun's diameter that could be made from one pound of lead. For example, a 20-gauge shotgun has a diameter of 15.6 mm, meaning that one pound of pure lead can make up 20 identical balls of a diameter of 15.6 mm each. Gauge numbers range from 4 to 26, which corresponds to 23.4 mm and 10.2 mm, respectively.

SEE ALSO Ballistics; Crime scene investigation; Microscope, comparison.

Cameras

A classical image of a crime or accident investigation involves an investigator photographing the scene. Cameras are vital to **forensic science**, providing a visual record of the scene. For example, a picture of a **blood spatter** can be used to help determine the cause of the spill long after the stain itself has been cleaned away.

A visual image is an ideal way to preserve a record of a scene before items are disturbed. Pictures are admissible as legal **evidence**, providing the

A Western .38 Special stamp marks a bullet used in forensics tests during the Kennedy assassination investigation. © CORBIS

prosecution or jury members with an evocative image of the scene. Visual images can aid in reaching a verdict on a crime.

A traditional camera functions by focusing light through a lens onto a surface coated with light-sensitive chemicals. Digital cameras have internal processors that record images in an electronic form, converting wave-like analog information into digital information represented by bits. The concept of the camera dates back to the Renaissance idea of the camera obscura, a small, dark chamber into which light was permitted only through pinholes. During the early nineteenth century, inventors perfected the camera obscura to make the prototype of the modern camera, but early **photography** was a cumbersome affair characterized by large, boxy cameras and slow exposures.

Surveillance cameras, which have long been an espionage tool, can also be a useful forensic tool. According to the Security Industry Association, by 2003 there were some two million **closed-circuit television** systems in operation, most of them operated by private businesses for security purposes, in the United States. Many households are also equipped with surveillance cameras.

A forensic investigator can gain legal access to the recordings made by a security camera. This can provide vital information of events before, during, and following the crime or accident.

Increasingly, municipalities are installing surveillance cameras at traffic intersections to monitor the license plate numbers of traffic violators. Such data can be useful forensically.

Virtually all traditional cameras have at least one glass lens, and one with a zoom or telephoto lens typically has three: front and rear convex lenses, with a concave one in between. Though zoom lenses clearly have an application in the world of law enforcement, they can also provide long-distance photos that are useful in a forensic investigation. Miniature and subminiature cameras are usually for photographing images at close range. Typically they would have only a single lens, perhaps with a coating to reduce reflections or glare.

In place of lenses, a pinhole camera uses tiny apertures, or openings, so small that they are known as pinholes. The value of a lens lies in its ability to focus and thus photograph distant objects or ones close by, depending on the settings. By contrast, the value of a pinhole camera is precisely the fact that it does not have lenses, and therefore can produce images of distant and nearby images equally well.

Forensic photography is typically the responsibility of a skilled photographer. The photographer will be careful to photograph the subject from a variety of angles and to use lighting conditions that will emphasize all the detail of the object.

Digital cameras can be useful, since the digitized information can be downloaded to a database for further scrutiny. But, even traditional film photographs can be digitized for electronic storage and analyses.

SEE ALSO Crime scene investigation; Evidence.

Canine substance detection

An important aspect of a forensic investigation can be the determination of the presence and location of compounds of interest. Probably the best example is the need to establish where illicit chemicals and agricultural plants are present.

Sophisticated detection equipment such as gas and gas-liquid chromatographs can detect extremely small levels of a variety of compounds. Their portability, however, can be limited. Fortunately, the detection sensitivity of these instruments is rivaled by the nose of a dog. Dogs play a central role in some forensic operations.

John Long and his bomb-sniffing dog Coby check luggage as they go through a drill at Lackland Air Force base in San Antonio, Texas, in February 2002. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

Canine substance detection involves the use of specially trained dogs, commonly golden or Labrador retrievers, for the detection of illegal substances. Dogs are now being used in settings that include workplaces, airports, and schools to detect weapons, contraband, **narcotic** drugs, medications, beverage alcohol, **firearms**, and **explosives**.

Dogs trained to detect the scent of illegal substances are useful as they can utilize their acute sense of smell to penetrate many hiding places which are inaccessible to other detection methods. A dog has about 200 million sensitive cells in its nose, compared to approximately five million in a human being, producing a detection sensitivity that outrivals us by some 40-fold. A dog's sense of smell is made even keener by an organ in the roof of the mouth that is not found in the human olfactory system. This organ enables it to "taste" a smell, in essence amplifying a weak signal into a stronger, more easily detectable signal.

This sensitivity enables a trained dog to be able to discriminate one odor from another, even when the latter is more intense. For example, drug-sniffing dogs can be trained to detect the odors of heroin, marijuana, and cocaine even when these items are concealed in a suitcase containing perfume.

Not surprisingly, canine detection of substances like drugs is a routine part of forensic investigations aimed at curbing the illicit traffic of drugs. Canine drug detection is a common sight at areas of cross border travel such as border crossings, airports, bus stations, and ports.

Some dogs are specially trained to detect the acidic smell of nitroglycerin and the sulfur in gunpowder for work with explosives detection. Forensic investigators use **arson** dogs to help in criminal investigations in the aftermath of fires. These dogs locate minute traces of gas or other flammable liquids in situations where arson is suspected. Arson dogs are trained in such a way that they can accurately detect traces of chemicals at the parts-per-million or even billion levels. This detection sensitivity rivals and can even exceed that achievable using electronic detectors.

SEE ALSO Analytical instrumentation; Bomb detection devices; Illicit drugs.

Carbon monoxide poisoning

Carbon monoxide, with chemical formula CO, is a compound of carbon (C) and oxygen (O_2). It is a colorless, odorless, and tasteless gas that in appropriate amounts is poisonous to human beings and, for that matter, to all warm-blooded animals and many other life forms on Earth. Carbon monoxide is poisonous when, as a result of being inhaled into the lungs, it combines with the blood's **hemoglobin**, which then prevents the absorption of oxygen into the respiratory system of the body. Carbon monoxide poisoning results when the human body is consistently denied essential oxygen. A person without sufficient oxygen in the blood stream will initially feel dizziness, fatigue, headaches, nausea, and shortness of breath, which will eventually lead to unconsciousness and eventually to asphyxiation and death.

Carbon monoxide is a component of air pollution, both as an intentional or accidental side product, that results from many natural and artificial products, materials, and processes such as gasoline-powered vehicles, furnaces, manufacturing plants, and forest fires. The identification of carbon monoxide poisoning is important to forensic scientists because carbon monoxide can be the primary or secondary cause of such investigations as accidents, homicides, and suicides, or can be used as a deceptive tactic by criminals to hide other causes of crimes. For example, a forensic investigator might examine three unrelated dead bodies inside automobiles within three different closed garages and find (1) one body with carbon monoxide in the blood stream, but without any other suspicious **evidence** (which indicates a suicide), (2) another body with carbon monoxide in the blood, but with greasy fingers and clothing (which indicates an accidental death), and (3) a third body with blunt injuries to the head and only a small amount of carbon monoxide in the body (which indicates a homicide).

In order to determine the level of carbon monoxide within the blood stream of a deceased person, the accurate measurement of the blood pigment carboxyhemoglobin is required. Carboxyhemoglobin is hemoglobin that is saturated with carbon monoxide. Several detection methods are used for the measurement of carbon monoxide including CO-Oximeter, flame ionization, infrared spectrophotometry, syringe capillary, thermal conductivity, ultraviolet spectrophotometry, and Van Slyke. In ultraviolet spectrophotometry, for example, carbon monoxide is expelled from the blood stream and is then measured when exposed to ultraviolet radiation.

SEE ALSO Asphyxiation (signs of); Hemoglobin; Poison and antidote actions; Toxicological analysis; Toxicology.

Careers in forensic science

A forensic scientist works in one of several scientific fields used in a court of law. He or she helps improve public health and safety by using scientific knowledge to contribute to a court proceeding and determine the facts in a given case. Thus, a career in **forensic science** combines science and public service. A forensic scientist may work for a law enforcement agency, uncovering **evidence** for the prosecution of a crime, or he or she may work for a law firm, detecting evidence for use in a criminal defense. However, not all forensics personnel are scientists. There are many careers in forensics that relate to non-science careers such as administrative, legal (non-jurisprudence), and security related fields. Most forensic professionals find jobs with police agencies, government agencies, universities, federal agencies, armed forces, and law offices.

Forensics professionals have two main objectives: to detect **physical evidence** and to link this evidence to the crime scene and a suspect. This requires the joint effort of many professionals with specific backgrounds. A crime has many aspects and several forensics professionals will often work on a case, each studying the aspect of the crime that relates to their particular specialty. Physical evidence is usually handled by the criminalist, whose chief role is to first identify the evidence, then coordinate the appropriate analysis of the evidence.

The criminalist uses results from all analyses of physical evidence to recreate the details of a crime scene. Physical evidence can be very small, such as a drop of **blood** or a hair follicle; it can also include toolmarks, footprints, a piece of clothing, or a distinct odor. A criminalist, therefore, must exercise a broad range of skills with the ability to apply various scientific and analytical approaches to answer questions related to a criminal investigation. They must also be able provide interpretations that non-scientists, such as members of the jury and court, can understand. Most criminalists have a strong scientific background with, minimally, a bachelor's of science degree in chemistry, molecular biology, or physics. Specific courses in forensic science targeted at preparing students for the American Board of Criminalistics certification test are also offered. Criminalists are usually employed by government forensics laboratories that are part of police departments or federal agencies, such as the Drug Enforcement Administration (**DEA**) or the Central Intelligence Agency (CIA). They are also employed by medical examiners offices, private companies, and to a lesser extent, universities.

A criminalist will often require the expertise of a forensic engineer to help recreate details in a crime scene. A forensic engineer is responsible for applying fundamentals of engineering to help understand aspects in a court case, particularly for civil suits, but also for regulatory or criminal proceedings. Since engineering specialties can vary considerably, the expertise required in each case also varies. For example, a forensics engineer that understands the physics of a firearm might be required to determine which gun was used during a crime, how it was fired and from where it was fired. A broad based repertoire of practical experiences and a strong engineering background is necessary for this type of position. Credentials for such a position are not yet systematic, and therefore, must be achieved separately with a moderate level **training** in legal and criminal coursework. Many of the engineers serve in forensics-related positions as consultants.

Many forensics specialties require strong backgrounds in the biological sciences. There is an increasing need for forensics scientists with molecular biology backgrounds. This is because **DNA** based analyses have revolutionized the capacity to identify and convict criminals by linking suspects to the scene of the crime or to physical evidence. For example, in cold cases (cases that have gone unsolved for several years) DNA matching has lead to reversing charges for wrongfully convicted individuals. Experience in DNA extractions from all types of samples is very important in the training of a molecular biologist that wishes to specialize in forensics. Specialty training in mitochondrial genetics is helpful for understanding techniques to use for paternity testing, matching a sample to a suspect, or screening DNA samples from a database of criminals. These individuals usually work in or direct crime labs in conjunction with state, local, or federal organizations. They can also be private companies that offer a service to federal or state investigations.

Forensic **odontology** (dentistry) is an important subspecialty in forensics that is usually associated with coroner's or medical examiner's offices, although many serve as specialized consultants. These professionals can use dental or cranial examinations to provide information regarding human remains including **identification** of missing persons, victims from catastrophic events (plane crashes, etc.), postmortem examination with searchable database record keeping, dental injury analysis in potential abuse cases, and examination of bite marks in assault or rape cases. A forensic odotonologist must obtain a doctor of dental science (DDS) degree and have considerable experience in the field of dentistry prior to transitioning or consulting in forensics applications. The American Society of Forensic Odontology is an organization that offers comprehensive courses to prepare dentists for a role in forensics specialization.

For applications that involve tissue evaluation beyond the scope of odontology, forensic anthropologists are helpful. Their expertise is usually related to direct skeletal examinations. By using archeological methods, bones and remains can be carefully extracted from precarious surroundings, without compromising the integrity the sample. If the skeletal sample is compromised, anthropologists can be helpful in recreating the skeletal configuration of the remains. They are also trained to examine the insect remains to determine the state of body **decomposition**, especially in cases that involve a considerable amount of decomposition. A forensic anthropologist should have a doctorate in **anthropology** and certification through the American Board of Forensic Anthropology.

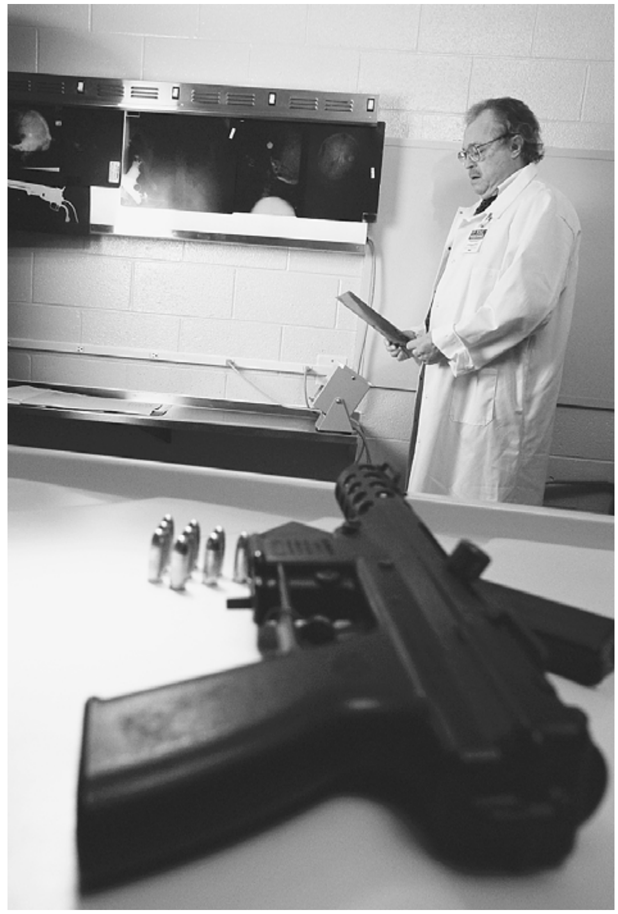
Other medical professionals are also in demand in the field of forensics. Psychiatrists are medical doctors that, with specialized forensic training, can help the forensics team understand pathological and criminal behavior. They can help predict and prevent repetitious crimes by, for example, **serial killers**. They can also help explain complicated crimes or cases that involve psychiatric patients by using behavioral patterns to uncover concrete motives in a crime. **Pathology** is another medical specialty that has forensic applications. Pathologists can perform microscopic **autopsy** evaluations of tissues, body **fluids** (blood, urine, skin), and organs to discover the **cause of death** in cases that involve, for example, poisoning or unusual injuries of unclear origin. They can be also help determine the **time of death** by evaluating the extent of tissue deterioration or obtaining tissue samples. Recently, forensic pathologists have been instrumental in coordinating medically related investigations of possible exposure to biological weapons such as **anthrax**. Pathologists require forensics specialty training and board certification. They are typically employed by the Centers for Disease Control, as well as medical examiners offices and hospitals. All medical professionals that serve in forensics careers can also serve to provide the courts with expert testimonials.

Sometimes a pathologist needs to send tissue samples to a toxicologist for further study. A toxicologist specializes in the medical and scientific study of poisons. Toxicologist are often involved in forensics cases by evaluating tissue samples for possible chemical exposures such as illicit drug use. Toxicologists can have a M.S. or a Ph.D. degree in **toxicology** with certification in both the American Board of Forensic Toxicology and the Forensic Toxicology Certification Board.

Not all forensics professionals are scientists or physicians. Trial lawyers that have forensics training can be valuable to criminal and civil court cases. Not only can forensic knowledge can help lawyers determine the admissibility of evidence, but it can also help them review the credentials of **expert witnesses**, understand the techniques and analysis that the expert employs, and cross-examine the expert witness. A law degree is required and positions can be found in both private practice as well as in state and district offices.

The subspecialties discussed here represent only a portion of the career paths available in forensics. Clinical personnel, computer programmers, accountants, archeologists, sculptors, coroners, **ballistics** experts, marine biologists, environmentalists, social workers, and nurses are all fields that can be useful in forensic science. All forensics professionals that have the appropriate credentials can serve as expert witnesses during court proceedings. The field of forensics is growing, and job vacancies in most areas of forensic science are expected to increase until at least the year 2012.

There are several professional organizations in forensic science. One such organization is the **American Academy of Forensic Sciences** (AAFS), a professional society that offers membership to a wide range of forensic specialties. The AAFS is dedicated to improving accuracy, precision, specificity, and sensitivity of forensic sciences by promoting educational resources in the form of meetings, training, and seminars. There are currently over 5,600 members, which include (but are not limited to) individuals with a variety of education backgrounds including physicians, attorneys, criminalists, engineers, toxicologists, dentists, and anthropologists. Representation spans the United States, Canada, and 50 additional countries worldwide. The AAFS hosts an annual scientific meeting, and produces an internationally recognized scientific journal (*Journal of Forensic Sciences*), which are both utilized by a wide variety of scientists and educators from various forensic specialties.



A nine millimeter semiautomatic gun lies before forensic physician Michael Baden as he examines evidence on an x-ray sheet.

SEE ALSO Anthropology; Coroner; Criminalistics; Entomology; Epidemiology; Forensic accounting; Forensic nursing; Geology; Linguistics, forensic stylistics; Medical examiner; Pathology; Psychiatry; Toxicology; Wildlife forensics.

Cases and mysteries, ancient

SEE Ancient cases and mysteries

William E. Cashin

1/19/1904–
AMERICAN
FINGERPRINT IDENTIFICATION EXPERT

William E. Cashin served the New York State Police Department in various positions for almost 45 years, most notably in the role of Director of the Division of Criminal Identification. Under his leadership, the division made groundbreaking strides in advancing the technology available for criminal investigations. Cashin also introduced a new system for searching latent prints. Officials from countries around the world came to New York to study and observe the new technologies Cashin's team was using. For his work, Cashin received numerous awards from various professional organizations.

Born in New Jersey in 1904, Cashin was fascinated with horses and became a trick rider as a youth. When he chose his career, he picked one that involved his equestrian interests, and joined the New York State Police. There he was able to trick ride as part of his job. But in 1926, he fractured his pelvis and had to give up riding. During his recovery, he became interested in **fingerprint** identification, and sought tutoring to help him learn about the field. When he returned to work, Cashin established a Bureau of Identification for his division and became a fingerprint instructor at the State Police School.

During the next phase of his career, Cashin moved up the ranks in his division and continued to study and research the area of fingerprints and personal identification. In 1936, he became the Director of the Division of Criminal Identification. In this role, he installed the first automated fingerprint searching machines and a machine that searched through files of physical descriptions. He also started a new system of searching latent fingerprints. Because of these advances, fingerprint experts from around the world came to study Cashin's department and observe the new technology at work.

In 1960, Cashin retired from New York State and accepted a position with the U.S. State Department, where he worked as an identification advisor in countries such as Brazil, Venezuela, and the Philippines. For his visionary leadership, Cashin received the 1956 Governor Charles E. Hughes Award, and the 1960 John A. Dondero Award from the **International Association for Identification**, given in recognition for those who have made substantial contributions to the science of forensic identification.

SEE ALSO Careers in forensic science; Technology and forensic science.

Casting

Casting is the process used to replicate three-dimensional prints or marks. It is widely used to obtain the exact replicate of toolmarks, **tire tracks**, **shoeprints**, and sometimes teeth. Casting is of paramount importance in forensic sciences as it allows a crime scene investigator to collect an identical copy of a mark or print from a scene, which can then be compared to a seized tool, shoe, or tire in order to establish a link between a suspect and a crime scene.

Casting can only be accomplished on three-dimensional marks or traces. In the case of toolmarks, for example, casting can be used to obtain the perfect copy of the mark of a screwdriver used to force open a door during a burglary. With a shoeprint, it allows for the shoeprint of a thief that was left in the soil outside the window of the apartment he or she exited to be preserved as **evidence**. A vehicle used to flee the scene of a murder could leave tire tracks in the snow, which can be recorded and saved for later comparison with a suspicious vehicle. Casting is also used to record dental characteristics of a body and compare these characteristics with known dental records in order to make a proper **identification**.

The choice of casting material depends on the mark to be copied and the surface on which it is found. For most toolmarks, a dental cast polymer is used. It consists of two pastes mixed together right before the cast is taken. Once mixed together, the paste is applied onto the mark and allowed to dry before being removed. With tire tracks or shoeprints, usually a plaster, such as plaster of Paris, is used. This kind of casting material does not provide as many details as the dental polymer, but can cover a bigger surface and will dry very well over surfaces such as soil. On snow, the use of plaster is not ideal, and molten sulfur offers a much better cast. Sulfur is heated until it liquefied and then poured onto the trace. As soon as the sulfur touches the cold snow, it immediately hardens and takes the shape of the print.

SEE ALSO Crime scene investigation; Microscope, comparison.

A plaster cast of the remains of a child incinerated in a garden after Vesuvius's eruption in 79 A.D. in Pompeii, Italy.

Cast-off blood

A moving source of **blood**, such as a bleeding victim or a blood-stained weapon, can give rise to cast-off blood—that is, droplets of blood flung from the object so as to make a trail of blood where it lands. Such bloodstain patterns can be very informative about the nature of an attack. Forensic scientists distinguish two types of cast-off blood dependent on the kind of movement producing it. In swing cast-off, the blood droplets come from an arcing motion of a weapon like a piece of wood or maybe the bloody hands of the attacker or victim. Cessation cast-off arises when the motion of a source of blood is suddenly arrested; the impact of a weapon with the victim is a typical example.

The laws of physics account for the phenomenon of cast-off blood. Wet blood tends to move to the end of an object, where it pools. Depending on the shape of the object, there may be one or more pools of blood ready to be cast off. If the momentum—product of mass and velocity—of the object can overcome the surface tension making the pool of blood cling to the surface, then the blood is cast off in a series of spherical droplets.

Swing cast-off is, in theory, more likely to occur during a forward swing because more momentum is gathered during this phase of motion than in the backward swing. But the situation is a bit more complex than this; in practice, more cast-off is seen in a backward swing, simply because more blood is available. Once the forward swing begins, most of the blood has already been cast-off. In cessation cast-off, the deceleration of the arresting impact transfers force to the blood. It is then cast-off in a pattern not unlike that seen in impact spatter, which is caused by a force such as kicking or beating applied directly to wet blood.

The size of the droplets of cast-off blood depends upon many factors such as the shape and surface of the object, its velocity, and the amount of blood it is carrying. Long, relatively light weapons create more cast-off staining than shorter, heavier weapons. The blood is usually flung away from the arc of movement, which means that it tends to land on nearby surfaces, rather than on the attacker. The resulting **cast-off trails** may help the investigator to deduce how the attack took place.

SEE ALSO Blood; Blood spatter; Bloodstain evidence.

Cast-off trails

Cast-off trails are the bloodstain patterns that are created by **cast-off blood**. When a **blood** source moves, drops slide towards its end and may be flung off if the object is moving fast enough. This is called cast-off blood and it moves away from its source as a spray of droplets. When these land on a nearby surface, a cast-off trail is formed. Analysis of the trails may tell the forensic investigator some key facts about the nature of the attack.

When droplets of cast-off blood land on a surface, they do so in a linear trail described as in-line staining. The actual size of the spherical splashes depends on many factors such as the size and shape of the blood source, which is often the weapon, as well as its velocity and the amount of blood it produces.

Cast-off trails occurring some way from the presumed attack, such as on a ceiling, may be indicative of the use of a long, relatively light weapon. Droplets cast-off from a forward swing of a weapon tend to be smaller than those from a backward swing. Pronounced cast-off, consisting of large drops at some distance from the attack, often indicates the end of a backswing from a weapon. This is a point at which particularly large forces are applied to any cast-off blood.

The physics of the trajectory of cast-off blood is quite complex. Generally, the droplets are flung at any angle from radial to tangential to the arc along which the source is moving. This means that the cast-off trail is usually found outside the arc of swing and the attacker is protected from it. One exception can occur, however, when the attacker is kneeling, and cast-off trails might be found on the lower leg. Sometimes cast-off trails are also found on the attacker's back.

There are so many factors affecting the nature of a cast-off trail that the investigator has to take great care in its interpretation. Nevertheless, the patterns can often provide some useful information. For instance, the minimum number of blows in an attack might be estimated from looking at the number of trails of in-line staining on a surface. Geometric analysis of the trails might also help assess the location of the attack.

SEE ALSO Blood; Blood spatter; Bloodstain evidence.

Catalyst

A catalyst is any agent that functions to speed up a reaction or process without being used up or changed itself.

In chemical reactions, molecules are changed by moving or rearranging atoms or clusters of atoms. For each reaction, to achieve these chemical transitions from one molecule to an altered molecule, a certain amount of energy is normally required to prepare the molecule to undergo change. This is referred to as the activation energy. Activation energy can be thought of as a barrier that prevents molecules from changing from one form to another.

In a chemical reaction, catalysts function to hold a molecule in a certain position or influence the strength of the individual chemical bonds that undergo change during the reaction. Catalysts speed up reactions by lowering the activation energy necessary for the reaction to take place. In living systems, most chemical reactions are catalyzed by proteins called enzymes.

Catalysts can be homogeneous or heterogeneous. A homogeneous catalyst is one that exists in the same phase (gas, liquid, or solid) as the reacting chemical. In biology, for example, enzymes are distributed in the liquid environment inside of cells, and the reacting chemicals are dissolved in the liquid state there as well. In contrast, heterogeneous catalysts exist in a different physical state than the reacting chemicals. For example, in automobiles, the catalytic converter is a solid phase platinum-based catalyst found in the exhaust system, but the reacting chemicals are found in the exhaust gases that pass through after combustion of the gasoline.

Catalysts can be slowed when various inhibitors or poisons are present. Inhibitors are agents that physically interact with the surface of a catalyst to slow or interfere with a chemical reaction. Often, molecules that act as inhibitors for a certain catalyst have shapes and structures very close to the chemical that normally interacts with the catalyst. The inhibitors differ chemically from the reacting chemical, however, so that they are unable to be chemically altered by the normal action of the catalyst. In the case of enzymes, specific inhibitors may often be used in drugs, such as the popular statin drugs used to lower cholesterol. In the example of the catalytic converter, heavy metals such as lead function as poisons by irreversibly combining with the catalytic surface of the platinum, destroying its catalytic properties.

Among the many catalysts used in forensic testing, scientists use inorganic catalysts in the analysis of paint samples and biological catalysts when analyzing **DNA**.

SEE ALSO Chemical equations; Endothermic reaction; Exothermic reactions.

CCTV SEE Closed-Circuit Television (CCTV)

CDC SEE Centers for Disease Control and Prevention (CDC)

Centers for Disease Control and Prevention (CDC)

The Centers for Disease Control and Prevention (CDC) is a federal agency primarily focused on protecting public health and safety. The CDC was founded in 1946 and is organized under the U.S. Department of Health and Human Services. The agency's headquarters are located in Atlanta, Georgia. Various programs of the CDC are directed toward disease prevention, controlling the spread of disease, promotion of good health practices, and public education to improve health. More recently, preparedness for health threats and **bioterrorism** have become key activities of the CDC. Forensic scientists are involved in almost all departments of the DCD, from identifying the **cause of death** during a disease outbreak, to supplying data and testimony at legal proceedings about injury trends and environmental or other health hazards.

The annual budget for operations within the CDC is just under $8 billion, including approximately $5 billion for primary CDC activities, and an additional $3 billion for the Agency for Toxic Substances and Disease Registry (ATSDR), childhood **vaccines**, and terrorism programs. Two broad areas of spending are in health promotion and prevention of disease, and in preparedness for health threats and terrorism.

The CDC employs more than 8,500 people within the United States, approximately 65% of whom are located in the Atlanta area with less than 20% at the primary headquarters. More than 100 employees of the CDC are stationed overseas in 45 different countries at any given time.

There are seven different National Centers within the CDC including:

- The National Crenter on Birth Defects and Developmental Disabilities provides national leadership for preventing birth defects and developmental disabilities and for improving the health and wellness of people with disabilities.
- The National Center for Chronic Disease Prevention and Health Promotion works toward prevention of premature death and disability from chronic diseases and promotion of healthy lifestyles.
- The National Center for Environmental Health focuses in the prevention and control of disease and death resulting from environmental agents.
- The National Center for Health Statistics is a key national resource that provides statistical information to guide actions and policies to improve health.
- The National Center for HIV, STD, and TB Prevention engages in prevention and control of human immunodeficiency virus infection, sexually transmitted diseases, and tuberculosis.
- The National Center for Infectious Diseases is primarily concerned with the prevention of illness, disability, and death caused by infectious agents (bacteria, viruses, and other organisms) in the United States and around the world.
- The National Center for Injury Prevention and Control works to prevent death and disability from injuries that are not work-related, including both acts of violence and unintentional causes.

The CDC also operates a National Immunization Program (NIP), providing leadership for planning, organizing, and implementation of immunization activities across the country. Primary activities within the NIP include consultations, training, statistical support, promotion, education, health monitoring, and technical services to assist health departments with immunization related services.

The Epidemiology Program Office at the CDC operates to strengthen the public health system through health monitoring, and provides national and international support for such public health efforts through scientific communications, consultation in epidemiology and statistics, and by training experts in disease surveillance, epidemiology, applied public health, and prevention effectiveness.

The Public Health Practice Program Office at the CDC attends primarily to four elements of public health practice: the public health workforce, organi-

Scientist at the Special Pathogens Branch of the Center for Disease Control processes SARS specimens. The CDC is part of a global collaboration to address the continuing emergence of the SARS virus. © CDC/PHIL/CORBIS

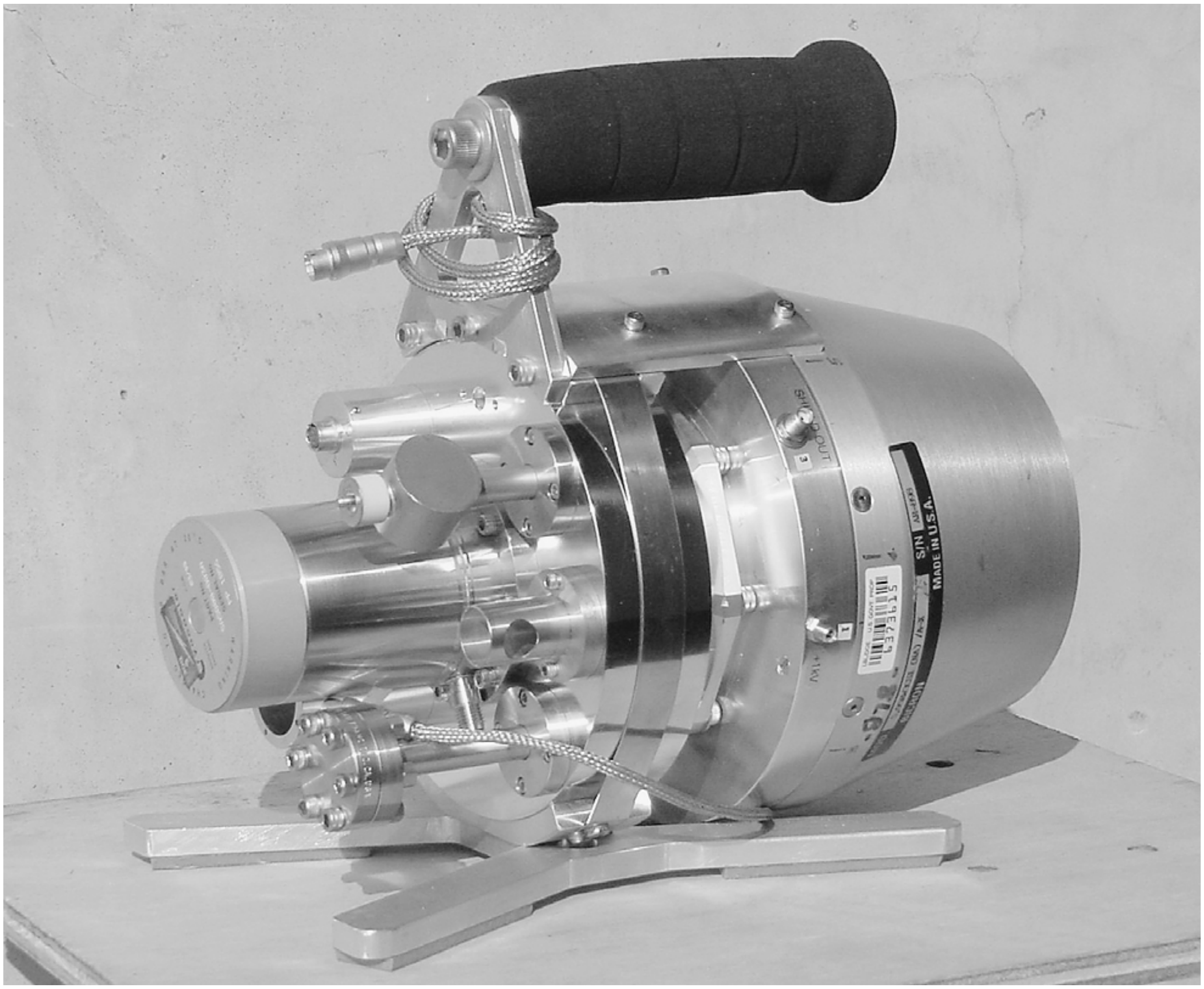
zational effectiveness, the scientific capacity of public health laboratories, and the systems that manage public health information and knowledge.

The National Institute for Occupational Safety and Health (NIOSH) is an institute within the CDC that serves as the primary government-sponsored agency responsible for conducting research and making recommendations for the prevention of work-related injuries and illnesses. Occupational injuries number in the millions each year in the United States, and thousands of deaths due to occupational injuries occur each year, with an annual cost of $40 billion. Additionally, work-related diseases result in nearly 50,000 deaths each year. NIOSH, and its sister organization in the Labor Department, the Occupational Safety and Health Administration (OSHA), were created by the U.S. Congress in 1970. While OSHA plays a more regulatory role in monitoring and enforcing safety standards, NIOSH provides research, training, education, and information directed toward the improvement of occupational safety and **identification** of potential hazards.

The Agency for Toxic Substances and Disease Registry (ATSDR) is an adjunct CDC agency focused on critical health assessment work related to toxic waste sites, and improving the health consequences of related exposures. ATSDR serves the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and disease related to toxic substances.

The CDC has identified a number of challenges and future programs will be developed to meet these challenges. This includes enhancing the extent to which science is applied to improving health, prevention of violence and unintentional injury, health and safety needs of a changing workforce, utilization of new technologies to provide credible health information, protection against the threats of bioterrorism and newly emerging infectious diseases, elimination of racial and ethnic health disparities, fostering safe and healthy environments, and promoting good health globally.

SEE ALSO Bioterrorism; Epidemiology; Toxicology.



A 10-pound, battery-powered hand-held detector that brings state-of-the-art radiation spectrometry anywhere radioactive materials are found, including inside a dirty bomb.

Chemical and biological detection technologies

A well-recognized national security issue is the detection of chemicals and either biological agents or their components (i.e., **toxins**). For example, the inability to rapidly inspect mailed letters for the presence of **anthrax spores** provided a route for the targeting of the mail with infectious microorganisms in the United States in 2001. This demonstration has spurred development of more sophisticated, accurate, and rapid detection technologies. Aside from national security concerns, detection of chemical and biological compounds is important in a forensic investigation.

X-ray examination has long been of value in scanning luggage at airports. The same technology can be used locate objects hidden inside other objects. As well, newer x-ray technology enables the discrimination of organic from inorganic objects. Most of the x-ray beam is reflected back immediately upon encountering an object. Some of the radiation, however, passes through the object. By analyzing the beams that actually penetrate through an object, information on the object's composition is provided. Another version sends two different x rays of different wavelengths through an object. The different beams can distinguish between organic objects, such as food and paper, and inorganic objects.

A chemical detection technology known as gas **chromatography** has been sped into routine use in airports since the U.S. terrorist attacks of September 11, 2001. The different chemicals present on a cloth that is swiped over an object can be separated based on their different preference for the gas mixture that is pumped through the sample chamber. A target chemical (i.e., an explosive) is detected within seconds.

Chemical detection technologies have also been adapted for use "in the field," such as by United Nations inspectors deployed in Iraq beginning in November 2002, to the presence of missiles that were supposedly destroyed by the Iraqi government in the mid-1990s. These portable technologies are beginning to find their way into forensic use.

Sound can also be used to detect chemicals. For example, the acoustic wave sensor uses a quartz surface to convert incoming sound waves into electrical signals. Over a dozen different chemicals can be detected within seconds, even from biological sources. In another sound-based technique, called acoustic resonance, the pattern of vibrations when sound waves are sent inside an object can reveal whether the object is filled with a solid or a liquid, and even the type of chemical present.

Light is another means of chemical detection. The use of light is called **spectroscopy**. Mass spectroscopy determines the mass of proteins, which is important in determining the identity of the chemical or biological agent. Matrix-Assisted Laser Desorption/Ionization Mass Spectroscopy (MALDI-MS) can identify proteins that are unique to *Bacillus anthracis* (the cause of anthrax) and *Yersinia pestis* (the cause of plague). Raman spectroscopy measures the change in the wavelength of a light beam by the sample molecules. Optical spectroscopy measures the absorption of light by the chemical groups and the subsequent emission of light by the same groups as the identification method.

The ability to detect genetic sequences that are unique to certain bacteria (**gene** probing) has been exploited to develop genetically based microbial detection methods. The best example of gene probing is the **polymerase chain reaction** (**PCR**), which can enzymatically detect a target stretch of genetic material and rapidly amplify that region to detectable levels. Handheld PCR detectors (i.e., Handheld Advanced **Nucleic Acid Analyzer**, or HANAA), used in the 2002–2003 inspections of Iraqi facilities by United Nations officials, are already being exploited in law enforcement.

Biological detection devices can monitor the surrounding air at regular intervals. Air is automatically drawn into the device and analyzed for target genetic sequences using the PCR technology. The results can be electronically relayed to a central database for analysis and shared with other law enforcement agencies.

Another biological technology utilizes antibodies that are produced in response to the presence of a specific microorganism. Tests are available that detect *Bacillus anthracis*, *Clostridium botulinum*, viruses (e.g., **smallpox**), and chemicals (e.g., **ricin**) in minutes.

Some older biological detection technologies still prove reliable in forensic analyses. Growth of microorganisms on artificial food sources (media) produces populations called colonies. A medium can be selected that produces colonies that have a distinctive appearance and color. Gel **electrophoresis** separates differently sized pieces of genetic material or other microbial components (e.g., protein) into bands. The banding pattern can be used to identify the microorganism. Finally, chromatography separates compounds from one another based on their differing speed of movement through a gas or a liquid mixture.

SEE ALSO Aflatoxin; Bacterial biology; Bioterrorism; Chemical warfare.

Chemical Biological Incident Response Force, United States

The Chemical and Biological Incident Response Force (CBIRF) is a unit of the United States Marines devoted to countering chemical or biological threats at home and abroad. Activated in 1996, the unit serves a number of protective functions. Since the terrorist bombings of September 11, 2001, its prominence has increased dramatically. Now part of the 4th Marine Expeditionary Brigade (MEB), it has performed homeland security functions that included the removal of suspected toxic agents from House and Senate office buildings during a rash of **anthrax** incidents that followed the September terrorist attacks in 2001. CBIRF is a precursor to investigative efforts of forensic experts.

Chemical agents have been a widespread threat since 1915, when first used by German forces on the Eastern Front in World War I. Soon the British developed their own chemical weapons, and the age of **chemical warfare** began, forever altering the battlefield equation. Both military and civilian personnel are increasingly vulnerable to chemical attacks, as evidenced by use of chemical weapons by Saddam Hussein on Kurdish civilians, use by both Iran and Iraq during their prolonged war in the 1980s, and use during the 1994 and 1995 attacks by Aum Shinrikyo (a Japanese cult) that released deadly **sarin gas** into the Tokyo subways, the latter of which killed 12 civilians.

U.S. Marines participate in a biochemical attack simulation in conjunction with the New York Fire Department, 2003.

On June 21, 1995, partly in response to the Aum Shinrikyo attacks, as well as the Oklahoma City bombing on April 19 of that year, the administration of President William Jefferson Clinton issued Presidential Decision Directive 39, United States Policy on Counterterrorism. The directive called for a number of specific efforts to deter terrorism in the United States, as well as that against Americans and allies abroad. In response to the need for a response team to deal with chemical and biological threats, the United States Marine Corps established the Chemical Biological Incident Response Force (CBIRF) on April 4, 1996.

In a 1999 article in the Marine Corps magazine *Leatherneck*, the CBIRF was described thus: "It's new, it's unique to the Armed Services, and right now, it's the only quick reaction force in the world equipped to help in the aftermath of a chemical, biological, or radiological (nuclear) attack." In the words of a force protection element commander for CBIRF, "We are a consequence management force. Our mission is to respond, to come in and save lives. We bring the full package: self-contained, expeditionary, and task-organized."

During the spring and early summer of 1996, CBIRF was deployed for **training** in a variety of environments throughout the United States. Its members closely studied the bombing that took place at Centennial Olympic Park in Atlanta on the night of July 27, and practiced coordinating a response with local fire and police. They also undertook an experiment at The Citadel, a military college in Charleston, South Carolina, where CBIRF personnel acted to control lethal agents released by a mock chemical weapons plant. Moving beyond training to real-world situations, CBIRF provided security for President Clinton's second inauguration in January 1997, and for the Summit of Eight in Denver, Colorado, that following summer.

In the aftermath of the September 11, 2001, terrorist attacks on the United States, CBIRF's mission became incorporated into the 4th MEB, along with the Marine Security Force Battalion, the Marine Security Guard Battalion, and the new anti-terrorism battalion. (The latter had evolved from the 1st Battalion, 8th Marines, that had been hit in the 1983 terrorist bombings of United States Marine barracks in Lebanon.) In December 2001, CBIRF sent a 100-member initial response team into the Dirksen Senate Office Building alongside Environmental Protection Agency (EPA) specialists to detect and remove anthrax. A similar mission was undertaken at the Longworth House Office Building in October, during which time samples were collected from more than 200 office spaces.

SEE ALSO Anthrax, investigation of the 2001 murders; Chemical warfare; Oklahoma bombing (1995 bombing of Alfred P. Murrah building); Sarin gas; September 11, 2001, terrorist attacks (forensic investigations of).

Chemical equations

Chemistry is a part of **forensic science**. By studying the reactions that occur during various tests, the forensic scientist can receive clues about the nature of the compound under study. Often, knowledge of the nature of the chemical reactions is helpful. This knowledge comes from the chemical equation that describes the reaction.

Chemical equations reveal the chemical species involved in a particular reaction, the charges and weight relationships among them, and how much heat a reaction generates. Equations define the beginning compounds, called reactants, and the ending compounds, called products, and which direction the reaction is going.

It is fairly difficult to take a few chemical compounds and derive chemical equations from them, because many variables need to be determined before the correct equations can be specified. However, to look at a chemical equation and know what it really means is not as difficult.

In general, reactants are placed on the left-hand side of the equation, and the reaction products are shown on the right. The symbol "$\rightarrow$" indicates the direction in which the reaction proceeds. If the reaction is reversible, the symbol "$\rightleftarrows$" should be used to show that the reaction can proceed in both the forward and reverse directions. Δ means that heat is added during the reaction, and not equal implies that heat escapes while produced. Sometimes, Δ is replaced by "light" (to initiate reactions) or "flame" (for combustion reactions.) Instead of showing the symbol Δ, at the same place we may just indicate the operating temperature or what enzymes and catalysts are needed to speed the reaction.

Each chemical species involved in an equation is represented by chemical formula associated with stoichiometric coefficients (numerical measures showing relationships between reactants and products in a chemical reaction). For instance, a, b, c, and d are the stoichiometric coefficients for A, B, C, and D, respectively.

The chemical equation needs to be balanced, that is, the same number of atoms of each "element" (not compounds) must be shown on the right-hand side as on the left-hand side. If the equation is based on an oxidation-reduction reaction which involves electron transfer, the charges should also be balanced. In other words, the oxidizing agent gains the same number of electrons as are lost by the reducing agent. For this reason, we must know the oxidation numbers for elements and ions in chemical compounds.

Because the stoichiometric coefficients are unique for a given reaction, chemical equations can provide us with more information than we might expect. They tell us whether or not the conversion of specific products from given reactants is feasible. They also tell us that explosive or inflammable products could be formed if the reaction was performed under certain conditions.

SEE ALSO Analytical instrumentation; Inorganic compounds.

Chemical Safety and Hazard Investigation Board (USCSB), United States

The United States Chemical Safety and Hazard Investigations Board (USCSB) is a federal agency formed to identify the causes of chemical accidents. In the event of a fatality (or fatalities) caused by a chemical incident, a forensic investigation often includes experts from this agency.

Created in 1990 as part of an amendment to the Clean Air Act, the USCSB did not begin functioning until it received funding in 1998. Although its purpose overlaps that of other federal agencies, notably the Occupational Safety and Health Administration (OSHA), the Environmental Protection Agency (EPA), and the **National Transportation Safety Board** (**NTSB**), the USCSB differs from these organizations in that it does not have the power to make or enforce rules affecting the routine day-to-day activities of businesses. Instead, the USCSB makes a unique contribution to the protection of workers, the public, and the environment by investigating chemical accidents in the country and attempting to prevent future mishaps. The only regulations put into place by the fact-finding agency involve the reporting of chemical incidences.

The establishment of the Washington, D.C.-based USCSB is a result of the belief that existing hazard investigation agencies, like OSHA, EPA, and NTSB, focus on violations of existing rules while ignoring factors that contribute to a chemical accident, but which do not constitute a violation of existing rules and regulations. By creating this independent, scientific, investigatory agency and modeling it after the NTSB, Congress hoped to produce fuller accident reports that could then be used to formulate new regulations and policies to prevent future dangerous chemical spills and explosions. The amended Clean Air Act of 1990, which gave birth to the USCSB, directs the board to investigate and report on the circumstances and the probable causes of chemical incidents resulting in a fatality, serious injury, or substantial property damages; to recommend measures to reduce the likelihood or the consequences of such accidents and propose corrective measures; and, lastly, to establish regulations for reporting accidental releases. The board has no enforcement authority, does not issue fines or penalties, and essentially plays a very limited regulatory role.

Accidental releases of toxic and hazardous chemicals occur frequently and often have serious consequences. The USCSB is notified of every chemical release in the country and then decides which accidents to investigate. The agency is required to coordinate its activities with OSHA, NTSB, and EPA. However, when an accident involves transportation, NTSB is the lead agency. Board members, appointed by the president to five-year renewable terms and confirmed by the Senate, are ultimately responsible for the conduct of investigations and the content of accident reports. Staffers and contractors conduct the actual investigations, which typically involve extensive site visits, **evidence** collection, and analytical work. Investigators may issue brief summaries or detailed investigative reports. Some investigations may conclude without the issuance of any report. Accident reports must be approved by a majority vote of the five board members before they are issued. Initially, the USCSB issued only a handful of reports, in part because of insufficient staffing but also as a result of serious disagreements among board members. Staff levels have since been raised and the board has established a more harmonious working arrangement. The agency is in the process of developing the Chemical Incidents Reports Center, an online database of chemical incidents that have occurred worldwide, in the hopes that the site may inspire researchers to investigate the incidents that the USCSB cannot examine for lack of resources.

The rise in global terrorism and the corresponding fear of a terrorist attack that utilizes chemicals makes the USCSB an important component of the United States Department's Homeland Security agency. It also provides **training** for forensic investigators.

By identifying hazardous practices, the agency promotes preventive actions by the public and private sectors that may make it more difficult for terrorists to create chemical incidents.

SEE ALSO Chemical and biological detection technologies; Chemical Biological Incident Response Force, United States; Chemical warfare; NTSB (National Transportation Safety Board).

Chemical warfare

Chemical warfare involves the aggressive use of bulk chemicals that cause death or grave injury. These chemicals are different from the lethal chemical compounds that are part of infectious bacteria or viruses. The latter constitute biological warfare.

Forensic examinations are a part of chemical warfare, especially when the nature of the attack is unclear. Examination of the scene of the incident and of the victims provide clues that are used to determine the nature of the attack.

A number of compounds cause choking or irritation of lung tissue. Examples include chlorine, phosgene (carbonyl chloride), diphosgene, chloropicrin, ethyldichloroarsine, and perflurorisobutylene.

Chlorine gas is suffocating and quickly burns tissues in the nose, mouth, and lungs. The burned tissue can die and slough off, causing lasting damage. Chlorine gas dissipates in the air very quickly. If exposure is not too long, than damage can be minor. In contrast, the compound called disphosgene is a liquid at room temperature, and so persists much longer.

Blister agents cause the formation of large and painful blisters on the skin. Eye and lung tissue can also be damaged. A well-known example of a

German storm troopers emerging from a thick cloud of phosgene gas laid down by German forces as they attack British trench lines.

blistering agent dating from World War I is **mustard gas**. The damage to cells of the skin cause blistering up to 24 hours after exposure to mustard gas. These blisters take a long time to heal and can send the body into a lethal shock reaction.

Other examples of blistering agents include nitrogen mustard, lewisite, and phenyldichloroarsine. The latter compound is a liquid, which can be sprayed onto an enemy or released from a balloon, helicopter, or airplane.

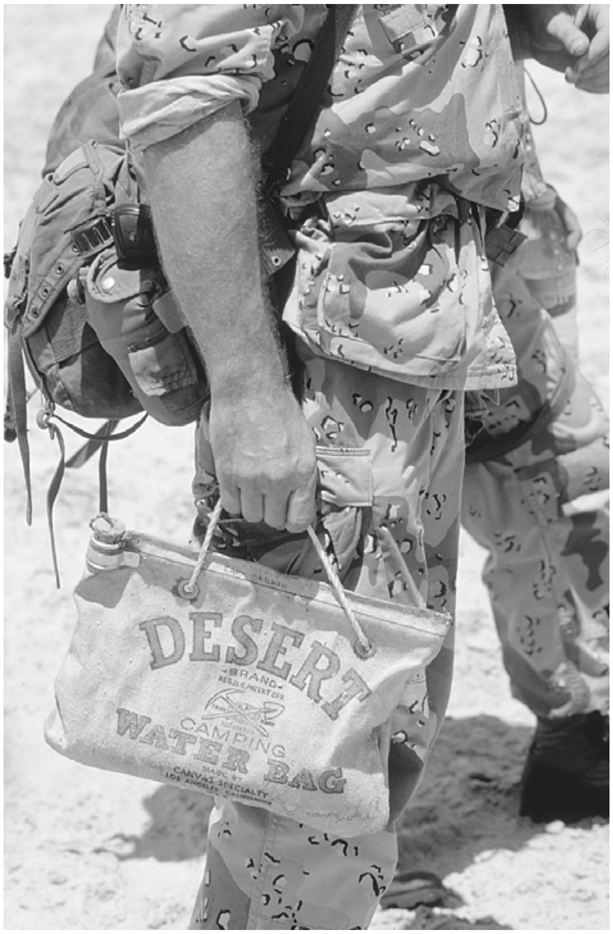
Blood agents interfere with the body's ability to transport oxygen in the bloodstream. This is done by either blocking the use of oxygen by cells in the body or by blocking the ability of the blood to take up the oxygen. Examples include hydrogen cyanide (also called prussic acid), cyanogen chloride, arsine, carbon monoxide, and hydrogen sulfide.

Hydrogen cyanide is initially a liquid at room temperature, but it quickly evaporates. This compound is noteworthy in recent world history, as it was used by Iraq in 1988 on an attack on the Kurdish town of Halabja during the Iran-Iraq war. Because of its past use by Iraq, hydrogen cyanide was one of the major concerns of United Nations inspectors who inspected various facilities in Iraq during the winter of 2003.

Compounds such as arsine and carbon monoxide destroy the ability of the **hemoglobin** component of the blood to bind oxygen. Arsine does this by destroying the red blood cells. Carbon monoxide binds to hemoglobin, blocking the binding of oxygen.

Nerve agents interfere with the body's transmission of nerve impulses. This is done by disrupting the activity of a chemical called acetyl cholinesterase, which functions to bridge the gap between adjacent nerve cells, permitting an electrical nerve signal to pass from one nerve cell to the next.

Nerve agents were first developed in 1936, following the development of organophosphate types of pesticides. The first nerve agent that was made is called **tabun**. It is a member of what is known as the G series of nerve agents. Other G series members are sarin and soman. Sarin is particularly lethal; a small amount absorbed through the skin can kill



During the 1990 Persian Gulf War, a soldier from the 7th Naval Expeditionary Brigade carries a bag of anti-chemical warfare equipment during a chemical warfare simulation. © JACQUES LANGEVIN/CORBIS SYGMA

someone within two minutes. When inhaled, death occurs within 15 minutes. Sarin is infamous as the gas released into the Tokyo subway system by the fringe group Aum Shinrikyo in 1995.

Another series of nerve agents are called the V series. Members of this series—which are commonly abbreviated according to their chemical composition—are more potent than the agents of the G series. As well, they persist longer in the environment. They can, for example, be applied to surfaces like roads as a slime.

Examples of V series agents include VX, VE, VG, and VM. VX is extremely potent; a drop of the liquid absorbed through the skin is lethal within a few hours if treatment is not provided.

Herbicides are chemicals that kill vegetation. Such chemicals are often used in everyday life to keep lawns free of weeds (although more environmentally-friendly alternatives are becoming popular). When used in war, herbicides are weapons of mass destruction to foliage. Destruction of plants and the resulting loss of leaf cover remove much of the concealment for an enemy in a forested area. These philosophies lead to the massive use of Agent Orange by the United States in the Vietnam War in the 1970s. Since that war, the damaging effects of herbicides like Agent Orange and paraquat on the human nervous and immune systems have become evident.

Incendiaries are chemicals that cause fires. In warfare, they are also used to remove vegetation. An infamous incendiary is napalm. Napalm is a mixture of naphthenic acid, coconut fatty acids, and palm oil. In addition to its highly flammable property, napalm absorbs into exposed skin, where it can cause severe burns if ignited.

SEE ALSO Chemical and biological detection technologies; Water contamination.

Childers hostel blaze

In June 2000 the century-old Palace Backpackers Hostel in Childers, Queensland, Australia, was burned to the ground. Fifteen young people of various nationalities lost their lives in the blaze. According to fire and explosion forensic expert Dr. John De Haan, the fire was not accidental.

The chief suspect was Robert Long, an itinerant fruit picker and former hostel resident with a history of mental illness who was said to despise backpackers. He disappeared after the fire and, when police found him hiding in the bush, Long attacked two dog handlers and a police dog with a knife. At the trial, survivors said Long had made various threats during the weeks leading to the fire, including a boast that he would burn the hostel down. One even saw him pour a liquid into a rubbish bin in the vicinity less than two hours before the fire, although this **evidence** was later called into question.

A forensic police officer said he was not able to determine the cause of the fire, but his tests suggested no accelerants had been used. A fire investigator hired by the insurers of the hostel said that in his expert opinion, the speed and intensity of the blaze made it unlikely that electrical malfunctioning or a smoldering cigarette was responsible. But, under cross-examination by Long's lawyer, he did admit that maybe an electrical fault could not be ruled out as the cause.

Firemen inspect the rear of a backpackers' hostel after a fire killed 15 backpackers and left three unaccounted for in Childers in the state of Queensland, Australia, in 2000. © REUTERS/CORBIS

According to Dr. De Haan, the blaze was caused by several fires, lit around the same time, in the television and lounge room of the hostel. Most likely, he said, the fire was started by direct ignition of furniture in the room by an open flame, which could have been a match, cigarette lighter, or candle. Long was found guilty of **arson** and two counts of **murder**.

However, Long was not the only guilty party in this case. Those of the 88 inhabitants of the hostel who survived were fortunate to do so. The old wooden building did not have sprinklers or fire extinguishers, nor were there plans to fit them. The fire alarm system was faulty and had been turned off. Dr. De Haan pointed out that in the first floor room where several of the fatalities occurred, the doors through which escape might have been possible were blocked by bunk beds, a clear fire hazard. Important lessons were learned from the Childers hostel fire requiring the hostel industry to take measures to reduce casualties in case of fire, and stricter safety regulations for backpackers hostels were enacted.

SEE ALSO Accelerant.

Choking, signs of

Determination of the **cause of death** is an important facet of a forensic investigation. Some causes of death are easily apparent. A gunshot wound or stab wound are two such examples. Other causes of death, such as poisoning and choking, can be less obvious. To a skilled investigator, even the less than obvious causes of death will leave telltale clues. Choking is defined as the complete obstruction of the airway. Choking can occur when an excessively large piece of solid food such as a piece of meat is swallowed. The object can become lodged in the airway, plugging the flow of air. Even reflexive gagging may be insufficient to free the obstruction.

Food is a common cause of choking. As well, especially when the victim is in a supine position, vomit can puddle in the airway in sufficient quantity to block air flow. Unless the obstruction can be cleared, air cannot enter the lungs and death can ensue within about four minutes.

Signs of choking are obvious in a conscious person. A victim may be unable to talk, cry out, breathe, or cough. Initially, a person may grasp at their throat, in an instinctive although futile attempt to clear the blockage. As the full comprehension of what is happening dawns, a person can become very anxious and even panicked in behavior. As oxygen limitation becomes accentuated, skin color can change from the normal pinkish hue to blue or dusky. Finally, a loss of consciousness can occur.

Once a person is unconscious and unable to communicate their plight, recognition of the severity of the situation and the application of emergency relief becomes more difficult. All the while, however, oxygen deprivation is causing a loss of brain function. If the airway obstruction is not soon removed, death will result.

In an unconscious or dead victim, another sign of choking is the inability to push air into the lungs when artificial respiration is attempted. This failure is evident by the inability of the lungs to artificially inflate with air and visibly expand when air is blown into the mouth.

In a deceased person, the task then becomes to establish that choking did occur. A forensic investigator will search out eyewitnesses to the choking event. Recollections of the aforementioned behaviors by eyewitnesses provide a clue as to what might have happened. Additionally, a change in skin pallor associated with oxygen deprivation may still be evident in a corpse, such as a bluish tint around the lips.

Observation of the scene around the victim can provide clues. For example, choking may lead to loss of consciousness, causing the victim to fall. A resulting blow to the head on a table or other object can occur. A cut on the scalp, bloodstain near the head, and signs of impact with furniture can all be clues to choking.

A prudent investigator would look for signs of a meal such as food or food debris, plates, and cutlery. Observation of vomit should be taken as at least a suspicion that choking occurred.

When someone is unconscious but still alive, clearance of the airway, either by sweeping of the mouth or modified Heimlich maneuver, is essential. As well, a forensic investigator who suspects choking will attempt to identify and recover the blocking object from the airway.

In both cases the procedure is the same. The mouth is opened by grasping the tongue and lower portion of the jaw between the thumb and fingers, then lifting. With the jaw elevated, the upper portion of the airway is visible. An obstruction in the upper airway can sometimes be swept out of the airway using a hooked index finger.

In the case of a forensic examination of a corpse, if choking is suspected but no object is recovered, it is prudent to probe for an obstruction deeper within the airway upon **autopsy**. **Imaging** techniques such as x rays or CT scanning can also confirm an airway obstruction in a deceased person.

SEE ALSO Antemortem injuries; Asphyxiation (signs of); Crime scene investigation; Death, mechanism of; Hypoxia; Lividity.

Chromatography

Chromatography is a family of laboratory techniques for separating mixtures of chemicals into their individual compounds. The basic principle of chromatography is that different compounds will stick to a solid surface or dissolve in a film of liquid to different degrees. Chromatography is used extensively in forensics, from analyzing body **fluids** for the presence of **illicit drugs**, to fiber analysis, **blood** analysis from a crime scene, and at airports to detect residue from **explosives**.

When a gas or liquid containing a mixture of different compounds is made to flow over such a surface, the molecules of the various compounds will tend to stick to the surface. If the stickiness is not too strong, a given molecule will become stuck and unstuck hundreds or thousands of times as it is swept along the surface. This repetition exaggerates even tiny differences in the various molecules' stickiness, and they become spread out along the "track," because the stickier compounds move more slowly than the less sticky ones do. After a given time, the different compounds will have reached different places along the surface and will be physically separated from one another. Or, they can all be allowed to reach the far end of the separation surface and be detected or measured one at a time as they emerge.

Using variations of this basic phenomenon, chromatographic methods have become an extremely powerful and versatile tool for separating and analyzing a vast variety of chemical compounds in quantities from picograms (10^{-12} gram) to tons.

Chromatographic methods all share certain characteristics, although they differ in size, shape, and configuration. Typically, a stream of liquid or gas (the mobile phase) flows constantly through a tube (the column) packed with a porous solid material (the stationary phase). A sample of the chemical mixture is injected into the mobile phase at one end of the column, and the compounds separate as they move along. The individual separated compounds can be removed one at a time as they exit (or "elute from") the column.

Because it usually does not alter the molecular structure of the compounds, chromatography can provide a non-destructive way to obtain pure chemicals from various sources. It works well on very large and very small scales; chromatographic processes are used both by scientists studying micrograms of a substance in the laboratory, and by industrial chemists separating tons of material.

The technology of chromatography has advanced rapidly in the past few decades. It is now possible to obtain separation of mixtures in which the components are so similar they only differ in the way their atoms are oriented in space, in other words, they are isomers of the same compounds. It is also possible to obtain separation of a few parts per million of a contaminant from a mixture of much more concentrated materials.

In gas-liquid chromatography (now called gas chromatography), the material that separates components is chemically bonded to the solid support, which improves the temperature stability of the column's packing. Gas chromatographs can be operated at high temperatures, so even large molecules can be vaporized and progress through the column without the stationary phase vaporizing and bleeding off. Additionally, since the mobile phase is a gas, the separated compounds are very pure; there is no liquid solvent to remove.

The shapes of chromatographic columns, originally vertical tubes an inch or so (2–3 cm) in diameter, became longer and thinner when it was found that this increased the efficiency of separation. Eventually, chemists were using coiled glass or fused silica capillary tubes less than a millimeter in diameter and many yards long. Capillaries cannot be packed, but they are so narrow that the stationary phase can simply be a thin coat on the inside of the column.

A somewhat different approach is the set of techniques known as "planar" or "thin layer" chromatography (TLC), in which no column is used at all. The stationary phase is thinly coated on a glass or plastic plate. A spot of sample is placed on the plate, and the mobile phase migrates through the stationary phase by capillary action.

In the mid-1970s, interest in liquid mobile phases for column chromatography resurfaced when it was discovered that the efficiency of separation could be vastly improved by pumping the liquid through a short packed column under pressure, rather than allowing it to flow slowly down a vertical column by gravity alone. High-pressure liquid chromatography, also called high performance liquid chromatography (HPLC), is now widely used in industry. A variation on HPLC is supercritical fluid chromatography (SFC). Certain gases (carbon dioxide, for example), when highly pressurized above a certain temperature, become a state of matter intermediate between gas and liquid. These "supercritical fluids" have unusual solubility properties, some of the advantages of both gases and liquids, and appear very promising for chromatographic use.

All chromatographs must have a detection device attached, and some kind of recorder to capture the output of the detector—usually a chart recorder or its computerized equivalent. In gas chromatography, several kinds of detectors have been developed; the most common are the thermal conductivity detector, the flame ionization detector, and the electron capture detector. For HPLC, the UV detector is standardized to the concentration of the separated compound. The sensitivity of the detector is of special importance, and research has continually concentrated on increasing this sensitivity, because chemists often need to detect and quantify exceedingly small amounts of a material.

Within the last few decades, chromatographic instruments have been attached to other types of **analytical instrumentation** so that the mixture's components can be identified as well as separated (this takes the concept of the "detector" to its logical extreme). Most commonly, this second instrument has been a mass spectrometer, which allows **identification** of compounds based on the masses of molecular fragments that appear when the molecules of a compound are broken up.

Absorption chromatography (the original type of chromatography) depends on physical forces such as dipole attraction to hold the molecules onto the surface of the solid packing. In gas chromatography and HPLC, however, the solubility of the mixture's molecules in the stationary phase coating determines which ones progress through the column more

After contaminated cattle feed was traced through the food chain in the Midwest in 1986, a scientist prepares to test a tube of mother's milk by gas chromatography to determine if the amount of Heptachlor in the milk is sufficient to harm babies. © BETTMANN/CORBIS

slowly. Polarity can have an influence here as well. In gel filtration (also called size-exclusion or gel permeation) chromatography, the relative sizes of the molecules in the mixture determine which ones exit the column first. Large molecules flow right through; smaller ones are slowed down because they spend time trapped in the pores of the gel. Ion exchange chromatography depends on the relative strength with which ions are held to an ionic resin. Ions that are less strongly attached to the resin are displaced by more strongly attached ions. Hence the name ion exchange: one kind of ion is exchanged for another. This is the same principle upon which home water softeners operate. Affinity chromatography uses a stationary phase composed of materials that have been chemically altered. In this type of chromatography, the stationary phase is attached to a compound with a specific affinity for the desired molecules in the mobile phase. This process is similar to that of ion exchange chromatography, and is used mainly for the recovery of biological compounds. Hydrophobic interaction chromatography is used for amino acids that do not carry a positive or negative charge. In this type of chromatography, the hydrophobic amino acids are attracted to the solid phase, which is composed of materials containing hydrophobic groups.

Chemists choose the mobile and stationary phases carefully because it is the relative interaction of the mixture's compounds with those two phases that determines how efficient the separation can be. If the compounds have no attraction for the stationary phase at all, they will flow right through the column without separating. If the compounds are too strongly attracted to the stationary phase, they may stick permanently inside the column.

SEE ALSO Analytical instrumentation; Gas chromatograph-mass spectrometer.

Chromosome

A chromosome is a threadlike structure found in the nucleus of most cells. It carries genetic material in the form of a linear sequence of deoxyribonucleic acid (**DNA**). In prokaryotes, or cells without a nucleus, the chromosome represents circular DNA containing the entire genome. In eukaryotes, or cells with a distinct nucleus, chromosomes are much more complex in structure. The function of chromosomes is to package the extremely long DNA sequence. A single chromosome (uncoiled) could be as long as three inches and therefore visible to the naked eye. If DNA were not coiled within chromosomes, the total DNA in a typical eukaryotic cell would extend thousands of times the length of the cell nucleus.

DNA is the genetic material of all cells and contains information necessary for the synthesis of proteins. DNA is composed of two strands of nucleic acids arranged in a double helix. The nucleic acid strands are composed of a sequence of nucleotides. The nucleotides in DNA have four kinds of nitrogen containing bases: adenine (A), guanine (G), cytosine (C), and thymine (T). Within DNA, each strand of nucleic acid is partnered with the other strand by bonds that form between these nucleotides. Complementary base pairing dictates that adenine pairs only with thymine, and guanine pairs only with cytosine (and vice versa). Thus, by knowing the sequence of bases in one strand of the DNA helix, you can determine the sequence on the other strand. For instance, if the sequence in one strand of DNA were ATTCG, the other strand's sequence would be TAAGC.

DNA functions in the cell by providing a template by which another nucleic acid, called ribonucleic acid (RNA), is formed. Like DNA, RNA is also composed of nucleotides. Unlike DNA, RNA is single stranded and does not form a helix. In addition, the RNA bases are the same as in DNA, except that uracil replaces thymine. RNA is transcribed from DNA in the nucleus of the cell. Genes are expressed when the chromosome uncoils with the help of enzymes called helicases and specific DNA binding proteins. DNA is transcribed into RNA.

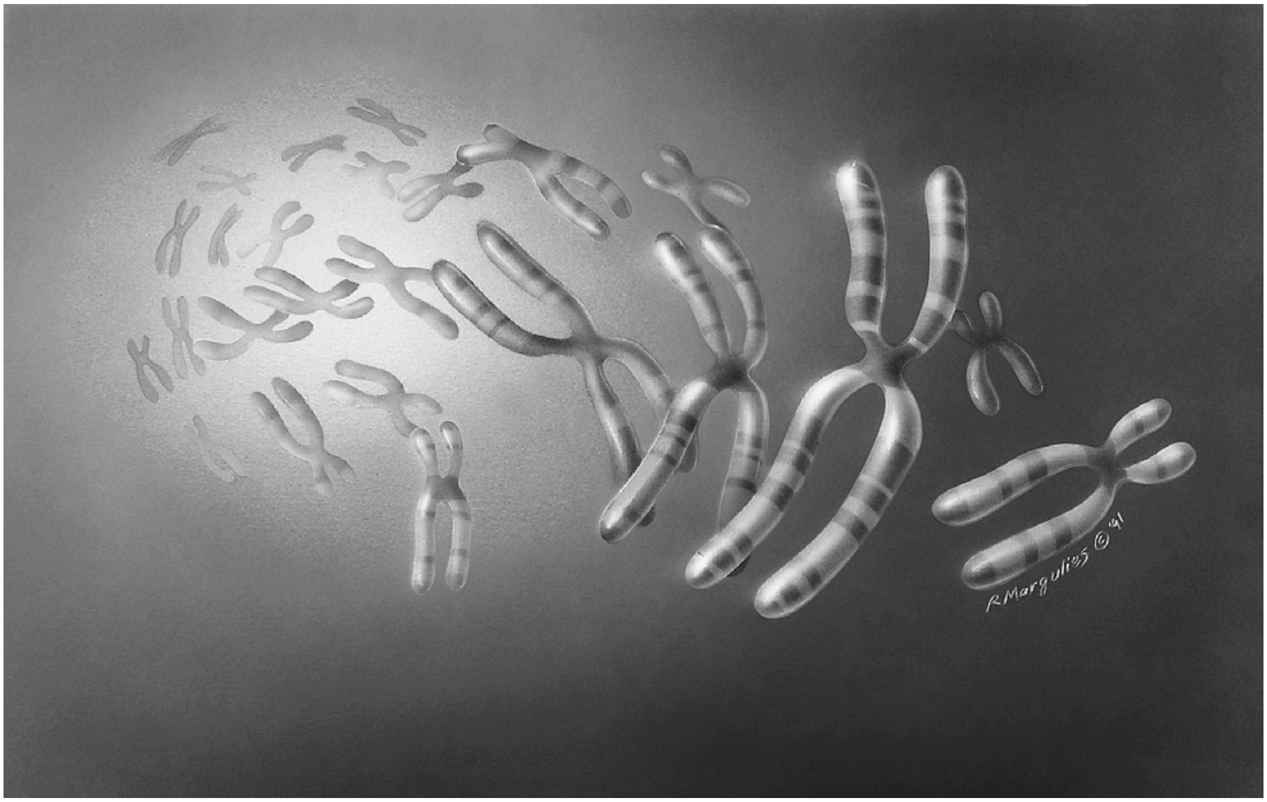
Newly transcribed RNA is called messenger RNA (mRNA). Messenger RNA leaves the nucleus through the nuclear pore and enters into the cytoplasm. There, the mRNA molecule binds to a ribosome (also composed of RNA) and initiates protein synthesis. Each block of three nucleotides, called codons, in the mRNA sequence encodes for a specific amino acid, the building blocks of a protein.

Genes are part of the DNA sequence called coding DNA. Noncoding DNA represents sequences that do not have genes and only recently have been found to have many new important functions. Out of the 3 billion base pairs that exist in the human DNA, there are only about 40,000 genes. The noncoding sections of DNA within a **gene** are called introns, while the coding sections of DNA are called exons. After transcription of DNA to RNA, the RNA is processed. Introns from the mRNA are excised out of the newly formed mRNA molecule before it leaves the nucleus.

The human genome (which represents the total amount of DNA in a typical human cell) has approximately 3×10^9 base pairs. If these nucleotide pairs were letters, the genome book would number over a million pages. There are 23 pairs of chromosomes, for a total number of 46 chromosomes in a diploid cell, or a cell having all the genetic material. In a haploid cell, there is only half the genetic material. For example, sex cells (the **sperm** or the egg) are haploid, while many other cells in the body are diploid. One of the chromosomes in the set of 23 is an X or Y (sex chromosomes), while the rest are assigned numbers 1 through 22. In a diploid cell, males have both an X and a Y chromosome, while females have two X chromosomes. During fertilization, the sex cell of the father combines with the sex cell of the mother to form a new cell, the zygote, which eventually develops into an embryo. If the one of the sex cells has the full complement of chromosomes (diploidy), then the zygote would have an extra set of chromosomes. This is called triploidy and represents an anomaly that usually results in a miscarriage. Sex cells are formed in a special kind of cell division called meiosis. During meiosis, two rounds of cell division ensure that the sex cells receive the haploid number of chromosomes.

Chromosomes can be visible using a microscope just prior to cell division, when the DNA within the nucleus uncoils as it replicates. By visualizing a cell during metaphase, a stage of cell division or mitosis, researchers can take pictures of the duplicated chromosome and match the pairs of chromosomes using the characteristic patterns of bands that appear on the chromosomes when they are stained with a dye called giemsa. The resulting arrangement is called a karyotype. The ends of the chromosome are referred to as telomeres, which are required to maintain stability and recently have been associated with aging. An enzyme called telomerase maintains the length of the telomere. Older cells tend to have shorter telomeres. The telomere has a repeated sequence (TTAGGG) and intact telomeres are important for proper DNA replication processes.

Karyotypes are useful in diagnosing some genetic conditions, because the karyotype can reveal an aberration in chromosome number or large alterations in structure. For example, Down's syndrome is caused



Chromosomes are a group of thread-like structures contained in the nucleus of a cell and composed primarily of genes, or DNA. Human cells normally have 23 pairs of chromosomes. © R. MARGULIES/CUSTOM MEDICAL STOCK PHOTO. REPRODUCED BY PERMISSION.

by an extra chromosome 21, called trisomy 21. A karyotype of a child with Down's syndrome would reveal this extra chromosome.

A chromosome usually appears to be a long, slender rod of DNA. Pairs of chromosomes are called homologues. Each separate chromosome within the duplicate is called a sister chromatid. The sister chromatids are attached to each other by a structure called the centromere. Chromosomes appear to be in the shape of an X after the material is duplicated. The bottom, longer portion of the X is called the long arm of the chromosome (q-arm), and the top, shorter portion is called the short arm of the chromosome (p-arm).

DNA in chromosomes is associated with proteins and this complex is called chromatin. Euchromatin refers to parts of the chromosome that have coding regions or genes, while heterchromatin refers to regions that are devoid of genes or regions where gene transcription is turned off. DNA binding proteins can attach to specific regions of chromatin. These proteins mediate DNA replication, gene expression, or represent structural proteins important in packaging the chromosomes. Histones are structural proteins of chromatin and are the most abundant protein in the nucleus. In fact, the mass of histones in a chromosome is almost equal to that of DNA. Chromosomes contain five types of these small proteins: H1, H2A, H2B, H3, and H4. There are two of each of latter four histones that form a structure called the octomeric histone core. The H1 histone is larger than the other histones, and performs a structural role separate from the octomeric histone core in organizing DNA within the chromosome.

The octomeric histone core functions as a spool from which DNA is wound two times. Each histone-DNA spool is called a nucleosome. Nucleosomes occur at intervals of every 200 base pairs of the DNA helix. In photographs taken with the help of powerful **microscopes**, DNA wrapped around nucleosomes resembles beads (the nucleosome) threaded on a string (the DNA molecule). The DNA that exists between nucleosomes is called linker DNA. Chromosomes can contain some very long stretches of linker DNA. Often, these long linker DNA sequences are the regulatory portions of genes. These regulatory portions switch genes on when certain molecules bind to them.

Nucleosomes are the most fundamental organizing structure in the chromosome. They are packaged into structures that are 30 nanometers in size and called the chromatin fiber (compared to the 2 nm DNA double helix, and 11 nm histone core). The 30 nanometer fibers are sometimes then further folded into a larger chromatin fiber that is approximately 300 nanometers thick and represented on of the arms of the chromsome. The chromatin fibers are formed into loops by another structural protein. Each loop contains 20,000–30,000 nucleotide pairs. These loops are then arranged within the chromosomes, held in place by more structural proteins. Metaphase chromosomes are approximately 1400 nm wide.

Chromosomes in eukaryotes perform a useful function during mitosis, the process in which cells replicate their genetic material and then divide into two new cells (also called daughter cells). Because the DNA is packaged within chromosomes, the distribution of the correct amount of genetic material to the daughter cells is maintained during the complex process of cell division.

Before a cell divides, the chromosomes are replicated within the nucleus. In a human cell, the nucleus just prior to cell division contains 46 pairs of chromosomes. When the cell divides, the sister chromatids from each duplicated chromosome separate. Each daughter cell ends up with 23 pairs of chromosomes and after DNA replication, the daughter cells have a diploid number of chromosomes.

In meiosis, the type of cell division that leads to the production of sex cells, the division process is more complicated. Two rounds of cell division occur in meiosis. Before meiosis, the chromosomes replicate, and the nucleus has 46 pairs of chromosomes. In the first round of meiotic cell division, the homologous chromosomes pairs separate as in mitosis (a stage called meiosis I). In the second round of cell division (meisosis II), the sister chromatids of each chromosome separate at the centromere, so that each of the four daughter cells receives the haploid number of chromosomes.

SEE ALSO DNA; DNA databanks; DNA fingerprint; DNA mixtures, forensic interpretation of mass graves; DNA profiling; Evidence; Gene; STR (short tandem repeat) analysis; War forensics.

Circumstantial evidence

Jurisprudence defines **evidence** as any written or oral testimony given under-oath, including documents, records, or physical objects admissible in a court of law, according to established rules of evidence, either to prove or disprove the authenticity of alleged facts, claims, or accusations. Circumstantial evidence is indirect information or secondary facts that allow the reasonable inference of the principal fact, without actually proving that such inference is true. Therefore, circumstantial evidence ideally requires further corroboration through other forms of evidence to prove a fact. All presented evidence will be considered by a jury, or by a judge, depending on the nature of the legal process, to test its relevancy and level of reliability, including the credibility of witnesses. In the United States, until 1975, the decision about which evidence was admissible in court was decided on the basis of judicial precedent (e.g., prior court decisions in similar cases). In the absence of a statutory law on a particular matter, the judge would make the rules. This common law jurisprudence descends from the colonial British legal system.

California was the pioneer American state in the creation of four statutory codes (in 1872): the Civil Code, the Code of Civil Procedure, the Penal Code, and the Political Code, in which the Code of Evidence was also implemented, establishing the necessary standard criteria of importance, validity, and legal weight of different types of evidence for civil and criminal courts. The California Evidence Code has inspired both the federal and other state legislations, in varied degrees, since then. However, only in 1974 did the Congress approve the implementation of the **Federal Rules of Evidence**, proposed by the U.S. Supreme Court in the preceding years.

The purpose of evidence in courts is to prove or disprove the existence of a fact. The level of proof or evidence presented must be solid enough to convince the court that such fact is true beyond a reasonable doubt, especially in **criminal trials**. In **civil trials** however, the standard of proof is often based on whether the true existence of the fact is more probable than not. Circumstantial evidence, therefore, carries different weight in criminal and civil trials.

Circumstantial evidence, in spite of its indirect nature, may be of great value, for instance, in highlighting inconsistencies between the behavior of a suspect and his allegations, thereby "filling in the blanks" of a probable crime scenario. For instance, although a suspect was unseen at the crime scene, the tire prints found on the scene match those of his car and a similar car was seen in the vicinity of the crime scene around the time the crime was committed. Or, sometime before the crime, the victim may have told a friend that they were afraid of the suspect, or a neighbor overheard a bitter and violent argument between the victim and the suspect in the recent past. Circumstantial evidence may be presumptive and inconclusive, admitting rebuttal by the other part, or, on the contrary, its quantity and pattern may be strong enough to substantiate a prosecution where other types of evidence are scarce and by themselves inconclusive.

One recent example of use of circumstantial evidence was the trial of Scott Lee Peterson, where the evidence presented was essentially circumstantial. A day after reporting that his eight-months pregnant wife was missing (December 23, 2002), Peterson was considered a suspect, because investigators found he had several extra-marital affairs since his marriage, and had recently been in a relationship with another woman. Petersen alleged that at the time of his wife's disappearance he was fishing at the Berkeley Marina, and was innocent. In April 2003, the remains of an unborn baby and the partial remains of a woman were found on the shores of the San Francisco Bay. **Autopsy** and other forensic tests identified the remains as those of his wife and her baby, although where, how, and when she died was not specifically determined. The **FBI** and forensic teams conducted extensive investigations at the Petersons' house, as well as searching Scott Peterson's boat, truck, toolbox, clothes, and personal objects, in search of forensic evidence of violence such as bloodstains or weapons. No physical piece of forensic evidence was identified that could link Peterson to the **murder** of his wife.

Although the prosecution could not present any **physical evidence** of Peterson's involvement with the crime, and the defense tried to defuse the circumstantial evidence, in November 2004, the jury convicted Scott Peterson of first degree murder for killing the wife "with special circumstances," and of second degree murder for killing his unborn baby. That December, the jury recommended a death sentence for Scott Peterson. In a press conference, the jurors declared that they had found Peterson guilty, in part, because of his demeanor. Circumstantial evidence including Peterson's change in haircut and color immediately after the crime, buying a car in his mother's name, and testimony by his ex-lover that he frequently lied and said he was a widower previous to the crime, weighed heavily with the jury.

One case where forensic evidence supported circumstantial evidence was California vs. Orenthal James Simpson in 1995. Nicole Brown, the ex-wife of famous football player and actor O. J. Simpson, was killed with her friend Ronald Goldman, on June 12, 1994. Evidence from the crime scene pointed to Simpson as a suspect, and he was later arrested for the crime.

The prosecution relied on forensic physical evidence along with circumstantial evidence to build the case against Simpson. Circumstantial evidence included footwear prints at the crime scene that matched Simpson's size, failure to keep an arranged appointment with the police to turn himself in, initiating a two-hour-long highway journey in a white Ford Bronco with police in pursuit, a left-handed glove found among Simpson's belongings that matched a bloody right-handed glove found at the crime scene, a documented history of domestic abuse against Brown, previous telephone calls made by the victim in which she relayed fears of being physically injured by Simpson to the police, and a letter from Simpson given to a friend that indicated an intention to leave the country in disguise.

Forensic evidence supported much of the circumstantial evidence. More than 40 bloodstains were tested for **DNA** fingerprinting, and each could be linked with either the victims and/or to Simpson. These samples were taken from the primary crime scene area, the secondary scene area, Simpson's Ford Bronco, and from Simpson's home. DNA profiles that matched the victims were found in **blood** taken from the crime scene and from Simpson's Bronco.

In spite of the circumstantial evidence, often supported with forensic evidence, the jury declared O. J. Simpson not guilty of murder in 1995. A civil jury, however, used much of the same evidence to convict Simpson on a civil court in 1997, and awarded the victim's families over 30 million dollars in damages.

In some countries, circumstantial evidence in the absence of other more solid testimonial and material evidence is not admissible in criminal courts. Circumstantial evidence is considered relevant to a case as an explanatory complement to existing testimonial and/or forensic evidence of indisputable accuracy. Controversy about the two cases above described continues among jurists and other experts, due to the perceived quality and relevance of evidence presented in each of those trials.

SEE ALSO Artificial fibers; Blood; Bloodstain evidence; Civil court, forensic evidence; CODIS: Combined DNA Index System; Crime scene investigation; Crime scene reconstruction; DNA fingerprint; DNA profiling; DNA sequences, unique; DNA typing systems; Evidence; Expert witnesses; Federal Rules of Evidence; Fibers; Hair analysis; PCR (polymerase chain reaction);

RFLP (restriction fragment length polymorphism); Statistical interpretation of evidence; U.S. Supreme Court (rulings on forensic evidence).

Civil court, forensic evidence

Civil lawsuits in civil courts often seek redress (financial compensation or repayment) to recover or restore loss due to damages inflicted by the defendant (lost wages, costs related to damage of property, financial compensation for pain and suffering, etc).

The United States court system contains two separate but parallel systems, the state and federal courts. Each of these courts has criminal and civil court divisions. Each of the court systems in the United States is governed and operated by means of specific sets of rules. In particular, the use of forensic **evidence** is dictated by the type of court (that is, federal criminal court, federal civil court, state criminal court, state civil court).

Civil courts deal with non-criminal matters and, although many of the procedures and rules are similar, there are fundamental differences in the burden of proof required for a verdict of guilty in a criminal trial as opposed to a verdict of "liable" in a civil trail. Because the defendant does not risk imprisonment in a civil court proceeding, the Constitutional protections afforded a defendant at civil trial are often less than those enjoyed in criminal court. For example, in a criminal trial, a suspect being tried cannot be called against their will to the witness stand to present testimony that may prove to be incriminating. According to the Constitution, a person may not be compelled to testify at his or her own criminal trail unless he or she makes an informed choice to do so. In a civil court proceeding, the plaintiff (the victim, or party making allegations against the defendant) can usually compel the perpetrator to testify under oath both before and during the trial.

Civil lawsuits may be filed regardless of the outcome of an associated criminal prosecution or lack of prosecution. A victim can sue in a civil court even if the alleged perpetrator was found "not guilty" in a criminal court.

One of the most famous examples of this involved former professional football star O. J. Simpson. Simpson was acquitted of **murder** charges at the state criminal court level in 1995, and later held liable for the deaths of his wife and a friend of his wife at a civil trial. In Simpson's civil trial, there was not only a lower threshold for proof of liability, Simpson was required to take the witness stand and offer testimony (something he was not required to do at his criminal trial). In the O. J. Simpson civil case the jury was unanimous in declaring Simpson liable, and he was ordered to pay penalties of roughly $8.5 million.

Civil penalties may consist of more than financial damages; the defendant may be required perform a specific action (such as community service) or refrain from a specific action (for example, not being permitted to practice **medicine** in a particular state). Either party has the right to appeal a civil verdict.

In criminal courts, the prosecution (the state or federal government) must prove the defendant guilty beyond a reasonable doubt. In civil court, the plaintiff need only prove that the defendant is liable by a "preponderance of evidence" (a greater of amount of evidence indicating liability than non-liability).

A civil action begins with a complaint sworn by the plaintiff, in which he or she makes a claim against another person (the defendant). The defendant must admit or deny every allegation made by the plaintiff, and then mount a defense against them (the allegations). A defendant may also choose to counter the plaintiff's claim with a claim of his or her own, or request the court to dismiss the suit for lack of valid proof. The next phase of a civil action involves discovery, a process in which either party may ask and answer questions, provide evidence, request documentation from other relevant sources (usually via subpoena), and/or be required to undergo physical or psychological evaluation or assessment.

During the discovery phase, lawyers may question potential witnesses under oath (a deposition) including forensic experts. The goal of such depositions is to examine potential testimony, or, in some special cases, preserve the testimony of individual who may later not be able to appear at trial.

With regard to rules of evidence that include the use of forensic evidence, however, many of the same standards apply to both criminal and civil cases (rules of admissibility related to **chain of custody**, etc.).

The **Federal Rules of Evidence** are used as the standard by which the federal court system makes decisions about evidentiary admissibility (including the rules regarding the use of forensic evidence). These rules govern the introduction of evidence in proceedings, both civil and criminal, in federal courts. While they do not directly apply to suits in state courts, the rules of many state courts (both criminal and civil) are often closely modeled on federal rules.

There is discretionary ability to either set individual rules of evidence (including rules for forensic evidence) for each state or to choose to follow some, or all, of the federal rules. Generally, individual state rules of evidence are created or determined by the state legislature and then imposed on the state courts.

There are three areas of evidentiary law (rules related to the admission of evidence at trial) in which the states generally draw heavily upon text and logic set forth in the federal rules of evidence, relevancy, shared burden of proof, and admissibility of oral testimony. In determining admissibility of evidence, many of the rules look first to the concept of relevancy. Some of the tests of relevancy are: does this expert's testimony or this opinion relate to the basic questions to be answered at this trial? Is the experience of this purported expert germane to the areas of law being examined in this case? Does the admission of this piece of material evidence have direct bearing on the outcome of the case, or is there some other underlying motive by the plaintiff's or the defendant's legal counsel in bringing it forward? Does it speak to the issues at hand, or is there some reason to exclude it?

Just as in criminal cases, during a civil proceeding forensics investigators or experts may be called to offer testimony or offer expert opinion as to the collection and handling of forensic evidence or testimony related to the findings and meaning of subsequent forensic tests.

SEE ALSO *Frye* standard; Trials, civil (U.S. law); Trials, criminal (U.S. law); Trials, international.

Civil trials SEE Trials, civil (U.S. law)

Closed-circuit television (CCTV)

Part of a forensic investigation can be to record the events that take place at a scene. If for example, a suspicious fire takes place at a factory, forensic investigators could examine tapes from surveillance **cameras** to see if anyone was on the property near the time of the fire. Thus, closed-circuit television (CCTV) can play an important role in **forensic science**.

CCTV involves the use of video cameras to produce images for display on a limited number of screens connected directly to a non-broadcast transmission system. Commercial cable TV is, technically, an example of CCTV, but the term "closed-circuit TV" is generally reserved for systems serving a small number of screens that are monitored for security purposes.

CCTV is a ubiquitous feature of institutional security systems. It is employed by prisons, banks, urban police forces, airports, military organizations, utilities, large corporations, various other organizations, and wealthy individuals. Examples include:

- X ray baggage-inspection devices at airports.
- Remote viewing of dangerous industrial processes, rocket liftoffs, and other operations.
- Perimeter security around power plants, military installations, warehouses, police stations, and other defended facilities.
- Intrusion or theft monitoring of secure spaces, whether indoors (halls, lobbies, specific doors and rooms, etc.) or outdoors (parking lots, automatic teller machines, loading docks, etc.).
- Monitoring of vehicular traffic for traffic-control purposes or detection of illegal activity.
- Identity-checking of persons desiring entry into a building.
- Computerized recognition of individual faces, with possible **identification** of "wanted" persons.

Prior to CCTV, in order to secure the perimeter of an area, it was necessary to post guards in such a way that their collective line of sight covered the entire circumference of the area. With CCTV, it is possible to reduce the number of personnel needed to secure a perimeter by placing TV cameras at strategic points and transmitting the resulting images to a control room where a few guards can monitor many screens. Ideally, these observers will note any suspicious event on their screens and alert a response team. CCTV has, thus, for decades been a component of the typical perimeter intrusion detection system (PIDS), which combines CCTV with devices designed to detect intrusion by other means, including ultrasonic motion detectors and window alarm-contacts.

CCTV technology, however, has not proved as effective in PIDS applications as was once hoped. As vigilance studies by psychologists confirm, guards who spend hours "screen gazing" at static scenes (>20 minutes, in tests) tend to become bored and less efficient, and are then likely to miss low-frequency events, such as a figure running up to and climbing over a fence.

Starting in the 1980s, designers sought to combat the bored-guard effect by using automatic video motion detectors (VMDs). These devices are designed to automatically detect scene action by comparing successive image-frames for changes. When change is detected that exceeds a predeter-

A British police CCTV (closed circuit television) image shows Southampton and Charlton Athletic soccer fans clashing in 2002 near Maze Hill train station in south London. © HANDOUT/REUTERS/CORBIS

mined threshold, an alarm is sounded. A guard then judges whether the alarm is false or valid.

VMDs, however, have not turned out to be a security panacea. There are too many sources of image change, especially in outdoor scenes, for a simple circuit to distinguish meaningful intrusions from nuisance alarms. VMD use is therefore restricted to artificially-lighted indoor spaces or to expensive systems that employ computer processing to reduce the false-alarm rate.

SEE ALSO Aviation security screeners, United States; Cameras; Fire investigation.

Codes and ciphers

Forensic analyses can be concerned with unraveling the true meaning of communications. This is particularly relevant in **forensic accounting**, where the trail of funds from person to person or within an organization is established. In the computer age, forensic accounting can involve the search of computer hard drives that have been seized as part of an investigation. An examiner may encounter information that has been converted into an unreadable format, at least until an algorithm is applied that unscrambles the information to a readable form.

From the beginnings of communication, there has been a need for secrecy. Codes and ciphers are a means of producing secret communications. Codes and ciphers are forms of cryptography, a term from the Greek *kryptos*, hidden, and *graphia*, writing. Both transform legible messages into series of symbols that are intelligible only to specific recipients. Codes do so by substituting arbitrary symbols for meanings listed in a codebook; ciphers do so by performing rule-directed operations directly on original message text. Because codes can only communicate concepts that are listed in their codebooks, they have limited flexibility and are not much used today. Rather, modern cryptography relies almost entirely on ciphers implemented by digital computers.

A code is a set of symbolic strings ("code groups") that are listed, along with their assigned meanings, in a code book.

Either a word or a number can be used as a code group. Code groups that are words are termed code words and those that are numbers are termed code numbers. Note that a single code group can encode a single word ("king") or an entire phrase ("deliver the films to agent number 3"). A coded message may, therefore, be shorter than the original message. It can also be made as long as or longer than the original message, if the codebook provides lengthy code phrases for single concepts or nonsense code groups for padding purposes. Such techniques can be used to make encoded messages harder for opponents to read.

A cipher uses a system of fixed rules (an "algorithm") to transform a legible message ("plaintext") into an apparently random string of characters ("ciphertext"). For example, a cipher might be defined by the following rule: "For every letter of plaintext, substitute a two-digit number specifying the plaintext letter's position in the alphabet plus a constant between 1 and 73 that shall be agreed upon in advance."

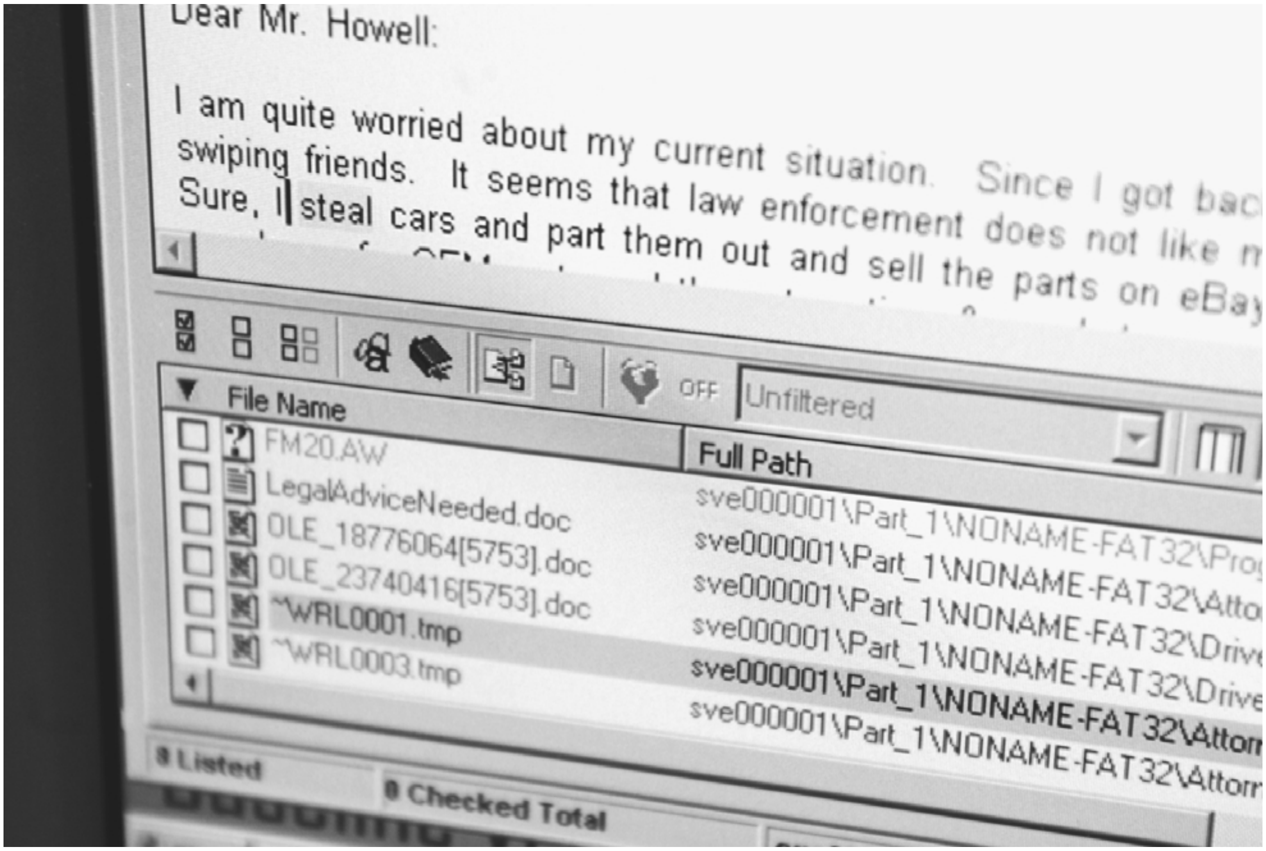
Incorporation of a variable term into a fixed algorithm is typical of real-world ciphers. The variable component is termed a key. A real key would be longer and would have a more complex relationship to the cipher algorithm than the key in this example, but its basic role would be the same: a key fits into an algorithm so as to enable enciphering and deciphering, just as a physical key fits into a lock to enable locking and unlocking. Without a key, a cipher algorithm is missing an essential part. In fact, so important is the concept of the key that in real-world ciphering it is not algorithms that are kept secret, but keys. Cipher designers assume that their algorithms will always become known to their opponents, but design the relationship between key and algorithm so that even knowing the algorithm it is almost impossible to decipher a ciphertext without knowing the appropriate key. Before a cipher can work, therefore, a key or set of keys must be in the possession of both the sender and the receiver.

If the key were always the same, it would simply constitute a permanent part of the algorithm, and keying would have no special advantage over trying to keep one's algorithm secret to begin with. Keys must, therefore, be changed occasionally. A new key may be employed every day, for every message, or on some other schedule.

Codes have the advantage of simplicity. No calculations are required to encode or decode messages, only lookups in a codebook. Further, because a code uses no fixed system for associating code groups with their meanings (even the amount of meaning assigned to a code word can vary, as seen above), a code may fail gracefully—that is, the meaning of a few code groups may be discerned while others are not. In contrast, a cipher produces ciphertext from plaintext (and vice versa) according to a fixed algorithm. Thus, if an enemy determines the algorithm and steals or guesses a key, they can at once interpret all messages sent using that key. Changing the key may restore cipher security, unless the enemy has developed a system for guessing keys. One such system, always possible in theory, is to try all possible keys until one is found that works.

Codes, however, have two great disadvantages. Users can only send messages that can be expressed using the terms defined in the codebook, whereas ciphers can transmit all possible messages. Additionally, all codes are vulnerable to code book capture. If a codebook is captured, there is no recourse but to distribute new codebooks to all users. In contrast, the key–algorithm concept makes cipher secrecy dependent on small units of information (keys) that can be easily altered.

Secure ciphers, however, entail complex calculations. This made the use of complex ciphers impractical before the invention of ciphering machines in the early twentieth century; codes and simple ciphers were the only feasible methods of ciphering. Yet, a



Scientists at the Silicon Valley Regional Computer Forensics Lab in Menlo Park, California, used various software tools to recover encoded evidence from data files, such as this e-mail message in 2005. © KIM KULISH/CORBIS

cipher that is simple to implement is proportionately simple to crack, and a cracked cipher can be disastrous.

Codes can be generally divided into *one-part* and *two-part* codes. In a one-part code, the same codebook is used for encipherment and decipherment. The problem with this system is that some systematic ordering of the code groups and their assigned meanings must be made, or it will be difficult to locate code groups when enciphering or their meanings when deciphering. (A randomly ordered list of words or numbers thousands of terms long is difficult to search except by computer.) Thus, code groups tend to be arranged in alphabetic or numerical order in a one-part code, an undesirable property, since an opponent seeking to crack the code can exploit the fact that code groups that are numerically or alphabetically close probably encode words or phrases that are alphabetically close. To avoid this weakness, a two-part code employs one codebook for encipherment and another for decipherment. In the encipherment codebook, alphabetically ordered meanings (e.g., A, ABDICATE, ABLE) are assigned randomly ordered code groups (e.g., 6897, 1304, 0045). In the decipherment code book, the code groups are arranged in order (e.g., 0045, 1304, 6897), for easy location.

Code security can be improved by combining ciphering with coding. In this technique, messages are first encoded and then enciphered; at the receiving end, they are first deciphered and then decoded. A standard method for combining coding and ciphering is the “code plus additive” technique, which employs numbers as code groups and adds a pseudorandom number to each code group to produce a disguised code group. The pseudorandom numbers used for this purpose are generated by modulo-arithmetic techniques closely related to those used in stream ciphering.

Ciphers that encrypt whole blocks of characters at once—sush as 10 letters at a time, or 128 bits—are termed block ciphers. Block ciphers have the advantage that each character in each ciphertext block can be made to depend complexly on all characters of the corresponding message block, thus scrambling or smearing out the message content over many characters of ciphertext. The widely used Digital Encryption Standard (DES) is a block cipher that employs a 56-bit key to encrypt 56-bit blocks. In DES, the key and each message block are used as inputs to a complex algorithm that produces a 56-bit block of ciphertext. The same key is used to decode the block of ciphertext at the receiving end.

Stream ciphers operate upon series of binary digits ("bits," usually symbolized as 1s and 0s), enciphering them one by one rather than in blocks of fixed length. In stream encipherment, a series of bits termed the key-stream is made available by some means to both the sender and receiver. This stream is as long as the message to be sent. At the sending end, the key-stream is combined with the message-stream in a bit-by-bit fashion using the EXCLUSIVE OR operation of Boolean algebra, producing the ciphertext. At the receiving end, the same key-stream is combined again with the ciphertext to recover the message stream. This system of ciphering is unbreakable in both theory and practice if the key-stream remains secret. Ongoing breakthroughs in quantum cryptography may soon make perfectly secret key-streams available by exploiting certain properties of photons. If these techniques can be made technologically practical, truly unbreakable cipher systems will have become available for the first time in history.

All ciphers require the use of a secret key. Public-key ciphers (those ciphers that are sent with a key that is not secret) first developed in the late 1970s, are no exception. However, public-key ciphers have the important advantage that the key possessed by the sender need not be the same secret key possessed by the receiver; thus, no secure transfer of keys between the sender and receiver is ever necessary. Software for a powerful public-key cipher algorithm known as Pretty Good Privacy (PGP) is downloadable for free from many sites on the Internet.

Codes and ciphers can be attacked by two basic means. The first is theft of codebooks or keys—espionage. The second is cryptanalysis, which is any attempt to crack a code or cipher without direct access to keys or codebooks. Cryptanalysis may proceed either by trial and error or by systematic analysis of plaintext and ciphertext. The analytic approach may involve both looking for patterns in ciphertext and solving mathematical equations representing the encryption algorithm.

Cryptanalysis by trial and error usually means guessing cipher keys. A cipher key can be guessed by trying all possible keys using a computer. However, designers of encryption systems are aware of this threat, and are constantly employing larger and larger keys to keep ahead of growing computer speed. Systematic cryptanalysis may seek patterns in ciphertext, either by itself or in conjunction with a known plaintext (the so-called "known-plaintext attack").

SEE ALSO Computer forensics; Computer hardware security; Computer software security; Cryptology and number theory; Decryption.

CODIS: Combined DNA Index System

CODIS, or the Combined DNA Index System, is a database and electronic search engine that allows crime laboratories throughout the United States to exchange DNA information about criminals, suspects, and victims of crime. CODIS is operated by the U.S. Department of Justice through the Federal Bureau of Investigation.

The CODIS project began in 1990 as a collaboration among 14 forensic laboratories. The DNA Identification Act of 1994 authorized the use of DNA data for forensic analysis and formalized CODIS. By October 1998, CODIS became operational on a national level. As of 2004, all 50 states along with Puerto Rico, the U.S. Army and the **FBI** were CODIS participants.

CODIS has a three-tiered hierarchical structure. DNA information originates at the local level (LDIS, Local DNA Index System), where biological samples are taken at police departments and sheriffs' offices. Data from the LDIS then flows into the state (SDIS, State DNA Index System) and the national (**NDIS**, National DNA Index System) databases. SDIS provides a means for local crime labs within a state to exchange information. The NDIS allows for the exchange of DNA profiles on the broadest scale at the national level. The hierarchical nature of CODIS allows investigators to use their databases according to the specific laws under which they operate.

CODIS consists of two major indexes. The Forensic Index contains DNA information from the crime scene, including DNA information found on the victim. The Offender Index contains DNA profiles of convicted felons. Most states require all people convicted of sexual offenses, as well as many convicted of violent crimes, to provide genetic information to CODIS. As of December 2004, CODIS contained 2,132,470 DNA profiles. The large majority, about 2 million, were made up of DNA profiles from convicted offenders and were included in the

Offender Index. The Forensic Index contained approximately 100,000 samples.

In addition, CODIS contains ancillary information that provides additional information for investigators to use in order to solve crimes. One index catalogues information collected from unidentified human remains and another collects DNA profiles voluntarily donated by the relatives of missing persons. CODIS also includes a population file consisting of anonymously donated DNA profiles. This file is used to quantify the statistical significance of a match.

Information entered into the Forensic Index from different locations in the United States can help link crimes together. For example, if the DNA profile taken from a crime scene in Tallahassee matches that taken from a crime scene in Miami, then there is **evidence** that the same person committed the crimes. This allows investigators to develop more leads and coordinate investigations. When a DNA profile from the Forensic Index matches one from the Offender Index, a suspect can be identified. After CODIS provides investigators with a potential match, experts in crime labs are always consulted for verification.

A DNA profile that is entered into CODIS consists of information that is gathered from stretches of the **chromosome** that are highly variable between different people. These variable regions are called polymorphisms. One type of polymorphism is a very short sequence of nucleotides, the building blocks of DNA, which repeats itself many times. This type of sequence is called a short tandem repeat, or STR. STRs are usually between two and five nucleotides long, and CODIS profiles specifically catalogue those that are four nucleotides long. STRs that are four nucleotides in length are referred to as tetramers. For example, the sequence of nucleotides "CGAACGAACGAACGAACGAA" represents five copies of the tetramer "CGAA." The number of times that "CGAA" repeats itself at a given location on the chromosome will vary from person to person. The CODIS core profile consists of STR information gathered from 13 different loci, or positions, on the chromosomes.

CODIS has been an extremely successful system that has aided in solving a variety of investigations. As of December 2004, CODIS produced more than 19,000 hits, which are defined as matches between suspect and crime that would not have been made without CODIS. CODIS has also assisted in solving 20,700 criminal cases in 47 states. Many of the investigations aided by CODIS have developed leads against sexual offenders. For example, in 1999, Virginia police received a phone call from a woman who had been stabbed and raped. By the time they arrived on the scene, the woman had bled to death. After gathering biological evidence from the woman's body, investigators developed a DNA profile of the suspect. Using CODIS, they produced a match in the Offender Index to a rapist who had been imprisoned in Virginia in 1989, but who had served out his term and been released. In another case, in 1996, two rapes occurred at in distant parts of St. Louis, both involving young girls who had been waiting at bus stops. The St. Louis Police Department was unable to solve the crimes. In 1999, they reanalyzed DNA evidence from the crimes and were able to generate a hit through CODIS to an offender in another rape case. He was eventually identified as the offender in both of the bus stop crimes. CODIS also played a role in the September 11, 2001 attacks. In the days following the attacks, the company that helped develop the CODIS software worked with the FBI and the New York Police Department to modify the software so that it could be used to identify the remains of those killed in the attacks.

SEE ALSO FBI crime laboratory; FBI (United States Federal Bureau of Investigation); Identification.

Coffin birth

Coffin birth (first defined by the German term *sarg geburt*) is the phrase used by coroners to explain the medical phenomenon when a pregnant woman spontaneously delivers her child after her own untimely death. The spontaneous birth happens when naturally expanding gases, built up in the abdominal and pelvic areas of a decomposing (pregnant) corpse, place sufficient pressure on the mother's uterus to force an unborn baby through the birth passageway and out the vagina. Coffin births have occurred throughout human history, with paleopathologic scientists discovering instances of coffin birth in ancient countries of what is now called the continent of Europe. However, with modern embalming techniques, the occurrence of coffin birth is very rare. On the other hand, coffin births still happen when (for example) accidental deaths and murders occur or in the unlikely situation where incorrect embalming procedures are performed. (As of the beginning of the twenty-first century, the term coffin birth has rarely appeared in medical literature for about twenty-five years due to its infrequency of occurrence.)

In April 2003 the chief **medical examiner** of San Francisco, California, along with other forensic investigators, initially stated that coffin birth was a possible reason as to why the decomposed bodies of an adult (pregnant) woman and an infant boy washed ashore separately (about a mile apart near Point Isabel Regional Shoreline) south of the city of Richmond, which is located northeast of San Francisco Bay. The media promoted such a theory during the coverage of the incident, but most scientists agreed at the time that coffin birth was only a possibility, one of many possible reasons why the pair was discovered apart. Forensic experts state that a coffin birth, sometimes called a postmortem birth, could take weeks or months to happen, depending on external factors such as outside temperature. It was later learned that the female corpse, Laci Peterson, was about seven and one half months pregnant and due to deliver a baby boy, Conner, on or about February 10, 2003, when she apparently disappeared from her Modesto, California, home on Christmas Eve 2002. Her husband, Scott, was convicted in March 2005 and sentenced to death for the murders of both his wife and unborn son.

SEE ALSO Decomposition.

Cold case

A cold case is any criminal investigation by a law enforcement agency that has not been solved for (generally) at least one year and, as a result, has been closed from further regular investigations. A cold case may be closed for various reasons such as: previously available technology was not able to adequately analyze the **evidence** in order to form a conclusion; witnesses were hostile and uncooperative; various time constraints hindered the investigation; the originally assigned detectives had a heavy workload; a lack of worthwhile leads stalled the case.

Almost assuredly, every law enforcement agency in the United States and in foreign countries has cold cases on their books that could be reopened and solved. However, since agencies have limited amounts of manpower and resources, usually only the most terrible cold cases such as violent crime are reopened. Plus, violent crimes such as homicides and sexual assaults are well matched to being reopened as cold case reviews because such cases generally produce the most evidence. However, the decision to reopen a cold case is also dependent on many other factors including: the overall severity and cruelty of the crime; cooperativeness, whereabouts, and number of witnesses; age of the crime; amount and condition of the inventory (including **physical evidence**) relevant to the case; whereabouts of previously identified suspects; and new technologies and tools that may help to determine evidence previously unable to be solved. Oftentimes, cases are reviewed and prioritized according to the likelihood of an eventual solution, with the highest priority cases given to those in which new witnesses, information, and evidence can now identify suspects.

Usually only the most talented and experienced law enforcement investigators are assigned to cold cases because of the thoroughness, persistence, and high motivation necessary to review the large numbers of detective notes, patrol reports, photographs, electronic information, laboratory documents, crime scene drawings and diagrams, witness lead sheets, and suspect information. Important characteristics required of cold crime members include: strong communication and interpersonal skills, seniority, strong research skills and deductive reasoning, creativity, patience, and enthusiasm. Sometimes a special "Cold Case Squad" may be organized, either temporarily or permanently, to deal solely with cold cases, especially when current cases prevent such older cases from being worked. In nearly all scenarios, cold case investigations present many varied and intense challenges to any law enforcement agency.

SEE ALSO Cold hit; Physical evidence.

Cold hit

A cold hit refers to an instance where one or more connections are made between a crime victim, a perpetrator, and/or a crime scene in the absence of a current investigative lead (i.e., a **cold case**).

In October of 1998, the **FBI** established the National DNA Index System (**NDIS**), the primary purpose of which was to make it possible for public sector forensic laboratories throughout the United States to electronically share and compare DNA samples and profiles. The overarching goal of this linkage system is to connect unsolved serial violent crimes to one another and to known violent offenders (particularly to known sex offenders).

In July of 1999, the FBI announced that the new system had produced its first successful cold hit, linking six unknown subject sexual assault cases in Washington, D.C. with three sexual assault cases then being investigated by the Sheriff's Office in

Jacksonville, Florida. Shortly thereafter, the forensic laboratory of the Florida Department of Law Enforcement announced that it had positively identified Leon Dundas (deceased) as the perpetrator in all six cases, based on their DNA analysis of a sample of the offender's **blood**.

CODIS, an acronym for the FBI Crime Laboratory's Combined DNA Index System, provides the framework for the Cold Hit programs. CODIS combines computer technology with **forensic science** to create a highly effective tool for linking, and potentially solving, violent crimes. Through CODIS, local, state, and federal forensic laboratories can compare and exchange DNA profiles.

The federal government established a series of grants for individual states' development of cold hit programs, in order to facilitate intra-state DNA database development and to defray equipment, administrative, and human resource costs during lab set up. In addition, forensic labs are funded in order to compensate for costs involved in screening external (not from within their own labs) DNA profiles for comparison with existing **evidence** and confirming hits on unsolved or suspectless sexual assault cases or violent crimes.

In addition to CODIS and NDIS, a website system within each state and across the nation exists for tracking the progress of each evidence kit from the time it enters the DNA analysis system through resolution. The Cold Hit Website system, which can be accessed by individual forensic labs, can be used to generate statistical reports as well as to track case status. Currently, forensic laboratories across all 50 states, Puerto Rico, and the U.S. Army participate in NDIS and the Cold Hit Program.

SEE ALSO Blood, presumptive test; Bloodstain evidence; Chemical and biological detection technologies; Cold case; Commercial kits; Decomposition.

Commercial kits

Commercial kits are used by forensic pharmaceutical or biochemical laboratories to make human **identification** possible through the use of **DNA profiling**. Commercial kits make use of standardized combinations of short tandem repeat loci (sequences of genetic material, also known as STR) in specific types of polymerase chain reactions (also known as **PCR** technology), which results in human identifications made with an extremely high degree of certainty. By using commercial kits with PCR technology, **DNA** profiles can be generated from exceedingly small, very old, badly preserved, or partially decomposed samples.

The **FBI** is a world leader in the development of DNA typing technology and the **CODIS** system, used to identify the perpetrators of violent and serial crimes. In 1997, the FBI announced the isolation and selection of thirteen STR loci that would form the core of the CODIS database (national DNA database). The thirteen specific STR loci used by the FBI in the CODIS system are: D3S1358, vWA, FGA, TH01, D21S11, D8S1179, D18S51, TPOX, CSF1PO, D16S317, D5S818, and D7S820. The thirteenth STR locus is used for gender determination on the X and Y chromosomes.

Because the CODIS system is widely available, and the 13 FBI-recommended STR have been standardized, it is relatively simple to use the CODIS system with a commercial kit in order to make a highly accurate identification.

The advantages of using STR loci, PCR technology, and commercial kits are:

- The CODIS system is available worldwide.
- Using commercial kits, STR alleles can be very rapidly determined.
- STR alleles (one member of a pair or series of genes at a specific location on a specific **chromosome**) are standardized and behave according to scientific principles which are well known and understood.
- The data are ideally suited to use within computerized database systems.
- Forensic laboratories all over the world are adding to the known DNA database.
- STR profiles require very minute samples for accurate determination of identification.

DNA samples can be obtained from nearly any human tissue, and are typically deposited at crime scenes in the form of **blood**, **semen**, tissue from the victim, hair follicles, and **saliva**. DNA samples are extracted from these (or other similar) items of **evidence** and compared to DNA extracted from reference samples from known individuals (either offenders or member's of the victim's biological family).

Commercial kits have done much to advance the speed and accuracy with which forensic scientists can use DNA technology to make human identifications.

SEE ALSO Ancient cases and mysteries; Blood; Cold case; Cold hit; Decomposition; Electrophoresis.

Competency to stand trial

Persons accused of criminal activities must be competent to stand trial; that is, must be capable of understanding the purposes and aspects of the legal proceedings held against them and must have the ability to contribute to their own defense. The mental capability of the accused only matters during the period of time it takes to prosecute the person, as the act of taking legal action against a debilitated person is a violation of the U.S. laws of due process. According to the justice system, any accused person who becomes mentally incompetent before or during the events of a legal proceeding, including after a conviction is made, may not be subjected to the criminal penalties and punishments implemented by the court. However, the accused and/or convicted person may be held and confined to a mental hospital or facility for their own protection and for the protection of the general public.

When determining the competency of a person to stand trial one psychiatrist (or several psychiatrists with different concentrations) may be used to decide if the accused is competent. A psychiatrist will consider several psychological disorders when determining a person's mental state. The major disorders that are generally considered include: (1) mental retardations (often caused by congenital conditions, brain injuries, or infections), (2) neuroses (repeated anxiety, depression, and various maladjustments, but without psychotic symptoms), (3) organic brain syndromes (physical defects or diseases such as those found within elderly persons in the form of, for example, hardening of the arteries and within the general population in the form of, for example, brain tumors and multiple sclerosis), (4) personality disorders (inabilities to conform to socially accepted behaviors such as antisocial personality), and (5) psychoses (derangements of personality and loss of contact with reality such as with manic depressive illnesses).

The examination performed by the psychiatrist on the accused includes a physical examination (to learn about behavior, emotional state, and general appearance), a check of family and personal background (to identify mental illness history), psychological tests (to show specific mental states, including intelligence tests and psychomotor tests for conceptual thinking and memory), and personality tests (to detect the presence of psychopathologic characteristics). The psychiatrist also possesses the ability to use the concept of diminished responsibility (sometimes called diminished capacity or partial insanity). The concept permits the justice system to take into account the impaired mental state of the accused even though the specific impairment does not qualify as being incompetent to stand trial under the tests performed by the psychiatrist.

SEE ALSO Psychology; Psychopathic personality.

Composite drawing

Composite drawing is the most widely known application of forensic art. Composite drawing uses descriptions given by witnesses to create a drawing that is a useful tool for identifying or eliminating a suspect. A composite drawing is not intended to be a portrait of an individual, but more of a two-dimensional likeness that is a visual record of the witness' recollections.

Creating a composite drawing requires skill that goes beyond the technical. The artist must also be able to interview and relate to the witness, eliciting valuable information that will form the basis of the drawing. A composite drawing is made in three stages. First, the artist will block out the facial proportions—whether the suspect has a long chin, for instance, or a wide forehead. Then they will fill in shapes of facial characteristics, such as a bulbous nose or thin lips. Finally, shading is used to create facial form and texture.

Composite drawing is a two-way process. The artist encourages the victim or witness to look at the drawing at all stages of its progress. Not until they are satisfied that the drawing is the best possible representation of their recollections can it be considered completed. Sometimes, the very process of talking to the artist will bring up other important facts and memories from the witness. The drawing can be a powerful corroboration of a witness statement.

The advantage of a composite drawing is that it can be widely circulated—in newspapers, on message boards, or by fax or email to interested individuals. Composite drawings help involve the public in the search for a missing person, a suspect, or a fugitive. In one example, Stephen Mancusi, an experienced forensic artist with the New York Police Department, worked with a rape victim who had been attacked in the lobby of her apartment building. It was thought the attacker was a serial rapist loose in Manhattan who had attacked four women in their twenties at knife point. Mancusi and the fourth victim together produced a sketch of the suspect that was widely distributed throughout the city. A Bronx Assistant District Attorney saw the poster a short

Police composite drawing of Richard Ramirez, the Los Angeles "Night Stalker" killer. © BETTMANN/CORBIS

time later and immediately recognized it as a relative. The assailant was tracked down to Florida and found to have a long history of sex offences. Put on trial, Anthony Mane admitted his crimes and was sentenced to 40 years in jail.

Composite drawings can be applied to a wide range of crimes—from shoplifting to homicide. Often kits are used to create the drawing. The Identikit approach uses a collection of noses, eyebrows, and other facial features to get the best fit to the witness description. Photofit pictures are created by putting together a picture from facial features drawn from a photographic library. The witness can pick out facial features of their suspect, including those from individuals of various ethnic origins, from such library collections. Advanced computer techniques allow synthesis of information from several witnesses, even those who only had a partial view. However the picture is generated, it is the skill and experience of the forensic artist, along with their empathy with witnesses that are still the keys to the success of the technique.

Composite drawing relies upon witness statements, but there are related techniques that use skeletal remains or photographs. There are computer programs that can create two or three-dimensional likenesses from **skull** bones. This helps identify missing people and murder victims. Photographs and sketches can also be aged. A photo of a child who went missing or was abducted many years ago can be used to create a picture of how they may look in the present day. To do this, the forensic artist uses knowledge of the complex patterns of craniofacial growth to reveal how the child turns into an adult.

Similar techniques can be applied to the aging of adults to help identify fugitives, using anatomical knowledge of how the human face ages. It is also possible to change features such as hair color and add spectacles or facial hair in case the individual is in disguise. In 1991 forensic artist Karen Taylor used aging of a picture to help catch the Cuban fugitive Virgilio Paz Romero, who had been on the run for 15 years. He was wanted for the murder of the Chilean ambassador Orlando Letelier. When he was caught, he was even wearing the red shirt that Taylor had predicted.

SEE ALSO Anthropology; Anthropometry; Missing children.

Computer forensics

Computers are often used in crime, whether to plot a terrorist attack, contact children for sexual abuse, commit bank or credit card fraud, or other

A hard drive taken as evidence at the FBI's Silicon Valley Regional Computer Forensics Lab in Menlo Park, California. The lab recovers digital evidence in a way that is legally acceptable to the courts. © KIM KULISH/CORBIS

crimes. Some crimes cannot actually be committed without a computer, such as hacking into company records. Others are just made easier by using a computer, such as sexual predators who can anonymously search for under-age victims on Internet chat sites. Whatever role the computer played, the machine can be seen as a crime scene in its own right. The police will often seize a computer if they suspect it holds **evidence** of an illegal act. They will then take it to a specialized forensic laboratory for examination. Computer forensics is a relatively new area of **forensic science** and one that requires considerable expert knowledge of operating systems, computer hardware and software, and the workings of the Internet.

As with any other crime scene, suspects leave behind **trace evidence** of their actions when using computers to commit a crime. Gathering evidence from a computer can be challenging, but valuable, because every operation that an individual carries out on a computer leaves behind a record that is usually dated. However, computer traces can also be fragile and, without the proper approach, files containing valuable evidence can be lost. Since 1990, guidelines on computer forensics have evolved by using the input of authorities around the world.

Generally the investigator is careful to do nothing that would alter the original data on the computer. Usually this means taking a copy of the hard disk for investigation, rather than the original data. Should it be necessary to look at original data, experts are consulted and only they are permitted access to data stored on hard drives. All processes involving the investigation of computer-based evidence is carefully recorded and examined and reproduced by an independent third party.

The first step in the forensic examination of a computer is to determine the condition of the computer, noting whether it is turned on, plugged in, connected to a network, or to the Internet. Then, modem or network connections should be unplugged so the computer's owner cannot access the machine remotely to destroy evidence. Note-taking and **photography** are used to record all the connections and any screen display. The computer is usually turned off by simply pulling the plug, as some computer criminals will manipulate the usual orderly shutdown process to destroy evidence. The next task is to create two physical backups of the hard drive, one for analysis and the other for evidence.

Further investigation of a computer crime scene involves looking at many different components and data, including compact disks (read only, read-write, and write-only), hard disks, and digital video disks. A hard disk is divided into various segments. Unallocated space on the hard disk, for instance, can be a rich source of forensic information as this is where files that the suspect believes deleted may be stored. Passwords and identifications sometimes appear in a part of the hard disk called slack space. Retrieving this kind of information may require specialist forensic software and, if the suspect is a computer expert, he or she may be one step ahead of the forensic investigator.

The Internet is another important source of evidence. Investigators will track a suspect's e-mail messages, their contributions to newsgroups, bulletin boards, and chat rooms. The websites accessed by a suspect can also be valuable evidence, especially when sexual crime is involved. Web browsers such as Netscape® and MS Internet Explorer® create cache files to improve performance. These show which sites have been visited recently. Although they are difficult to view, there are utilities that can allow their contents to be revealed, showing if a suspect has been indulging in incriminating use of the Internet, such as visiting child pornography, or terrorist or racist web sties.

Computer forensics can provide key evidence in both civil and criminal investigations. For example, sometimes employees from a large organization want to break away and set up a rival company. To do this, a dishonest employee could break into the organization's network and steal information about clients. In many cases, the suspects have been taken by surprise when a manager called in a computer forensic expert to examine their machines. Inappropriate use of the Internet in the workplace, for instance to access pornographic websites, can also be uncovered by this type of investigation. Computer forensics is one of the most challenging branches of forensic science. It is not just computer technology that moves fast, but also the criminals who exploit it. Keeping up or even outpacing them can be a source of satisfaction to the computer forensic expert.

SEE ALSO Computer hardware security; Computer security and computer crime investigation; Computer software security.

Computer fraud and abuse legislation

Forensic science relies on data. Using the global resources of the Internet, forensic scientists can probe databases to sift out information. Furthermore, much information they gather, such as digital images and reports, is preserved as computer files. This reliance on computer technology comes at a price. The data is vulnerable to theft or alteration by those who can gain access to the files. Federal forensic science data falls under the protective umbrella of legislation that was created several decades ago. Such legislation also provides a set of laws under which forensic investigators can act to develop **evidence** in cases where computers (and other devices housing digital information) are used or are compromised in violation of law.

The United States Computer Fraud and Abuse Act of 1986 served to define criminal fraud and abuse for computer crimes on the federal level. The act specified a **misdemeanor** crime for the trafficking and misuse of passwords. Two **felony** offenses were specified by the act for unauthorized access to federal information systems and private computers deemed to have a "federal interest." The act removed several legal ambiguities that surrounded computer information theft, such as the lack of specific legislation mentioning computers and the slightness of legal precedence in such cases.

Computer data systems of varying sorts had been used by the United States government since the 1960s. This is certainly true for forensic science, with national and international databases available for information on fingerprints, **ballistics**, felons, and genetic sequences of disease causing microorganisms.

In the early 1980s, the first computers for business and home use were available in the marketplace. This expanse of the computer-owning and software-literate population forced the government to begin finding ways to protect data, either through encryption or protective barrier mechanisms around certain files. With the advent of intranets and computer-to-computer communication through telephone lines, hacking, or the breaking into other computer systems, became more commonplace. In 1981, a computer-savvy 24-year-old named Ian Murphy hacked into several government systems, including the White House switchboard. Murphy used the switchboard to order various products before turning his attention to cracking the **codes** protecting sensitive military files. Murphy was arrested, but prosecutors did not have the legal recourse to try him for computer crimes, as no such laws existed. Murphy was eventually convicted of theft and knowingly receiving stolen goods.

By 1982, Congress began collecting data on computer crime, and gathering testimony from computer fraud victims. Most of the victims were major corporations who did not want their security breaches and vulnerability to become public knowledge. Not only was it easy for random hackers to crack a system, but also corporations could hack into the data systems of rival companies, engaging in corporate espionage. After five years, Congress introduced the Computer Fraud and Abuse Act of 1986. The bill passed decisively. That same session, the Electronic Communication Privacy Act of 1986 was passed, criminalizing the seizure and interception of digital messages and communication signals.

In January of 1989, Herbert Zinn was the first person to be convicted under the Computer Fraud and Abuse Act. As a teenager, Zinn broke into computer systems at the Department of Defense, wreaking havoc with several hundred files. Zinn was sentenced to nine months in prison and fined; he would have possibly received a harsher judgment if he had been over eighteen years-old at the time of the crime.

Since its inception, the Computer Fraud and Abuse Act has weathered changing technology and the development of the Internet. However, computer crime is once again on the rise, and only a fraction of victims report these crimes. Subsequent court proceedings and legislation such as the Computer Abuse Amendments Act of 1994 have provided specific wording criminalizing the promulgation of computer viruses and other damaging code.

In 1996, the act was amended, extending the “federal interest” to include any computer that is connected to the Internet. Appropriately, the phrase “federal interest” was replaced by the broader phrase “protected computer.” Thus, the act that originally applied just to computers directly associated with federal functions now potentially applies to any computers that are involved in interaction with the federal government.

The United States Patriot Act was signed into law on October 25, 2001. The act, which was designed to strengthen the country’s ability to withstand terrorist action, affected the Computer Fraud and Abuse Act. The Patriot Act specifically addressed the concept of “damage” in the act, providing more substance of what constituted damage and loss in a computer hacking incident. An individual can now be prosecuted for deliberately attempting to cause damage, even if no damage resulted from the hacking. Whether these amendments stand up to legal scrutiny awaits court challenges.

SEE ALSO Computer hackers; Computer hardware security; Computer keystroke recorder; Computer modeling; Computer security and computer crime investigation; Computer software security; Document destruction.

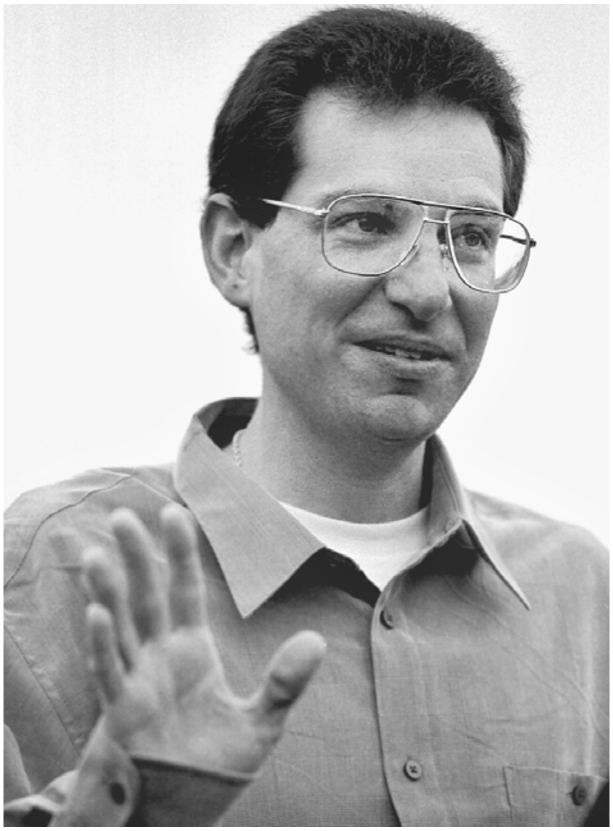
Computer hackers

Forensic science utilizes the global resources of the Internet to access databases and to communicate with concerned experts. This form of communication, however, can make forensic databases and files vulnerable to deliberate sabotage. Computer hackers are people who gain remote access (typically unauthorized and unapproved) to files stored in another computer, or even to the operating system of the computer. In the 1950 and 1960s, hackers were motivated more by a desire to learn the operating characteristics of a computer than by any malicious intent. Indeed, in those days hackers were often legitimate computer programmers who were seeking ways of routing information more quickly through the then-cumbersome operating systems of computers.

Since then, however, computer hacking has become much more sophisticated, organized, and, in many cases, illegal. Some hackers are motivated by a desire to cripple sensitive sites, make mischief, and to acquire restricted information.

In the late 1990s, several computer hackers attempted to gain access to files in the computer network at the Pentagon. The incidents, which were dubbed Solar Sunrise, were regarded as a dress rehearsal for a later and more malicious cyber-attack, and stimulated a revamping of the military’s computer defenses. In another example, computer hackers were able to gain access to patient files at the Indiana University School of Medicine in February 2003.

One well-known hacker is Kevin Mitnick. Beginning in the late 1970s and continuing through the late 1980s, Mitnick was apprehended at least five times for hacking into various computer sites. Indeed, his lenient one-year jail sentence and subsequent



Convicted computer hacker Kevin Mitnick declining questions as he reads statement in improvised news conference after being released from Federal Correction Institute, Lompoc, California. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

counseling was based on his defense that he suffered from a computer addiction. In 1989, he vanished, only to reappear in 1992, when police became suspicious of tampering with a California Department of Motor Vehicles database. Mitnick was arrested in 1995 and remained in prison until his release in 2002. He was barred by law from using a computer until January 21, 2003 and later published *The Art Of Intrusion: The Real Stories Behind The Exploits Of Hackers, Intruders, And Deceivers* in 2005.

The U.S. Patriot Act was signed into law on October 26, 2001. The intent of the act was to curb the danger posed to the country by terrorism. Computer hackers did not escape the legislative crackdown, since hacking represents a potential national security threat.

Under the act's provisions, the power of federal officials in criminal investigations involving hacking activities has been increased. These increased and somewhat secretive powers were among the contentious issues debated in 2005 as provisions of the Patriot Act come up for renewal.

Indeed, the threats to civilian privacy and national security from computer hackers was deemed so urgent that the U.S. government further enacted the Cyber-Security Enhancement Act in July 2002, as part of the Homeland Security measures in the wake of the terrorist attacks on September 11, 2001. Under this legislation, hackers can be regarded as terrorists, and can be imprisoned for up to 20 years. In seeking to prosecute a suspected hacker, investigators have the power to conduct Internet searches or telephone taps without court-sanctioned permission.

One tool that a hacker can use to compromise an individual computer or a computer network is a virus. Depending on their design and intent, the consequences of a virus can range from the inconvenient (i.e., defacing of a web site) to the catastrophic (i.e., disabling of a computer network). Within a few years during the 1990s, the number of known computer viruses increased to over 30,000. That number is now upwards of 100,000, with new viruses appearing virtually daily.

Despite the threat that they can pose, computer hackers can also be of benefit. By exposing the flaws in a computer network, hackers can aid in the redesign of the system to make information more inaccessible to unauthorized access.

SEE ALSO Computer hardware security; Computer keystroke recorder; Computer security and computer crime investigation; Computer software security.

Computer hardware security

A phenomenal amount of information now resides on computers. Individual computers, computers that communicate with each other in geographically-restricted local networks, and computers that communicate globally via the Internet contain billions of pages of text, graphics, and other sources of information. Without safeguards, this information is vulnerable to misuse or theft.

This is true for computers used in **forensic science**, which help with the acquisition, storage, and analysis of data. As with any data stored on a computer, there are vulnerabilities. **Computer security** provisions are a prudent facet of any top-quality forensic science operation.

Computer security can take two forms. Software security provides barriers and other cyber-tools that protect programs, files, and the information flow to and from a computer. Hardware security protects the machine and peripheral hardware from theft and from electronic intrusion and damage.

Physical on-site security can be as easy as confining mission-critical computers to a locked room, and restricting access to only those who are authorized. This also holds for servers, which are computers that function as a central routing point for information to and from the networked computers and the Internet. Many personal computer users pay to have this service provided by an Internet service provider (ISP). However, having an outside provider can generate security threats and can be disruptive if the ISP ceases operation. Nowadays, many corporations opt to establish an in-house ISP. In this way the security of the corporate server is under direct control.

Computers also have an internal form of a lock and key. A security password that is needed to gain access to all of a computer's functions can be stored on a chip known as the BIOS chip. Unfortunately, a dedicated thief can easily circumvent this hardware security feature, by removing the hard drive and putting it into another computer with a different BIOS chip.

With the exploding popularity of the Internet, hardware security has been extended to this electronic realm. Computers that are connected to the Internet are vulnerable to remote access, sabotage, and eavesdropping unless security measures are in place to buffer the computer from the outside electronic world.

Many corporations whose computers are linked to one another employ a local version of the Internet. An intranet or local area network (LAN) allows the exchange of information between the linked computers, while at the same time enabling the erection of hardware and software (i.e., firewalls) that screen information flowing to and from the Internet. Remote users of the internal network, such as telecommuting employees, can be protected through what is known as a virtual private network (VPN). A VPN establishes a protected communications link across a public network between the remote computer and the computers physically linked in the local network.

The individual computers that are linked in a network, and the dedicated devices that route information back and forth, are also known as nodes. The security measures that have been discussed above also function to safeguard nodes.

At the core of a network is a physical device called the hub. The hub exchanges the information between all of the connected computers. As such, it is key to a network. A hub should be kept away from high traffic areas, and preferably in a secure room. This restricts tampering.

While a hub relays information indiscriminately from computer to computer, a device called a switch is more selective. Information can be sent to one user computer but not to another. The use of a switch allows a network administrator to control the information flow to authorized viewers, which can be a security issue.

Fluctuations in the power supply can play havoc with computers. For example, a blackout or brownout can cause a computer to shut down abruptly. Information that is stored only in short-term memory will be lost. As well, the fluctuation can physically damage computer components. The use of a surge protector can guard against electrical spikes and drops. An uninterruptible power supply (UPS) can also be hooked up to a computer. A UPS is essentially a battery that will power the computer in the event of a power outage. This can provide time for information to be saved and for a computer to be shut down correctly.

SEE ALSO Computer hackers; Computer keystroke recorder; Computer software security.

Computer keystroke recorder

In isolation or linked globally via the Internet, computers contain billions of pages of text, graphics, and other sources of information. Without safeguards to the computer hardware and software, this information is vulnerable.

This use and vulnerability of computers holds true for **forensic science**. Like other computer-intensive operations, safeguards that can monitor the activity of computer users can be a wise provision in forensic science.

One such safeguard is known as the computer keystroke recorder. As its name suggests, a computer keystroke recorder is a device for sequentially recording all the keys pressed on a computer keyboard. Numerous versions of keystroke recorders are available commercially, but much more sophisticated devices are used by government agencies such as the Federal Bureau of Investigation (**FBI**).

Also called a keystroke logger, key logger, or keylogger, a computer keystroke recorder is a program that runs in the background as the computer operates, recording all key depressions or strokes. Some such devices are plugged in manually, but the more effective types operate by means of a computer program. The latter may be introduced to the computer by means of a Trojan horse, a remotely inserted program that operates much like a virus.

An example of an FBI keystroke-recording Trojan is Magic Lantern, which made it possible to log keystrokes by means of a **computer virus** sent to a remote user's machine. The revelation of the device's use, reported by MSNBC News on December 12, 2001, invoked the ire of civil libertarians, as well as computer companies whose assistance the government sought. According to the MSNBC report, vendors of anti-virus software refused to cooperate with FBI requests to bypass special government-created Trojans and viruses used for security purposes.

The FBI and its computer keystroke recording technology also made the news in late 2001 due to its involvement in *United States vs. Scarfo*. The first known case of its kind, *Scarfo* involved a request by the defense to allow analysis of the keystroke recording technique used to gather **evidence** against the defendant. The government claimed protection of classified information under the Classified Information Procedures Act (CIPA), and the court granted the government's motion.

The remote use of programs like Magic Lantern has been encouraged by the passage of the U.S. Patriot Act in 2001 and the Cyber Security Enhancement Act of 2002. These legislations, which were prompted by security concerns in the United States in light of the September 11, 2001, terrorist attacks, have given government authorities far-reaching powers of access to any computer that is attached to the Internet. In some cases, the security procedures do not require court approval before being carried out.

SEE ALSO Computer hackers; Computer hardware security; Computer software security.

Computer modeling

Computer modeling is a general term that describes the use of computers to simulate objects or events. As such, it is sometimes known as computer simulation. Forensic applications of computer modeling can produce purely graphical results (for example, the face of an unknown murder victim reconstructed from a **skull**) or mathematical idealizations of physical, chemical, biological, or geological processes (for example, calculations performed to estimate the speed of a vehicle before an accident). Most forensic computer models are extensions of graphical and mathematical techniques that have been used by forensic scientists for many years, but which have become much more complicated and visually compelling because of continuing advances in computer technology.

Craniofacial reconstruction (re-building the shape of the skull and face) is one example of a purely empirical graphical forensic technique that is adaptable to computer modeling. The traditional approach is to shape layers of clay placed on a cast of a skull in order to produce a likeness of an unknown person. The thickness of clay on different parts of the skull is constrained by information from tissue thickness databases, which were originally obtained from cadavers but now measured using techniques such as computerized tomography (CT) scans, magnetic resonance **imaging** (MRI), or ultrasound imaging of living subjects. This has been an important advance, because cadaver measurements represented only a small segment of the general population. In computer-assisted craniofacial reconstruction, a virtual representation of the skull is created using a **laser** scanner or stereo **photography** to produce a three-dimensional mesh of points. Tissue thickness at selected points on the skull is specified mathematically, often using statistical relationships derived from large CT scan or MRI database, and the shape of the face is modeled as a smooth three-dimensional surface that passes through the measurement points. The main weakness of any craniofacial reconstruction technique is that the soft tissue thickness is always an estimate and it is difficult to infer facial characteristics reflecting age, weight, sex, and ethnicity from skull shape (although this information can be inferred from a complete skeleton). Superficial characteristics such as hair color and skin texture are impossible to infer from skull shape and are only artistic embellishments. Therefore, a general resemblance between a craniofacial reconstruction and a deceased person is the best that can be achieved.

Process-based forensic computer models combine equations describing physical or chemical processes with empirical information in order to reconstruct sequences of events. One widely used computer program for automobile **accident reconstruction**, known as SMAC (Simulation Model of Automobile Collisions), was originally developed by the National Highway Traffic Safety Administration. It uses Newton's laws of force and motion to simulate colliding automobiles as moving bodies in much the same way that one might simulate the collision of billiard balls. Factors such as road condition and tire type are incorporated using empirical coefficients, and the model input is adjusted until the output agrees with observations made at the accident site. Whereas this kind of computer model might calculate the energy at impact, it would not explicitly simulate the crumpling and deformation of the automobiles. Computer **animation** can be used to visualize the results of process-based models by depicting the automobiles as specific makes, models, and colors rather than nondescript masses or by incorporating realistic topography and scenery to simulate the accident scene. This kind of animation, in which variables such as vehicle position and speed are the result of scientific analysis and inference, is known as forensic animation.

A more sophisticated kind of process-based computer modeling involves the detailed simulation of physical or chemical processes in two or three dimensions (and often over time) in order to reconstruct an event or process. For example, a sophisticated accident model might simulate the bending and buckling of each structural member in an automobile rather than just the total amount of energy absorbed by one moving mass colliding with another. Another example is the use of computer models to simulate the two and three-dimensional movement of chemicals contaminating an aquifer. In order to obtain accurate results using this kind of model, geologists must collect detailed information about the materials comprising the aquifer by drilling test wells, taking samples of the aquifer materials, and conducting a variety of tests. The velocity and chemical composition of the groundwater are then calculated at many thousands, and perhaps even millions, of points within the simulated aquifer and the model is calibrated by adjusting the input until the results agree with observed conditions. Experts can use this kind of model to infer the source of the contaminants or the time that they entered the aquifer, which can be important in legal proceedings such as the well-known lawsuit concerning groundwater contamination in Woburn, Massachusetts. Fire scientists likewise use computational fluid dynamics models to simulate the spread of fires in buildings, and other computer models can be used to simulate the mechanics of solid objects, the flow of fluids, and chemical reactions. As computer models become more complicated, however, they also become more difficult to apply because the quality and quantity of input increase dramatically. As is the case for simple process-based models, the results of multidimensional can be visualized using static and animated computer graphics.

SEE ALSO Accident reconstruction; Aircraft accident investigations; Crime scene reconstruction; Fire investigation.

Computer security and computer crime investigation

Computer crime, or cyber crime as it is often known, is the fastest-growing type of criminal activity in the world today. As more advanced computers are manufactured, the more sophisticated the cyber criminals become. Computer crime covers a large range of illegal activity, including bank and credit card fraud, computer hacking, industrial espionage, organized pedophilia, and terrorism. What is more, computer crime has no national boundaries. Investigators face many technical and legal barriers when it comes to trying to identify perpetrators of cyber crimes. Yet there have been some successes, and **computer forensics** is becoming an increasingly important part of **forensic science**.

Much undesirable, if not actually illegal, computer activity happens in the workplace. A recent survey carried out by the Federal Bureau of Investigation showed that most organizations have found security breaches of their computer networks. The most serious outcome was theft of confidential information, costing millions of dollars to companies as a whole. Almost all companies had had viruses infecting their computers with loss or potential loss of valuable data. Another major form of unwanted computer activity consisted of defacement of the company's website. There was also widespread reporting of abuse of computer privileges by employees by downloading pornography or pirated software.

Hacking is the most common form of computer crime. It is defined as willful penetration of a computer system for malicious purposes. All computer users are vulnerable to hacking, regardless of how secure they assume they are through anti-virus software, firewalls, and password protection. It happened to software giant Microsoft after all, so it could potentially happen to anyone. Sending a virus, a small program that acts on the victim's computer, is one of the main ways in which hackers operate. There are many types of viruses. They do not all destroy data; some viruses are designed to send valuable data back to the hacker. Trojan horse viruses, for example, consist of hidden instructions in e-mails or software which, when opened, will damage, modify, or send important data. Another is the aptly

Photo of a computer opened on a exam table to retrieve data evidence at the FBI's Silicon Valley Regional Computer Forensics Lab on January 7, 2005, in Menlo Park, California. © KIM KULISH/CORBIS

named logic "bomb" that only takes effect a while after it has been sent, allowing the perpetrator ample time to clear away the **evidence**.

Once a hacker has access to a computer, he or she has access to much of the information inside it, such as bank details, credit card numbers, and passwords. On a personal scale, this kind of identify theft can be disastrous. For a company, it can lead to loss of revenue, delays, and loss of customers. Another growing form of computer nuisance is the sending of spam, or unsolicited e-mail. Measures are underway in many countries to make spam illegal, because it threatens to destroy people's ability to send and receive e-mail.

Investigating and stopping computer crime is difficult. Hacking is often not difficult to accomplish and the tools required to hack are freely available. Many hackers argue that hacking is often a victimless crime. Additionally, the Internet is international and the hacker is anonymous, which makes it hard to pursue and catch them. One answer is to step up computer security but, in reality, anti-virus software can only, by definition, deal with known viruses and so the software is always one step behind the inventive hacker.

Investigation of computer crime is also challenging because it can be hard to prove that a crime has actually been committed. Data can be manipulated after the event, because the hacker is rarely caught soon after the crime. Successful prosecutions are rare and punishments tend not be severe.

While computer forensics and approaches to investigation continue to develop, it is up to the individual and organizations to find ways of improving their computer security. Sometimes crimes are committed just by guessing someone's password. Longer passwords are harder to guess, therefore, most security experts recommend using passwords of at least 6–8 characters where possible. It may also help to get the hackers to turn their talents to helping the people they once attacked, by pointing out the weak points in their systems.

Despite the challenges, there have been some successful prosecutions of computer criminals. Recently, the U.S. government caught up with 19 individuals who ran one of the world's largest online centers for trafficking in stolen identities and financial fraud. The team, from the U.S. and several other countries, ran a site called Shadowcrew with 4,000 members dedicated to computer hacking for obtaining counterfeit documents, as well as stealing credit and debit card numbers. The U.S. Secret Service spent a year tracking down the gang. While operating, the gang had trafficked in at least 1.7 million stolen credit cards, causing losses in excess of four million dollars. In short, the site acted as a "one stop shop" for **identity theft**. They will trade no longer, and the successful conclusion of this case gives investigators renewed confidence in the fight against computer crime.

SEE ALSO Computer forensics; Computer hackers; Computer hardware security; Computer forensics; Computer virus; Identity theft.

Computer software security

Computers are an important facet of **forensic science**. Individual computers as well as computers that are electronically connected via the Internet house text, graphics, and other sources of forensic information.

This information can be vulnerable to unauthorized scrutiny, outright tampering, theft or misuse.

As with many other computer operations, computers that are critical to a forensic science operation ought to be equipped with a variety of hardware and software security features that help safeguard the information.

Software can prevent damage to computer files, programs, and operating systems, as well as to monitor a personal computer (PC) or laptop for theft.

A recommended feature for any computer that is connected to the Internet is software that protects the computer from viruses. Like biological viruses, computer viruses need the machinery of another host, in this case a computer, to make new copies of themselves and infect another host computer. There are upwards of 100,000 known viruses, with new viruses being detected literally every day.

Some viruses are hidden inside a program that appears safe. Once the program is downloaded into a computer and executed, the "Trojan" virus can enact great damage. Another type of virus called a worm usually is ferried into a computer via e-mail. The virus can then be emailed out to everyone in the computer's email address book. Thus, the virus can spread very widely and very quickly.

An infamous example is the "Love" virus, which infected millions of computers worldwide within hours of its release in May 2000. This virus was also a Trojan because it was contained in an innocuous appearing email attachment.

There are a wide variety of anti-virus software programs available that will recognize, quarantine and destroy many of these viruses. Anti-virus programs need to be updated frequently (often accomplished automatically "on-line" with some vendors products) to keep pace with the appearance of new viruses.

Next to viruses, theft represents the biggest security issue for computer users. Various hardware options are designed to lessen the chance of theft. Anti-theft software is also available. There are several software programs that aim to lessen the usability, and so the appeal, of a stolen computer (particularly laptop computers). In one setup, a registered identifier number is beamed out when the stolen computer is hooked up to the Internet. Proprietary software can detect and even track the location of the sending computer. Another strategy uses motion-sensing software that is adjusted to the motion patterns of the normal user. A different range of motions that are uncharacteristic of the principal user can trigger an audio alarm. As well, the computer is triggered to shut down and reboot. The user then needs to supply a complicated password to use the computer and even to read the scrambled files (see below) from the hard drive. This protection occurs even when the computer is shut off.

Another software security option is known as encryption. Encryption is the scrambling of the data into an undecipherable format. Encryption programs can scramble the data that is resident in the computer as well as data sent to another computer via email. The message can be reassembled to the original format if the receiving computer has an encryption program installed.

Computers connected to the Internet are often equipped with software known as a firewall. The firewall functions to monitor incoming transmissions and to restrict those that are deemed suspicious. It is a controlled gateway that limits who and what can pass through. A number of vendors offer firewall programs. Like anti-virus software, these programs can and should be frequently updated, since those who seek to maliciously gain remote access to computers are constantly developing methods to thwart the firewall barrier.

SEE ALSO Computer hackers; Computer hardware security; Computer forensics; Computer security and computer crime investigation; Computer virus; Document destruction.

Computer virus

As with other computer-based applications, **forensic science** can be compromised by agents that alter or disable computers, such as computer viruses.

A computer virus is a program or segment of executable computer code that is designed to reproduce itself in computer memory and, sometimes, to damage data. Viruses are generally short programs; they may either stand alone or be embedded in larger bodies of code. The term virus is applied to such code by analogy to biological viruses, microorganisms that force larger cells to manufacture new virus particles by inserting copies of their own **genetic code** into the larger cell's DNA. Because DNA can be viewed as a data-storage mechanism, the parallel between biological and computer viruses is remarkably exact.

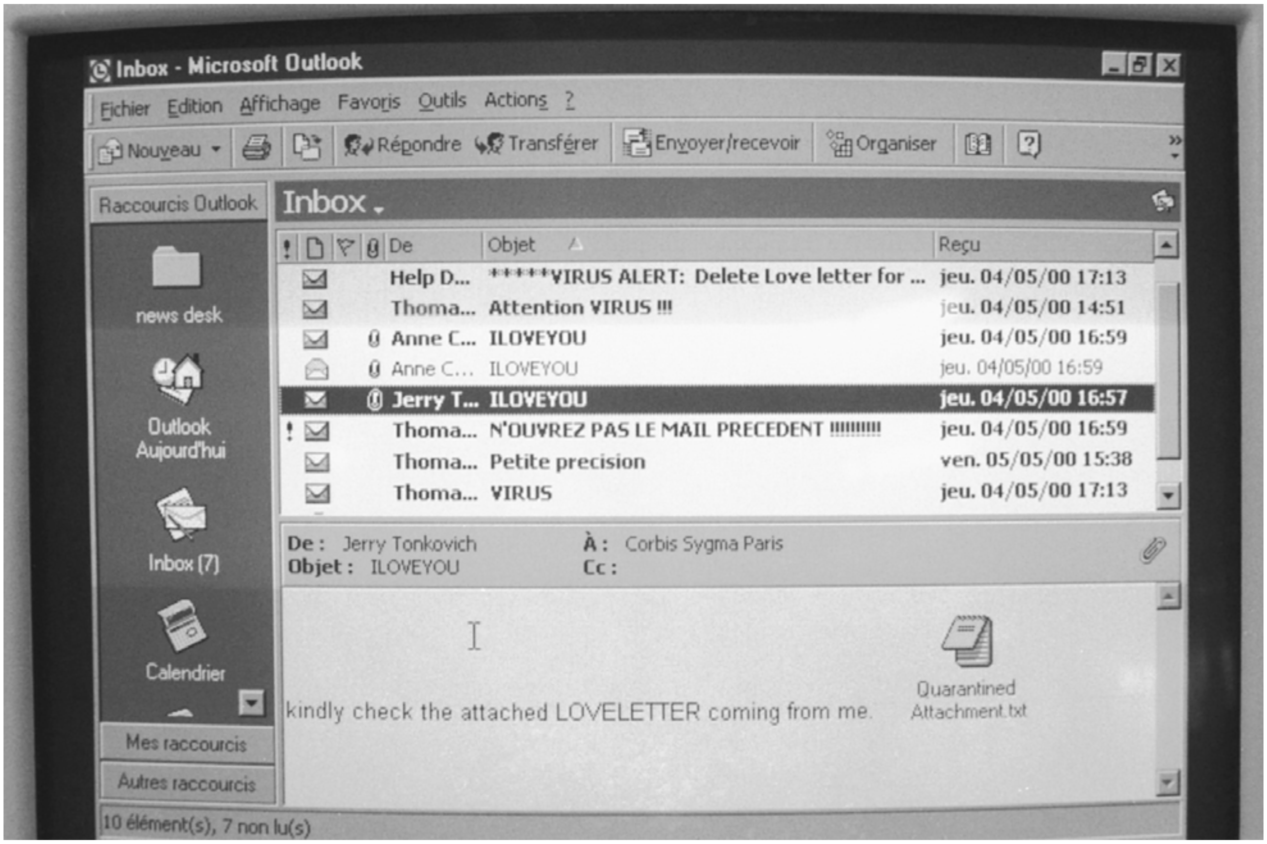
Many viruses exploit computer networks to spread from computer to computer, sending themselves either as e-mail messages over the Internet or directly over high-speed data links. Programs that spread copies of themselves over network connections of any kind are termed worms, to distinguish them from programs that actively copy themselves only within the memory resources of a single computer. So many worm/virus hybrids have appeared that any distinction between them is rapidly disappearing.

A program that appears to perform a legitimate or harmless function, but is in fact designed to propagate a virus is often termed a Trojan Horse, after the hollow, apparently-harmless, giant wooden horse that was supposedly used by the ancient Greeks to sneak in inside the walls of Troy and overthrow the city from within. Chain letters have also been used as carriers for executable viruses, which are attached to the chain letter as a supposedly entertaining or harmless program (e.g., one that will draw a Christmas card on the screen).

The first wild computer viruses, that is, viruses not designed as computer-science experiments but spreading through computers in the real world, appeared in the early 1980s and were designed to afflict Apple II personal computers. In 1984 the science fiction book *Necromancer* by William Gibson appeared; this book romanticized the hacking of giant corporate computers by brilliant freelance rebels, and is thought by some experts to have increased interest among young programmers in writing real-world viruses. The first IBM PC computer viruses appeared in 1986, and by 1988 virus infestations on a global scale had become a regular event. An anti-virus infrastructure began to appear at that time, and anti-virus experts have carried on a sort of running battle with virus writers ever since. As anti-virus software increases in sophistication, however, so do viruses, which thrive on loopholes in software of ever-increasing complexity. As recently as January 25, 2003, a virus dubbed SQL Slammer (SQL Server 2000, targeted by the virus, is a large software package run by many businesses and governments) made headlines by suspending or drastically slowing Internet service for millions of users worldwide. In the United States alone, this caused some 13,000 automatic teller machines to shut down for most of a day.

All viruses cause some degree of harm by wasting resources, that is, filling a computer's memory or, like SQL Slammer, clogging networks with copies of itself. These effects may cause data to be lost, but some viruses are designed specifically to delete files or issue a physically harmful series of instructions to hard drives. Such viruses are termed destructive. The number of destructive viruses has been rising for over a decade; in 1993 only about 10 percent of viruses were destructive, but by 2000 this number had risen to 35 percent.

Because even non-malicious or non-destructive viruses may clog networks, shut down businesses or websites, and cause other computational harm (with possible real-world consequences, in some cases), both the private sector and governments are



The "ILOVEYOU" computer virus cyber greeting as it appeared as an e-mail message. © SERRA ANTOINE/CORBIS SYGMA

increasingly dedicating resources to the prevention, detection, and defeat of viruses.

The first virus designed to be mass propagated, and perhaps the most famous virus to date, is a virus dubbed Melissa. The virus' creator, David Smith, initially unleashed the virus as part of an attachment in a file posted to a pornographic news group. The popularity of the group ensured a swift spread. For his dubious efforts, Smith was ultimately sentenced to 20 months in federal prison and fined $5,000.

Another infamous virus is the Michelangelo virus. Having infected a computer's hard drive, the viral program can wipe out information on the drive. The viral destruction is triggered by a certain date (March 6, presumably the birthdate of the Italian Renaissance artist and inventor Michelangelo Buonarroti). While some viruses are rather innocuous, the Michelangelo virus is malicious. Fortunately, the threat posed by this virus has passed.

An exhaustive list of current viral threats is essentially impossible. Twenty to 30 new viruses are identified every day, and over 50,000 viruses have been detected and named since the early 1980s, when computers first became integrated with the world economy in large numbers.

Most viruses are written merely as egotistical pranks, but a successful virus can cause serious losses. The ILOVEYOU virus that afflicted computers globally in May 2000 is a dramatic recent case that illustrates many of the properties of viruses and worms.

The ILOVEYOU virus was so named because in its most common form (among some 14 variants) it spread by looking up address-book files on each computer it infected and sending an e-mail to all the addresses it found, including a copy of itself as an attachment named LOVE-LETTER-FOR-YOU.TXT.VBS. ("VBS" stands for Visual Basic Script, a type of file readable by World Wide Web browsers.) If a recipient of the e-mail opened the attachment, the ILOVEYOU virus code would run on their computer, raiding the recipient's address book and sending out a fresh wave of e-mails to still other computers.

The ILOVEYOU virus first appeared in Asia on May 4, 2000. Designed to run on PC-type desktop computers, it rapidly spread all over the world, infecting computers belonging to large corporations, media outlets, governments, banks, schools, and other groups. Many organizations were forced to take their networks off line, losing business or suspending services. The United States General Accounting Office later estimated that the losses inflicted by the ILOVEYOU virus may have totaled $10 billion worldwide. Monetary losses occurred because of lost productivity, diversion of staff to virus containment, lost business opportunities, loss of data, and loss of consumer confidence (with subsequent loss of business).

National security may also be threatened by computer viruses and similar software objects. During the ILOVEYOU incident, the U.S. Department of Health and Human Services was disrupted for many hours. An official of the department stated that if a biological outbreak had occurred simultaneously with this "Love Bug" infestation, the health and stability of the Nation would have been compromised with the lack of computer network communication.

The U.S. National Security Agency has stated that at least 100 governments are developing viruses and other cyberweapons, as well as terrorist groups. To counter such threats, the U.S. government has established a National Infrastructure Protection Center in the Federal Bureau of Investigation to coordinate information on threats to infrastructure, including threats (such as viruses) to computers and telecommunications networks.

SEE ALSO Computer hackers; Computer hardware security; Computer keystroke recorder; Computer modeling; Computer software security.

Confocal microscopy

The examination of samples obtained from an accident or crime scene can be a sophisticated process. Some of these examinations can determine the presence of certain compounds or materials. Various microscopic methods can be used to visually examine samples. The choice of the microscopy technique can be determined in part by the size of the target. For example, **gunshot residue** may be too small to be seen using a visible light microscope. Rather, the increased magnification available through the use of electrons or **laser** light is needed to resolve the residue.

Another sophisticated form of microscopy that is useful in forensic analyses is called confocal microscopy. As one example, the technique has been used to visualize the marks on bullets and cartridge cases that were otherwise not easily seen using conventional light microscopy

In confocal microscopy, the source of illumination is laser light. A laser light wave can be focused to a very small area on a specimen, which permits very detailed examinations on a sample to be done.

As well, the wavelength of light used can be specifically selected. This is advantageous because some molecules and stains that can be applied to a sample will fluoresce when exposed to the particular wavelength. **Fluorescence** occurs when the sample molecules acquire more energy when they absorb the laser light. This energy increase is transient, and some energy is subsequently emitted. The emitted energy is the fluorescent light.

When a solid sample is examined, the confocal microscope can be equipped with detectors to capture the light that is reflected back off of the surface and the fluorescent light that is emitted. This information can be analyzed using a computer that is connected to the microscope and a very detailed image of the specimen can be produced.

If a specimen is transparent to the laser light, then the light beam can be progressively focused at different depths through the thickness of the specimen. The information collected from the reflected light at each of these so-called optical planes can be stored in the computer. Subsequently, each image can be analyzed separately to assess the composition and structure of the specimen throughout its depth. As well, the collected images can be merged together to produce a three-dimensional image of the specimen.

When confocal **microscopes** first appeared in the 1980s, they were expensive and beyond the range of many labs. However, now they are quite affordable and have become a popular addition to a forensic laboratory.

SEE ALSO Analytical instrumentation; Crime scene investigation; Fluorescence; Imaging; Scanning electron microscopy.

Contact crimes

As it is defined in the United States, a contact crime is one in which the perpetrator is known to the victim, or the victim and perpetrator repeatedly encounter each other through everyday activities, such as working in the same environment or riding the same subway train. A contact criminal is one who knows his victim (the term "he" is used as a convention throughout, as the majority of contact and other criminals are male). Most contact crimes involve some form of sexual assault, and the preponderance of sexual assault victims are female. More than 70% of contact murders are committed against females, and more than 80% of nonlethal contact crime victims are female.

A contact criminal need not be well known to the victim. Some contact criminals use the same location or environment in the perpetration of their crimes. Others seek out and get to know their victims, while still others place themselves in locations where they will encounter and desensitize potential victims (build an acquaintance-type relationship, creating a semblance of trust in the potential victim). According to the Bureau of Justice Statistics on victims of crime, nearly 70% of all reported female rape victims were acquainted with, related to, or intimately knew their assailants. Of young children murdered, approximately one fifth were killed by family members; adolescents (ages 15–17) were most likely to be murdered by an acquaintance or a friend.

A by-product of contact crime is its low incidence of reporting and successful prosecution. According to statistics released by the United States Senate Judiciary Committee, less than 10% of all violent contact crimes are actually reported to the police. Of those violent crimes reported, less than 1% result in a conviction involving incarceration. Some social scientists characterize the justice system as viewing contact crimes as less serious than other crimes, where the assailant is a stranger to the victim.

Contact crimes are often considered difficult to prosecute because there are rarely any witnesses, the victims do not always seek immediate medical assistance, appropriate forensic **evidence** is not always collected when the offense is promptly reported, and perpetrators rarely confess voluntarily. A significant deterrent to the reporting of contact crimes is the perception that the negative attention generated could make victims seem as much on trial as the alleged assailants. When children are the victims of contact crime, they are statistically unlikely to report it voluntarily, often as a result of intimidation by the perpetrator. Children are often not considered either accurate historians or reliable witnesses. Contact crimes against children are infrequently successfully prosecuted without ample **physical evidence** or eyewitness testimony.

SEE ALSO Expert witnesses; Gang violence, forensic evidence; Illicit drugs; National Institute of Justice; PERK (physical evidence recovery kit).

Control samples

Control samples are any type of well-known forensic samples used to assure analyses are properly performed so that results are reliable. Also called controls, known samples, and knowns, these control samples are fully known to the forensic community with respect to composition, identification, source, and type. Examples of control samples include known combustible substances used for **arson** cases, known drug samples for suspected illegal drug samples, known **blood** types in violent crime investigations, and known **DNA** types for **trace evidence** cases.

Control samples are an important part of quality control and assurance procedures that forensic scientists use to eliminate the inaccuracy of laboratory results. Without control samples such scientific results could yield false positives (any result that is true when in reality it is false) and false negatives (any result that is false when in reality it is true). For example, a forensic scientist tests a control sample along with a suspect sample when conducting DNA analysis. The control sample is collected before the suspect sample to reduce the possibility of contamination.

Control samples are acquired through any source that is considered completely reliable and whose identification has been verified through proper authorities. These sources include commercial vendors and manufacturers for such items as ammunition, **fibers**, and paints. The Forensic Science Service (FSS) in England, for example, examines fibers and paints recovered from crime scenes with microspectrophotometers. These sophisticated devices measure the spectra of a single suspect sample for comparison with the spectra of a control sample. Because the FSS is recognized internationally as a leader in applied forensic technology, its complex comparisons of suspect (or crime scene) samples and control samples are regularly used as **evidence** in courts of law.

Another often used type of control sample is one that contains nothing, a blank. In these cases, the control sample is known not to contain whatever substance is being considered. The idea behind a blank sample is to verify that the test instruments, equipment, or other implements are not contaminated with the substance being considered (which would lead to a false positive result). As an example, if an instrument has been used to test an illegal drug, then it is necessary to make sure that the instrument has been sterilized. When a blank sample is tested on the instrument, one that is known to be free of that illegal drug, a positive result will identify a contaminated instrument and require that the instrument be sterilized before proceeding with analysis.

SEE ALSO Forensic Science Service (U.K.); Quality control of forensic evidence.

Patricia Cornwell

6/9/1956–
AMERICAN
WRITER

Patricia Cornwell is an award-winning novelist of forensic mysteries and police procedurals that focus on medical autopsies and investigations. Her novels are characterized by the graphic authenticity of their detail and their compelling psychological studies of law enforcement and forensic professionals at work.

Cornwell has helped expand the role of the female detective in the mystery genre with her two recurring heroines—medical examiner Kay Scarpetta and police chief Judy Hammer. Her books' accurate detail is based upon research Cornwell did while a journalist working the beat in the Virginia medical examiner's office, where she witnessed scores of autopsies. Cornwell has also gone on police homicide runs. Cornwell's books regularly debut on the *New York Times* bestseller list and have a reputation for confronting readers with the occasional stomach-turning passage due to their graphic descriptions of dismemberment, murder, autopsies, and forensic **pathology**.

Cornwell was born in Miami, Florida, to Sam and Marilyn Zenner Daniels. Her parents divorced when Cornwell was five years old, and her mother moved her daughter and two sons to Montreat, North Carolina. By the time Cornwell was nine years old her mother was suffering from severe clinical depression. Unable to cope, she turned her children over to her Montreat neighbors, the Reverend and Mrs. Billy Graham. Ruth Graham put the children into foster care with a missionary couple who had recently returned from the Congo. It was Ruth Graham who encouraged young Cornwell to pursue writing. In high school Cornwell earned top grades, but pushed herself in other areas as well, battling anorexia and bulimia. She was briefly hospitalized for depression in the same facility where her mother had once stayed.

With Mrs. Graham's ongoing encouragement, Cornwell returned to school at Davidson College in North Carolina, majoring in English. After graduation she married Charles Cornwell, one of her former professors, and began working as a crime reporter for the *Charlotte Observer*. In 1980, Cornwell received an investigative reporting award from the North Carolina Press Association for a series she did on prostitution. At a time when Cornwell felt her career was getting underway, her husband decided that he wanted to become a minister, and the couple moved to Richmond, Virginia, where Charles Cornwell attended Union Theological Seminary. During this period, Cornwell began working with her husband to expand a newspaper profile she had written on Ruth Graham into her first book, *A Time for Remembering: The Story of Ruth Bell Graham.*

Patricia Cornwell holds a knife that was available in England when "Jack the Ripper" went on his killing spree. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

The book was such a success, Cornwell decided to try writing crime novels with the information she had gathered as a reporter. To make her murder plots seem more believable, she engaged in in-depth research. For advice and information, she turned to the deputy **medical examiner** at the Virginia Morgue, pathologist Dr. Marcella Fierro. Cornwell soon became a regular visitor at the forensic center and also took on technical-writing projects for the morgue to absorb more of the forensic knowledge she craved. The result was *Postmortem*, the first in a series of mysteries chronicling Cornwell's fictional investigative forensic pathologist, Dr. Kay Scarpetta. *Postmortem* focuses on the rape and murder of several Richmond women by a serial killer.

In subsequent novels of the series, Cornwell introduces Temple Gault, a serial killer whose intelligence matched that of Scarpetta. Gault, who specializes in the murder of children, only narrowly escapes being captured by Scarpetta herself in Cornwell's 1993 novel, *Cruel and Unusual*. Scarpetta faces Gault again in *From Potter's Field*, published in 1995 and set in New York City.

In 1996, Cornwell signed a contract with publisher Penguin Putnam, reportedly in the realm of $24 million for three books. *Cause of Death*, which appeared in 1996, was her first for the publisher. Her impressive sales figures continued with *Unnatural Exposure* in 1997, *Point of Origin*, published in 1998, and with her new, lighter series of crime fiction featuring Andy Brazil, a young police detective with a journalism background. *Hornet's Nest*, *Southern Cross*, and *Isle of Dogs* belong to this second series. Cornwell has also penned a novelette centered on a holiday-season get-together, *Scarpetta's Winter Table*, as well as a cookbook, *Food to Die For: Secrets from Kay Scarpetta's Kitchen*.

Cornwell took some 13 months to research and write her nonfiction book *Portrait of a Killer: Jack the Ripper—Case Closed*. In the book she claims to have solved the mystery of Jack the Ripper's identity, which was still unknown a century after the mysterious killer committed a series of gruesome murders in London's East End. Cornwell came to believe that the respected British Impressionist artist Walter Sickert (1860–1942) was the real Jack the Ripper, and her book makes the case for this theory. Sickert's artwork provides one source of **evidence** for Cornwell, who claims that several of Sickert's paintings of nude women resemble the Ripper's victims. She also argues that letters supposedly written by Jack the Ripper to London newspapers match Sickert's handwriting and were written on stationery owned by Sickert. Cornwell asserts that she has also identified later victims of the Ripper, victims not before linked to the infamous killer. She also used the book to take the "opportunity to push **forensic science** to limits that it hasn't been pushed to before—for example, using **DNA** on a 114-year-old case."

Cuyahoga County Coroner Elizabeth Balraj talks Tuesday, Jan. 18, 2000, in Cleveland, Ohio, about the results of tests conducted on the exhumed remains of Marilyn Sheppard as part of the state's attempt to show that Dr. Sam Sheppard killed Marilyn in 1954. TONY DEJAK/AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

SEE ALSO Autopsy; Crime scene investigation; DNA databanks; Literature, forensic science in; Medical examiner.

Coronal plane SEE Anatomical nomenclature

Coroner

The coroner is the person who is responsible for the legal investigation of any unexplained or suspicious death occurring within their area of jurisdiction. It is the coroner's job to determine the manner and **cause of death**. The manner refers to whether the death occurred naturally or by another's hand or by accident. The cause is the medical reason for the death.

Las Vegas Coroner Michael Murphy looks over autopsy x rays on Jan. 27, 2004, of two recent self-inflicted gunshot deaths of visitors to Las Vegas. JOE CAVARETTA/AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

The coroner system has a long history in English speaking cultures, with the office existing in England before the tenth century. Indeed, the word coroner comes from the title of the person who crowned the king. Originally, the coroner was not required to have any particular **training** and many were not even qualified doctors. Coroners were appointed or elected to the position as to any other local political role. In the nineteenth century, when medical education became more formalized, coroners began to be replaced by medical examiners (MEs) in some states, beginning with Massachusetts. The change gathered pace through a series of scandals in New York City where deaths occurring through incompetent anesthesia were not, it was felt, properly investigated. Consequently, the New York administration required that deaths through surgery be examined by a medical practitioner. The ME is medically qualified, although their specialty is not necessarily forensic **pathology**, or even pathology. Some modern coroners are both lawyers and physicians, although there are still some medically unqualified coroners in rural areas.

Today a coroner who is not medically qualified will consult an ME or forensic pathologist for carrying out autopsies, supervising the forensic laboratory, and testifying in court. The ultimate duties of the coroner include the **identification** of the deceased in a suspicious death, determination of the **time of death** (as well as its manner and cause), collection of **evidence** relevant to the death, and the certifying and signing of the death certificate.

The coroner or ME typically investigates any death that is traumatic, which might have arisen from accident, **murder**, or suicide. Deaths that are sudden, unusual, or unexpected will also be reported to the coroner. Any death that is unattended by a physician or which occurs within 24 hours of hospital admission or during a medical or surgical procedure will also be reported. Deaths in prison or in police custody are also brought to the coroner's attention. Perhaps a quarter of all deaths will be brought to a coroner's attention each year, although clearly this varies from time to time and from place to place. If there is cause for doubt, then the attending physician will not issue a death certificate, but will refer the matter to the coroner. The remainder of deaths are clearly from natural causes and the doctor can immediately sign the death certificate and release the body for burial or cremation.

Not all of the deaths reported to the coroner will justify an **autopsy**. The coroner will consult with the person's physician and may decide the death occurred through natural causes if there are no suspicious circumstances and the medical history of the deceased lends support to this view. If either party has any doubt, however, an autopsy and full investigation should be carried out. The rate of autopsy varies. Often a low autopsy rate occurs where it is the practice to have an ME perform an external examination on every corpse referred for investigation, as this measure alone is often sufficient to establish the manner and cause of death.

If the autopsy reveals death by natural causes, and sometimes this can only be determined by an internal examination, then the coroner can sign the death certificate and release the body to the family for burial or cremation. If the death was not by natural causes or if there is some public interest in it, then the coroner will hold an inquest, which is a public inquiry into the death. The inquest is not a trial; it seeks to find out who the victim is, where and when they died and, most difficult, how. There is a specific list of possible verdicts that can form the conclusion of an inquest. These include: unlawful killing, lawful killing, accident, suicide, natural causes, and an open verdict, where there is insufficient evidence to reach any other conclusion. Unlawful killing includes murder as well as **manslaughter** and death by dangerous driving. If the death is due to criminal activity, such as murder or manslaughter, then the inquest is usually adjourned if the police charge someone with causing the death.

SEE ALSO Autopsy; Careers in forensic science; Death, cause of; Medical examiner.

Counterfeit currency, technology and the manufacture of

In crimes involving counterfeit banknotes, a **forensic science** lab is often consulted to determine the presence of latent fingerprints and the origin of dyes and other materials used in producing the forged currency. Counterfeiters use a variety of methods to escape detection.

In the past, counterfeiters produced false banknotes with printing presses, and some of the more skillful counterfeiters went to great lengths to imitate the original. Today, sophisticated computer printers and copiers enable even unskilled would-be counterfeiters to produce notes that bear at least a superficial resemblance to real ones. However, the federal government continually works to stay a step or more ahead of counterfeiters, updating currency and making it ever more difficult to duplicate.

For virtually as long as there has been regular currency, there has also been false currency, which has provided a highly lucrative illegal trade to those who can successfully pass off false banknotes as the genuine article. The period since the middle of the twentieth century has seen two significant waves of counterfeiting. First, there was a surge in the illegal production of banknotes during the 1960s, when advances in printing and graphic arts technology enabled counterfeiters with the right equipment and skills to produce highly accurate copies of federal currency. By the 1990s, however, counterfeiting by means of the printing press had diminished in significance compared to a new variety of counterfeit currency manufacture, this one using computer printers.

The phenomenon of P-notes, or printer notes, first came to the attention of law enforcement in the early 1990s. In 1995, authorities made a total of 37 arrests nationwide in connection with the production and distribution of currency produced on ink-jet or laser-jet printers. By 2000, this number had skyrocketed to 4,500 arrests, and officials estimated that P-notes accounted for as much as 40% of the currency seized by the United States Secret Service (USSS) and other agencies annually.

The change in choice of technology also signaled a change in the profile of the average counterfeiter. The old variety of criminal operating in this field tended to be mature and skilled—a professional, highly trained practitioner who usually possessed, or at least had access to, printing equipment whose operation would require knowledge far beyond that of a novice.

The 1990's variety of counterfeiter, by contrast, fit a quite different profile. Rather than being professional counterfeiters, they were more likely to be drug dealers who used their P-notes in connection with other crimes, most notably the purchase of

A "100" visible only under ultraviolet light helps distinguish genuine German Mark currency from counterfeit bank notes.
© ROYALTY-FREE/CORBIS

drugs. Typically youthful (many were juveniles), these new counterfeiters lacked skills for counterfeiting. Whereas the old model at least required some degree of human ingenuity, the new type of counterfeiting was primarily a matter of possessing the right equipment.

Equipment loomed large in the old counterfeiting technology as well, but practitioners had to know how to use it. Counterfeiters of that era carefully studied currency, and made numerous photographs of it with graphic-arts **cameras** using different filters so as to break down the various stages of the printing process. Only after considerable trial and error could a workable set of printing plates be produced.

In contrast to this painstaking process, the new counterfeiting process required only that one use a high-quality scanner to obtain an image of a bill, then print that bill on a printer with high resolution. Given the ease of production, counterfeiting again became a growth industry during the 1990s, and in 2001, the federal government seized a record $47 million in counterfeit currency. By the following year, the figure had dropped to $43 million.

The fact that the value of counterfeit currency seized in 2002 had dropped by almost 10% is not an indication of looser standards in interdiction. Rather, after the September 11, 2001, terrorist attacks on the United States, the federal government was more likely to be aggressive in searching for counterfeiters, whose ranks could presumably include foreign operatives funding illegal operations while undermining the value of U.S. currency. The reduction in seizures is probably an indication of success in efforts by the federal government to make its currency more difficult to duplicate.

In 1996, partly as a response to the proliferation of P-bills, the U.S. currency underwent its first major redesign in 70 years. Already difficult to duplicate, the currency became much more so thanks to measures such as the use of optically variable ink (OVI). The latter contains tiny particles of special film such that it changes color depending on the angle from which it is viewed. Extremely expensive and therefore used in limited quantities, OVI is just one of several specialized varieties of ink used in producing currency. None are commercially available—another hurdle in the production of false currency.

A number of other features distinguish genuine currency from counterfeit. One of the most obvious ones is the paper itself. Every variety of national currency is made with a special type of paper (the Australian dollar is actually printed on very thin plastic), and U.S. currency uses a highly durable variety made from cotton pulp. Not only does it have a distinctive texture, it is far more resistant to tearing, deformation, moisture, or sunlight than most varieties of paper. Again, currency paper is not commercially available.

For the counterfeiter, a genuine banknote is a veritable minefield of potential pitfalls, and literally every square millimeter presents its own challenges. There are watermarks, embedded threads, see-through features, microprinting, holograms, latent images—even forms of embossing to facilitate recognition of various denominations by the blind and visually impaired. The printing of currency is also highly complicated, involving various processes at different stages. In addition to lithography, letterpress, and sometimes silkscreening, there is intaglio, an extremely expensive, technically difficult process in which the surface of the paper is deformed very slightly—another distinctive feature of official currency production.

Aside from these challenges to the would-be counterfeiter, there is also the problem of producing a usable serial number. Given these challenges, a drug dealer with a computer printer or copier is unlikely to enjoy long-term success in this illicit trade. For those using a copier, the problem is rendered even greater by additional measures. Most modern forms of currency have anti-copy features, tiny designs that have words such as *VOID* or *FAKE* embedded in them in such a way that they will be visible if copied.

Manufacturers of color copy machines have also implemented a number of measures to circumvent the use of their equipment for illegal purposes. Most modern copy machines carry and embed unique **codes**, invisible in ordinary light, such that their products are traceable to a specific machine. There is also technology that detects specific design elements of currency, and will cause the copier to shut down if is used for illegal purposes.

SEE ALSO Ink analysis; Latent fingerprint; September 11, 2001, terrorist attacks (forensic investigations of); Typewriter and printer analysis.

Crime scene cleaning

When a crime is committed, forensic investigators come in, survey the scene, collect the **evidence** they need, and then depart. Any bodies are, of course, removed. Crime, especially **murder**, suicide or robbery, is a messy business and the scene may be left in a state of some disarray. The next stage is crime scene cleaning, restoring the premises to the state they were in before the crime was committed. The police do not carry out crime scene cleaning. The job is usually assigned to a specialist technical company.

Crime scene cleaning is a specialized job employing highly trained technicians. First, the cleaners inspect the scene and make a written proposal of what needs to be done. Biohazardous waste, including **blood**, bodily excretions, and human tissue, is often present even after the forensic investigators have taken their samples. The technicians, dressed in surgical gloves and thick protective jumpsuits, will collect this waste, package it up, and have it disposed of through a licensed waste company. They also take up and remove soiled or stained material such as carpets and curtains. Cleaning companies follow guidelines issued by the health authorities for handling and disposing of biohazardous waste.

The site is then cleaned, disinfected and deodorized. This is particularly important if bodies have lain at the scene for some time. If there is structural damage, through breaking and entering for instance, the cleaners can repair, restore, and repaint. The technicians are also trained to preserve the scene should they discover additional evidence during their clean up.

There is a human side to this work too. Knowing they are not responsible for cleaning up the scene of a crime is important to a victim's relatives. A good clean up company will do the work for them in a safe and discreet manner. They will also be able to help the victims with work on any insurance claims arising from the damage done by the crime. At a time of distress this kind of support is often appreciated. Crime scene clean up may be an unpleasant job, but the people who are prepared to take it on do a valuable job for both the police and the victims of crime.

SEE ALSO Crime scene investigation.

Crime scene investigation

Scene **processing** is the term applied to the series of steps taken to investigate a crime scene. Although the methods and techniques may differ between the experts involved, their goals are the same: to reconstruct the exact circumstances of the crime through the identification of the sequence

Jewish officers in Brooklyn, New York, clean blood from the scene of a shooting according to tradition. © MARK PETERSON/CORBIS

of events and to gather **physical evidence** that can lead to the identification of the perpetrators.

Crime investigation usually begins at the place where the crime was committed. The area must be isolated and secured to prevent the destruction of crucial physical **evidence** that can lead police to link the perpetrators to the victim. The size of the area to be isolated and secured varies with each case, and a series of protocols designed to secure and protect evidence are followed.

The first police officer on the scene is responsible for preventing other non-essential police personnel and civilians from entering the scene and often establishes a perimeter around the crime scene with ropes or tapes. If witnesses are present, they are identified and remain outside the perimeters of the crime scene while waiting for questioning by the investigation team. If a death has occurred, a **coroner**, a crime scene technician, and investigators are requested to the scene to assist the police.

The crime scene technician is an expert in finding and identifying physical evidence such as hairs, **fibers**, empty bullet capsules, bloodstained objects, and body **fluids** which may be found in carpets, on furniture, on walls, etc. The scene and each piece of evidence is carefully photographed and then properly collected and conditioned to avoid contamination, to be later analyzed at the crime laboratory. This expert also writes a thorough report of the scene and describes the evidence found.

The investigator interviews witnesses, gathers information from the police on the scene, the crime scene technician, the coroner, pathologist, and other specialists that are present (such as a forensic anthropologist). The investigator is also responsible for the management of information given to the press, deciding what should or should not be initially disclosed to the public in order to not endanger the success of the investigation. The investigator will discuss with the prosecutor's office the available evidence and other information to determine the legal direction of the investigation, since both are responsible for the entire investigative process and for building a case when prosecuting persons charged with the crime.

The coroner or **medical examiner** on the scene instructs the pathologist as to what physical evidence

Police crime scene investigators look for clues and evidence at the burial site of a murder victim near the River Kent in Kendal, Cumbria, England, in 2004. © ASHLEY COOPER/CORBIS

should be collected from the corpse and determines how the victim was killed and what caused the death. The coroner or medical examiner is also the liaison person between the crime scene technician, the pathologist, and the investigators, providing useful information that can either identify the murderer or yield important leads. The pathologist collects physical evidence from the body, such as chemical or metallic residues, body fluids, hairs, or skin residues under the nails. **DNA** content from such organic samples may be compared against **CODIS** (the Combined DNA Index System) to verify whether it belongs to a known criminal, or it can be compared to other samples collected from specific suspects.

For investigative purposes, the area of a crime scene is always larger than the actual site or room where the crime occurred. Therefore, the first officer on the scene must be trained to identify and isolate the primary and secondary areas of the scene. If a body was found indoors, for example, the crime scene primary area is the room where it was found. The secondary crime scene perimeter is the remainder of the house or building, along with all the doors, windows, and corridors that give access to the primary area, including front and back yards. The secondary areas may contain important evidence of a fight, footwear prints, fingerprints, broken windows or doors, tire prints, or bloodstains.

In cases when a highly probable suspect is known, the suspect's house or car may also be treated as a secondary crime scene area, even when it is not located in the proximity of where the crime was committed. All physical evidence identified in both areas may help in the reconstruction of the chain of events of the criminal act.

The services of a forensic anthropologist are requested when highly decomposed or charred human remains are found, when difficulty in gathering physical evidence is experienced, or when the identification of the victim or the **cause of death** is not apparent. A series of physical changes and interactions with soil bacteria, insects, and animals takes place when humans are buried, especially in mass graves. In these cases, the anthropological analysis of hair, bones and soft tissues (if available) may reveal race, gender, stature, approximate age at the **time of death** and, often, the cause of death. The conduction of evidence gathering in these cases is a different procedure, usually not familiar to most crime scene technicians, and involves archeological techniques, soil analysis, identification of buried debris, recognition of buried marks of hands or footwear, and **animal evidence**.

Forensic anthropologists are often consulted for "cold case" investigations when human remains are unexpectedly found. These scenes should also begin with securing of the scene by the police, in case a determination is later made that a crime was committed. At least 10 yards around the spot where the remains are (or are believed to be buried) should be isolated. The anthropological gathering of evidence will take at least a full day, and when the remains are buried, two days. Only after this phase is completed can the remains be removed from the site. Forensic **anthropology** techniques may supply not only relevant physical evidence but also contextual information about the circumstances of the death, through the three-dimensional mapping and analysis of the scene, the location and interrelationship of physical evidence scattered around the remains, depth of the grave or pit, and geological characteristics of the soil.

SEE ALSO Analytical instrumentation; Animal evidence; Anthropology; Anthropometry; Artificial fibers; Autopsy; Ballistic fingerprints; Bloodstain evidence; Bite analysis; Crime scene reconstruction; CODIS: Combined DNA Index System; Death, cause of; Decomposition; DNA fingerprint; Entomology; Exhumation; Fingerprint; Hair analysis; Impression evidence; Pathology; Trace evidence.

Crime scene reconstruction

The process of working out the sequence of events before, during, and after a crime is known as crime scene reconstruction. It is perhaps one of the aspects of **forensic science** that fascinates the public most, featuring in most police dramas. Reconstruction requires not just a scientific approach but also logic, experience, and open-mindedness on the part of the investigating team who must be prepared to set aside any hypothesis that does not fit with the actual **evidence** presented to them.

Reconstruction starts when the investigator takes a first walk through the scene where the crime took place. Even at this stage, it may be possible to construct a rough hypothesis of what may have happened and how. A hypothesis is a set of ideas or a general picture of what may have happened. It does not become a theory until it fits all the available evidence and supporting information.

While the investigator is forming a first impression, others are recording the scene and gathering evidence. Crime scenes vary enormously, from a petty theft or break-in to violent crime that may involve fire or explosions. The principles of investigation remain the same, although the investment of time and energy into it will vary with the seriousness of the crime. The investigator will want to establish who was involved—that is, what are the identities of the victim, perpetrator, and witnesses. They also need to know where, when, how, and why the crime took place.

The crime scene is first documented through note-taking, video, **photography**, and sketching. The investigating team will then search for, record, collect, and take away various kinds of evidence such as toolmarks, hair, bloodstains, **fibers**, and footprints. According to **Locard's exchange principle**, every contact leaves a trace. That is, those involved in the crime always leave something behind or take something with them. Think of putting your hand on a patch of wet paint. The handprint may be clearly visible. You will also have paint stains on your hand. Evidence of this kind in a crime situation is known as **trace evidence** and consists of tiny amounts of substances like fibers, paint, mud, soil, or **blood**. Often is it only visible through a microscope and needs specialist laboratory investigation to assess its significance to the investigation.

To render trace and other types of evidence valid and admissible to the court, it is essential to have strict control of how the site is investigated to avoid undue interference or contamination. That is why access to the crime scene has to be limited and those involved will always proceed from the police cordon to the site of the crime itself down a common approach path, which will be set so as to allow minimal interference with any evidence.

Everyone who handles a piece of evidence is recorded and hands it on the next in line so that a tight chain of custody—from the scene to the laboratory and, eventually, the court room—is created. There are special ways of transporting evidence to protect it. Dry trace evidence, such as hairs and fibers, might be placed in druggists' folds, which are small, folded papers. Wet evidence, including bloody clothing, has to be allowed to air dry because moisture can attract molds that might decay the specimen, rendering it useless. After being placed inside an appropriate primary container, pieces of evidence are then placed inside a larger container, completely sealed with tamper-proof tape and carefully labeled.

Each item is packed separately to prevent cross-contamination, which could otherwise destroy the credibility of the evidence. In the case of toolmarks on points of entry, it may even be necessary to remove a whole door or window rather than attempt to excise the mark, which may damage it. Once in the forensic laboratory all the pieces of evidence are then analyzed and interpreted.

Bloodstain patterns are a vital aid to the reconstruction of a violent crime. When blood drips from wounds, weapons, or other objects, a splash or spatter pattern is created. The shape of the splash can show whether the source of the blood was moving and, if so, in which direction. Should the victim or perpetrator attempt to run away, the trail of blood will tell the investigator more details about the escape attempt because the shape of the blood drops will help reveal it. When someone is shot or hit with a blunt object, blood is projected from the wound and hits surrounding surfaces and objects. The resulting pattern can be analyzed to show how the weapon impacted the victim. There may be a break in the pattern; no blood where it would be expected on, for instance, a wall. This may suggest where the attacker was standing and whether the victim was struck or shot from the front or behind.

Blood is messy. During an attack it is also transferred to clothes, shoes, and hands and may leave behind bloody prints. Blood-soaked fabric makes marks with a characteristic weave pattern upon objects it comes into contact with, like a getaway car.

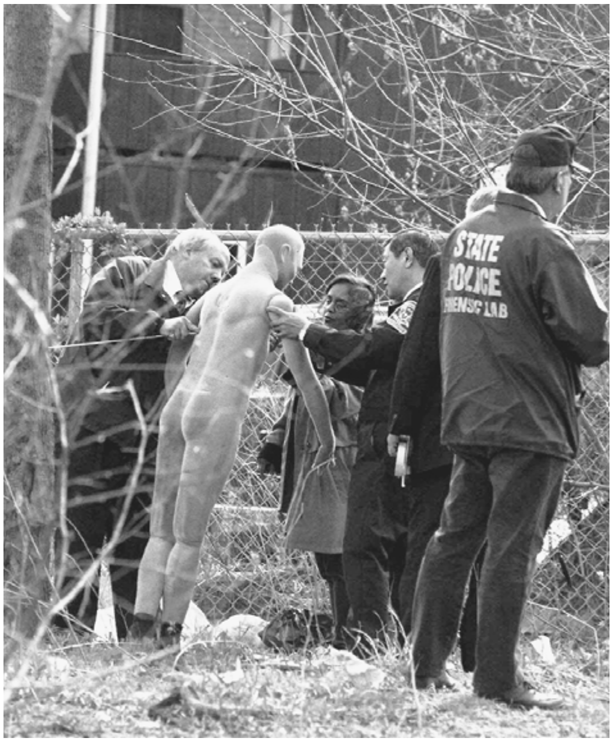
Some forensic tools are particularly important in crime scene reconstruction. Fluorescent light sources will glow when they are exposed to ultraviolet light. An important example is **luminol**, a chemical that reacts with **hemoglobin**, the red pigment in blood. Luminol detects blood at a concentration as low as one part in five to ten million or even lower. It is extremely valuable in revealing blood that the perpetrator believes he or she has cleaned away, such as bloodstains in a car used to remove the victim's body. However, luminol cannot detect bloodstains that have been wiped away with bleach. In such cases, fluorescein can be used as an alternative. In other words, fluorescent chemicals and light can be used to detect invisible trace evidence, giving a truer picture of the crime scene.

Footprints are a particularly rich source of evidence in a reconstruction because they can link a suspect to the crime scene. Even if a suspect says they were not there, their footprints, if matched, can tell a different story. Footprints have proved to be especially important in cases of homicide, assault, robbery, or rape. When someone is at the scene of the crime, their soles come into contact with surfaces and leave an imprint, visible or not, which can be detected, examined, and assessed. Some prints, such as those made in the blood of a victim, are particularly obvious. If the print is in contact with a soft surface such as sand, soil, or snow, it will leave a three dimensional print. Should the contact be with a hard surface, the print is two-dimensional. Either the surface itself is removed and taken to the laboratory, or specialized photographs are made. The footprint can be linked to a particular kind of shoe by comparison with a footwear database. Individuals also wear down their shoes in a certain way, depending upon their gait. Other features such as scuffmarks can also be identified within the prints. Unless a suspect has had the foresight to destroy their footwear, examination of their shoes and comparison with footprints found at the scene can link them with the crime.

The investigators often carry out their own experiments to test the hypothesis. For instance, in establishing the relative location of victim and perpetrator in a shooting incident, it is important to know the distance between the gun and the point of impact. Was the victim shot from in front or behind? Was the suspect shooting at point blank range or from a distance? Simulation experiments to solve this question would involve shooting an identical weapon from different distances at a laboratory target. The resulting damage from the bullet could then be compared to that found at the actual scene of the crime.

The investigators must then relate all the evidence they have collected and analyzed with other information, such as **autopsy** reports and witness statements, continually refining or even rejecting their original hypothesis. The autopsy may show, for example, the **time of death** and whether the body has been moved. A witness statement may not be consistent with the evidence, which may provide a basis for further **interrogation** with questions directed by the interpretation of the evidence. This process will generate new information to be fitted into the hypothesis.

New information may continue to come in and must be examined to see if it is consistent with the hypothesis. A murder weapon or even a body may be found during the investigation. Maybe a witness will change or add to their statement. The final reconstruction is the investigator's presentation of the sequence of events before, during, and after the crime. It gives the location and position of everyone involved. More important, it tells how and why the crime occurred. The investigators can expect to be challenged in court, of course. While investigators



Henry Lee works with members of the Connecticut State Police forensic lab, using a dummy to reconstruct the crime scene where Officer Robert Allen shot and killed 14-year-old Aquan Salmon. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

can never be sure of what actually happened at the scene of the crime, if they have used scientific principles and their experience in the reconstruction they can play a valuable role in explaining the crime and seeing that justice is done.

SEE ALSO Crime scene investigation; Crime scene staging; Evidence, chain of custody.

Crime scene staging

Sometimes a perpetrator will attempt to confuse the forensic investigators by staging a crime scene. This involves altering the scene to try to disguise what really happened. When reconstructing the crime scene, the investigating team must always be on the lookout for staging. Typically, **evidence** or bodies will be moved, or there will be signs of a break-in that did not actually happen.

A crime scene is often staged to make a **murder** appear like an accident or suicide. In historical cases, assailants have carefully placed a gun in the victim's hand, but the nature of the victim's wounds were found not consistent with being self-inflicted. A murderer may move a body into the bathroom and pretend the victim fell when he or she got out of the bath or shower. Removing bloodstains with a cleanser like bleach is also not uncommon. However, invisible traces often remain which can be subjected to forensic analysis.

Staging a burglary on top of a murder is a common form of crime scene staging; the assailant may break a lock or a window, turn over drawers, and remove valuable items. Staged burglaries may also be set up as part of an insurance fraud where the owner pretends a valuable item has been stolen when he has actually removed it himself. Should they leave **trace evidence** from their own bodies or clothing at the break-in site, with no evidence present from the supposed robber, then the story will be called into question.

It takes a particular type of criminal to set up a successful staging. Sometimes the forensic psychologist can help with a profile of a suspect. A man who kills his wife in a fit of jealousy, for instance, and then tries to make it look like a burglary can give himself away unless he is calculating and careful. Crimes of passion often involve excessive violence, like multiple stabbings or gunshots. Most burglars are opportunists and will kill only if they panic. Such murders will generally not be as violent as those where anger against the victim is the motive. When a victim has died in a violent manner and it looks as if the motive is burglary, the investigator always considers the possibility that staging has taken place.

SEE ALSO Criminal profiling; Crime scene reconstruction.

Criminal profiling

Psychology can be applied to help catch criminals through the criminal **profiling** process. A perpetrator does not leave behind just **physical evidence** at the scene when he or she commits a crime. They also leave behind clues about their behavior and personality. Profiling was originally introduced to investigate violent **serial killers** where catching the perpetrator is a matter of great urgency.

The forensic psychologist, or specially trained officer, builds a criminal profile from crime scene **evidence** and **autopsy** data. The psychologist seeks to find out how the killer gained access to the victim, what was the killer's attraction to the victim, what did the assailant do to the victim, and whether the killer then tried to cover his or her tracks. Most important, the profiler wants to know what motives and fantasies drove the killer to the crime. The profile helps narrow down the search for suspects and also guides the **interrogation** process. Knowing what kind of person the investigators are dealing with helps officers better formulate their questions.

The profiler will be also interested in the suspect's modus operandi (MO), which describes the tools and strategies used to carry out the crime. This reveals aspects of the suspect's behavior, which in turn reflects upon the suspect's personality.

Forensic psychology has revealed three main types of offender. The organized offender plans the crime, sometimes meticulously, bringing tools and taking them away again. This type of offender will take care not to leave evidence behind and will also hide or dispose of the body. The organized offender is usually of average to high intelligence with a stable lifestyle, tending to be married and employed. The disorganized offender often leaves a mess behind. They don't plan or bring tools; instead, they use whatever they find at the scene to attack the victim. This type of offender generally lives alone or with a relative, may be unemployed and have a history of mental illness. The attacks by this type of offender are often accompanied by considerable violence. The third category is the mixed offender, who shows some characteristics of the first two types. While the approach may be carefully planned, the assault itself may be frenzied, showing a person losing control over deep-seated urges and fantasies.

Another important aspect of criminal profiling is looking at the suspect's signature, which is a feature of the crime unique to that individual. It bears no relation to how the crime is actually committed but is very revealing about personality and motive. Examples of signatures include torture and mutilation, having sexual intercourse with the corpse, using excessive violence, or posing the victim after death in a particular way. Sometimes, as part of their signature, killers take away a trophy or souvenir that they may use to relive the crime later on. In the mind of the offender, a trophy is taken as a symbol of accomplishment, while the souvenir is an object taken to remind him of the event. Such items are often of little value in themselves, but can be very revealing about the psychology of the serial killer.

Research on the psychology of serial killers has revealed further trends. Most are male and in their 20s or 30s. Most murders of this kind do not cross racial lines; whites tend to murder whites and blacks murder blacks, etc. Most serial killers begin by hunting down victims close to home but, as their confidence grows, they may move further afield. Those with social skills, like Ted Bundy, may be able to trick their victims, while true loners tend to attack by surprise.

It can also be useful to profile the victim, to gain a full psychological picture of the crime. An understanding of the victim's lifestyle, habits, and behaviors may explain more about the suspect and why he chose this particular person to attack. Some victims are clearly at high risk of attack, if they meet many strangers, go out at night, and maybe if they make themselves vulnerable through drug or alcohol use or promiscuity. At the other end of the spectrum are low risk victims who stay close to home, do not venture out routinely at night, and have a steady routine job. Many people fall between these two categories. Whatever the type of victim, there is something about them that fulfils a serial killer's fantasies and then they are at great risk if they find themselves in the wrong place at the wrong time.

Criminal profiling was used to good effect to catch Carmine Calabro, who killed a young schoolteacher in 1979 with a pen and umbrella after raping her. Her mutilated body was placed in the shape of the Chai, which is the Jewish symbol of good luck. She was wearing a Chai pendant, which the killer seemed to have taken as a souvenir. This pointed to a disorganized killer driven by his own sexual fantasies. His profile would possibly be a person of low intelligence, with feelings of sexually inadequacy and a history of mental illness. This led the police to Calabro, an unmarried, unemployed 30-year-old whose father lived in the same apartment block as the victim. Calabro was undergoing psychiatric treatment at the time of the crime. Bites found on the body of the victim matched his dental anatomy and were instrumental in his conviction.

SEE ALSO Psychological profile.

Criminal responsibility, historical concepts

The precise definition of criminal responsibility varies from place to place but, in general, to be responsible for a criminal act implies the perpetrator must understand what they are doing and that it is wrong. Clearly, most young children are too immature to fully appreciate the difference between right and wrong. Most countries have fixed an age below which a child cannot be held criminally responsible for their actions. Commonly this is set at ten years, although the age of criminal responsibility can vary between six and 12 years.

An individual may also not be held responsible for their crimes on grounds of mental disorder. It has long been recognized that some people do not have control over or understanding of their actions and the issue of criminal responsibility has been a subject of debate since ancient times. A landmark case occurred in 1843, when Daniel M'Naghten shot and killed the secretary to Britain's Prime Minister Robert Peel. The medical **evidence** found M'Naghten to be insane. This led to the famous M'Naghten Rule where someone could evade criminal responsibility if it could be proved that they did not understand the "nature and quality" of the act they were committing. Equally, they were not held responsible if they did understand what they were doing, but did not appreciate that it was wrong.

Over the years, there has been much discussion over the meaning of these terms. In countries or states that do not have the death penalty, the difference between being found guilty and responsible and guilty and not responsible is a prison term or a stay in a mental institution. Where the death penalty applies, it may mean the difference between death and life. In March 2005, the United States Supreme Court ruled that while persons under the age of 18-years-old can be held responsible for crimes and punished by imprisonment, they are not subject to the death penalty for crimes committed while under the age of 18.

There are many situations in which someone may not be responsible for their actions. Psychosis may mean they were out of touch with reality at the time of the crime. Criminals suffering from schizophrenia may cite "inner voices" driving them to **murder** someone. Disorders of impulse control may mean someone is unable to stop himself or herself from attacking someone. People whose actions and judgment are affected by prescription drugs may also not be fully responsible. Crimes with no apparent or rational motive may also be committed by those who are not fully responsible for their actions.

The forensic psychiatrist will examine the accused and will also look for evidence of whether he or she understood what they were doing was wrong. Wearing gloves or a mask or giving a false alibi or name are all clear indicators of knowing a criminal act is being committed. Suspects who dispose of evidence, flee the scene, or lie to police are also likely to appreciate that they are doing wrong. Some criminals can be very manipulative and may feign mental illness, thinking that a stay in a mental hospital is preferable to prison or, indeed, the death sentence. It is up to the forensic psychiatrist to examine all the evidence and the suspect and then to assess if the suspect is, or is not, responsible for the crime.

SEE ALSO Ethical issues; Psychological profile; Psychopathic personality.

Criminal trials SEE Trials, criminal (U.S. law)

Criminalistics

Criminalistics is one subdivision of forensic sciences. The terms criminalistics and forensic sciences are often confused and used interchangeably. Forensic sciences encompass a variety of scientific disciplines such as **medicine**, **toxicology**, **anthropology**, **entomology**, engineering, **odontology**, and of course, criminalistics. It is very difficult to provide an exact definition of criminalistics, or the extent of its application, as it varies from one location or country to another. However, the American Board of Criminalistics defines criminalistics as "that profession and scientific discipline directed to the recognition, **identification**, individualization, and evaluation of **physical evidence** by application of the physical and natural sciences to law-sciences matters." The California Association of Criminalistics provides a slightly different definition: "that professional occupation concerned with the scientific analysis and examination of physical **evidence**, its interpretation, and its presentation in court." These definitions are very similar to the ones used for forensic sciences, as both disciplines have as a goal to provide scientific analysis of evidence for the legal system.

It is also challenging to define a clear origin of criminalistics. The term comes from the German word *Kriminalistik*, invented by Austrian criminalist **Hans Gross** (1847–1915). While the field of criminalistics started long before Gross' time, the first serious and well-documented applications of scientific principles to a legal purpose, started in the middle of the nineteenth century. The famous novel hero Sherlock Holmes, invented by Sir **Arthur Conan Doyle**, was probably the first fictional founder of criminalistics. The real recognition of criminalistics as a science by itself can be attributed to Hans Gross who published his book *Handbuch fur Untersuchungsrichter als System der Kriminalistik* in 1899. The development of **anthropometry** (the study of human physical dimensions) by French anthropologist **Alphonse Bertillon** (1853–1914) and of **fingerprint** analysis in the same period by Scottish scientist **Henry Faulds** (1843–1930), English scientist **Francis Galton** (1822–1911), and English Commissioner Sir Edward Henry (1850–1931), also contributed to the reinforcement of criminalistics. The progress made in forensic **photography** by Swiss criminalist Rodolphe-Archibald Reiss (1875–1929) was also a major contribution to the world of criminalistics. Finally, the beginning of the era of modern criminalistics is attributed to French criminalist **Edmond Locard** (1877–1966) and some of his pupils such as Swedish criminalist **Harry Söderman** (1902–1956). In the United States, the work of American criminalist Paul Kirk (1902–1970) reinforced the predominant position of criminalistics in forensic sciences.

As an integral part of the forensic sciences, criminalistics encompasses the broadest variety of disciplines. These commonly include the examinations of **toolmarks**, **firearms**, fingerprints, **shoeprints**, **tire tracks**, soil, **fibers**, **glass**, paint, serial numbers, light bulbs, drugs of abuse, **questioned documents**, fire and explosion, biological **fluids**, and last but not least, crime scenes. Criminalistics also typically includes physical evidence that is not directly studied by another field of forensic sciences. The main goal of criminalistics is to apply the principles of sciences to the examination of evidence in order to help the justice system determine that a crime has been committed, to identify its victim(s) and perpetrators, and finally, determine the *modus operandi*, or **method of operation**. Criminalistics uses other scientific disciplines to examine physical evidence. Among these are chemistry, biology, physics, and mathematics. People performing criminalistics are referred to as criminalists.

Crime scene investigation consists of the detailed examination of a crime scene, and detection, recognition, and collection of pertinent evidence, as well as permanent documentation of the scene. Fingerprint examination consists of detection and revelation of fingerprints from different surfaces and comparison with other fingerprints, such as those provided by a suspect, in order to establish a link. Toolmarks, shoeprints, and tire tracks examination consists of recording and observing impressions in order to establish links with a potential tool, shoe, or tire. Drug analysis consists of the identification and quantification of a drug of abuse. The examination of biological fluids, also referred to as forensic **serology**, consists in the detection, recognition, and collection of body fluids and their subsequent analyses in order to identify the person from whom they originate. **Trace evidence** encompasses a large variety of minute pieces of evidence such as fibers, glass, soil, and paints. Traces are examined and compared to potential sources of origin in order to identify their origin. Questioned documents consist of the examination of documents to determine their authenticity or to identify forgery or counterfeiting, and of handwriting and signature analysis to identify the person who wrote them. The examination of serial numbers consists of the determination of their authenticity and the restoration of the ones that have been erased. The study of light bulbs consists of determining if they were on or off at time of their breakage. This is particularly helpful in road accident investigation.

SEE ALSO American Academy of Forensic Sciences; Analytical instrumentation; Animal evidence; Anthropology; Anthropometry; Artificial fibers; Autopsy; Ballistic fingerprints; Bite analysis; Bloodstain evidence; Casting; CODIS: Combined DNA Index System; Crime scene investigation; Crime scene reconstruction; Death, cause of; Decomposition; DNA fingerprint; Entomology; Evidence; Exhumation; Fingerprint; Hair analysis; Impression evidence; Locard's exchange principle; Pathology; Quality control of forensic evidence; Trace evidence.

Criminology

Criminology was born as one of the theoretical fields of social sciences or sociology because crime and criminal behavior are social phenomena with direct impacts on societies. The efforts to understand not only the social determinants of criminality, but also the possible biological, moral, and psychological factors involved when someone commits a crime attracted researchers from other academic fields, such as **anthropology**, **medicine**, and **psychiatry**. As a consequence, a great variety of criminological theories have gradually developed in the last three centuries. In more recent years, criminology acquired an even wider scope, with the inclusion of new scientific fields such as **forensic science**, criminal **psychology**, and analysis of crime statistics.

The concept of crime is itself an object of study, as definitions of crime vary across cultures and change throughout history. For instance, for many centuries the practice of torture of prisoners, the destruction of civilian populations and cities by invading armies, child labor exploitation, and the capture and selling of human beings as slaves were almost universally practiced and accepted worldwide. These activities were part of the customs and values of previous times. As societies change and evolve, the moral standards also change to reflect the new social conventions. In consequence of such changes, some previously condemned behaviors may become accepted, whereas others, until then considered legally and morally justified, may be rejected as barbaric or criminal practices. Laws and penal codes reflect the values of a given historical period and tend to be amended or abolished to meet new emerging social and scientific consensus.

Criminological theories may be classified according to historical/cultural periods, or by the scope of their investigations. Some theories are developed around the psychological traits of criminal subjects, as well as the crime incidence among the general population or among a particular ethnic group or social strata. Other theories investigate the relation between socio-economic contexts and crime incidence, or between abuse and neglect in childhood and juvenile criminality, while others discuss the legal definition of crime, legal and social methods of punishment and rehabilitation, or means of crime prevention. The main theoretical schools of criminology are the classical school, positive school, and the Chicago school. However, criminological theories are more recently also classified according to scopes, such as biological, psychological, disorganization-ecological, learning, control, labeling, radical-conflict, feminist, middle-class, and integrated theories.

The classical school is considered the cradle of modern criminology, and was basically a product of philosophers and physicians of the seventeenth and eighteenth centuries. The classical school was a consequence of both the preceding Renaissance cultural movement and the social and humanistic ideals of the time, such as individual rights, egalitarianism, and democracy, which led to the American and French revolutions. Criminality was viewed as the result of free will and individual choice, as all human beings were considered to be endowed with natural rationality. The emphasis of the classical school was therefore, not the analysis of criminal behavior, but in the social and legal definition of crime, on the need of consensus between society's best interests, and the role of the state and laws in the protection of the common good.

The mainstream premise behind the Classical School was the existence of a natural and implicit social contract between the individuals of a society and their government. Cesare Beccaria (1738–1794), author of a seminal book of this school *On Crimes and Punishment* explained criminality as a consequence of bad and unjust legislation. Like Thomas Hobbes (1588–1679), Beccaria and others professed that men, in their natural state, are rational beings, always pursuing pleasure and self gratification and trying to escape suffering. Such pursuit inevitably led to the conflict between individuals' interests, thus preventing the maintenance of social peace and the individual fruition of happiness.

According to Hobbes, government was a natural necessity to protect society and to define the social common good and moral standards to be forcefully followed by all. In contrast to Hobbes, who was essentially a totalitarian (e.g., government dictates the rules), Beccaria insisted that governments should not suppress individual liberties but instead, be their guarantor. When government failed the expectations implied in the social contract or created oppression and injustice, social unrest and increased criminality would be the result. Beccaria declared that legal equality to all citizens was essential to the success of the social contract, but laws and regulations should be kept to an optimum minimum to avoid unnecessary restriction of individual liberties.

Another influential thinker of this school was Jeremy Bentham (1748–1832), with his utilitarian approach, in which individuals were believed to always consider the overall utility of government or of a law through the benefits it could yield in the present or in the future, weighted against those painful results or pleasures that could result from breaking the law or the social contract. The greater the benefits promoted by the government for the greater number of individuals, Bentham reasoned, the lesser the tendency of breaking the law among the population. Historical examples of the social contract application are the premises that justified the Declaration of Independence and the Constitution of the United States.

The positive school was born inside the positivist movement that rapidly dominated academic thought after the French Revolution, with the separation between science and religion. The positivist philosophy of Auguste Comte (1798–1857) was the cornerstone of this movement, whose emphasis was the systematization of scientific investigation, the consolidation of a scientific methodology, and the construction of rational hypothesis through the empirical observation, quantification, and analysis of facts or of natural phenomena. The positive school of criminology sought, therefore, to explain criminality as a human phenomenon whose probable causes were to be identified in both the human nature and/or in the social determinants. Cesare Lombroso (1835–1909), an Italian physician, is considered the founder of positivist criminology because he rejected criminality as a result of free will and rational decisions on the premises that criminal subjects should be studied in both their biological and social contexts. However, Lombroso assumed that biological diseases, such as **epilepsy** or some mental illnesses, were the main causes of criminal behavior, with socio-economic factors acting as secondary triggers. Lombroso and others studied the psychological and physical characteristics of thousands prisoners and mental hospital patients in an attempt to identify common features associated to criminal tendencies.

Lombroso described two main criminal types: the "born criminal type," whose compulsion to commit violent crimes was beyond the individual's control, and the "criminoid" type, a less dangerous (often harmless) and treatable and/or preventable pathological condition. Among the psychological features of born criminal types, Lombroso reported that they were incapable of remorse (an emotional process), displayed absence of moral values, lack of self-control, with many showing various degrees of mental illness. Therefore, Lombroso considered born criminals as psychopaths who needed to be isolated from society, as their condition was untreatable. Contrary to the general assumption, Lombroso never denied the social and cultural determinants, such as poverty, demographic density, educational deficiencies, childhood maltreatment and adolescence trauma, etc. as contributing factors or even direct causes to criminality, especially in the case of criminoid types. He also proposed several institutional solutions for the rehabilitation of criminoids, such as a reform in the prison system, with less emphasis on punishment and the introduction of educational and professional programs for those convicted of lesser crimes, along with social, medical, and educational policies to prevent criminality in problematic urban areas. However, his comparative anthropometrical study of physical morphological features between criminals and non-criminal individuals, a theory now widely discredited, is the best known and the most often cited of all Lombroso's theories.

The theory of social and environmental determinism (e.g., social conditions as the causal root) of criminal behavior gained force in the United States after 1910 with the Chicago school. This theory especially took hold after World War I. The concept of cultural relativism of moral values in opposition to the existence of human-inherent universal values was an emerging paradigm in American sociology as a result of immigration, fast and disorganized urban growth, economic crisis, and the industrialization boom, which attracted to the cities an ever-growing numbers of people from rural areas. These combined factors were seen as disruptive to the social organization of urban communities. Social organization was defined as a socially developed consensus about ethical norms and moral values that determined the regularity of behavior in a given community. The ensuing augment of crime incidence and the appearance of new types and styles of criminal behavior in certain "disorganized" local urban areas posed new questions to criminologists and sociologists.

Social scientists W. I. Thomas and Florian Znaniecki published in 1920 the result of a comparative social study between Polish rural populations and the process of cultural assimilation of Polish immigrants in the slums of Chicago. They concluded that in contrast to the older immigrants, who had lived in rural communities in Poland and whose social values and cultural traditions were well established and assimilated, the younger Polish generations in Chicago (who had never lived in those rural communities) were in a kind of socio-cultural limbo. They could not identify with the values of the older generation and were not assimilated by the socio-cultural values of their present urban environment and country. The authors associated this state of socio-cultural limbo to the increasing incidence of crime and delinquency among the Polish-descendant youth of Chicago.

Inspired by this study, social scientists created the Chicago concentric zone model of Chicago, dividing the city into five "natural urban areas," as follows: zone 1, the central business district; zone 2, the transitional zone (the area where recent immigrant groups lived in an environment of deteriorated houses and poor sanitation, among abandoned buildings, and factories); zone 3, the working class zone, where working families lived in apartment buildings at low rental rates; zone 4, the residential zone, where the middle class population owned single-family homes with garages, surrounded by back and front yards; and zone 5, the commuter zone, or suburbs. The scientists analyzed each zone in terms of family income, types of economic activities, community infrastructure and organization, and ethnic predominance. They called such sets of characteristics "the natural ecological habitat" of each of those populations. In other words, it was defined as the environmental conditions wherein a given urban community lived and related to one another. These social scientists established a direct relation between higher crime incidence, gang organization, and juvenile delinquency and the more impoverished and precarious urban environments. They proposed that as the residents of zone 2, for instance, progressed and moved to zone 3, other immigrants took their place in zone 2. As they moved farther from the center, crime incidence dropped.

The model was also used to study juvenile delinquency in the various zones of Chicago, when data was collected from 56,000 court records of juvenile delinquency between 1900 and 1933. The group also concluded that higher crime rates were associated to the more central zones, where immigrants, non-whites, and low-income families lived. These and other theorists of the Chicago school viewed poverty, population high density, and industrialization as the main factors inducing the deterioration of family ties and community relationships, which led to social isolation and juvenile delinquency. The group interpreted the results as showing that delinquency was the result of a defiant rejection of the established cultural norms and social values, which tended to grow through proximity and direct exposition of new individuals to delinquent groups.

Disorganization and criminality were, therefore, more prevalent in the central zones and tended to decrease with distance towards the suburban areas. In 1947, Edwin H. Sutherland published the theory of differential association, which he elaborated using elements from prior studies. Sutherland also introduced new data gathered from studies of patterns of learned behaviors through the relationship between the individual and his intimate group, which led him either to accept or reject criminal behavior, depending on which set of values is more emphasized by such influential groups or persons. In brief, Sutherland's theory proposed that: 1), criminal behavior is learned; 2), is learned through the interaction with other individuals or groups close or significant to the individual; 3) together with criminal behavior, individuals also learned techniques to commit specific forms of crime; 4), the choices, motivation, and preferences to commit certain types of crime derived from the quantity of exposition to accepted criminal behaviors in his/her relationships, whose definitions of behaviors that are justifiable, in spite of their illegality, and which are not justifiable, played an important role in criminal behavior.

Because human societies and human beings are both complex and dynamic entities, hardly a single-approach theory, or even a partially-integrated one, will offer the final answer to multi-sided human and social problems to which multiple contributing factors can be associated. Social theories tend in general to contain a variable degree of bias because the prevailing premises and implicit paradigms of their own cultural and personal backgrounds, as well as of their political beliefs in general influence the researchers of each generation. Theoretical criminology is a vast arena where a constellation of these and other recent studies, each tending to explain criminal behavior or its causes through different and often mutually excluding view points, are constantly fueling the academic debate.

SEE ALSO Anthropometry; Forensic science; Misdemeanor; Psychological profile; Psychopathic personality.

Cross contamination

Trace evidence like hair, **fibers**, paint, and **blood**, is by its very nature readily transferred from item to another. This raises the problem of cross contamination, where the source of trace **evidence** found on a significant item is uncertain. The trace evidence may have attached itself to a relevant item during the crime itself, in which case it becomes significant evidence. However, it is also possible that the evidence was transferred to the item via a third party during the investigation. This would be cross contamination, and such evidence is detrimental to an investigation. When a case comes to court, **expert witnesses** will always be on the lookout for the possibility of cross contamination, especially when a serious crime like **murder** or rape is involved. The only way of avoiding cross contamination is to follow strictly controlled forensic procedures during an investigation. This means making certain that the only way trace evidence could have arrived on an item is during the crime.

For instance, supposing fibers or hair from a victim are found on the clothing of a suspect. Such trace evidence could be highly incriminating. But what if an officer comes from the scene of the crime to the suspect's home and packs up his clothes for forensic examination? It is possible that the officer picked up trace evidence from the scene of the crime and acted as an intermediary, transferring it to the clothing of the suspect. Ideally, investigators would not attend more than one scene linked to the crime—in this case, the scene itself and the suspect's home—to avoid cross-contamination of this kind. Given there is a finite number of personnel available for each crime investigation, sometimes the same officer will be involved at more than one scene. In such cases, he or she must follow a strict decontamination process between attending different crime scenes. Careful records must also be kept of the movements of investigators between different scenes.

Cross contamination could also occur if packaging and re-packaging of items is not done correctly. It is essential to package each piece of evidence separately in an unused container. Obvious sources of cross contamination should always be kept well separated. For instance, the clothing of the suspect should never be packaged or handled in the same room as that of the victim and the investigators should be able to prove this procedure was followed. Only by following such procedures to prevent cross contamination can the true value of trace evidence be revealed in court.

SEE ALSO Evidence, chain of custody.

Jean Cruveilhier

2/9/1791–3/10/1874
FRENCH
ANATOMIST

Jean Cruveilhier was the first professor of **pathology** at the University of Paris. He introduced the descriptive method to the field of pathology, and this method was defined by the lithographs in his massive two-volume atlas, *Anatomie pathologique du corps humain (Pathological Anatomy of the Human Body)*.

Cruveilhier was born on February 9, 1791, in Limoges, France, as Léon Jean Baptiste Cruveilhier, the son of a career military surgeon. He was raised almost exclusively by his mother, as his father was usually away with the army during the French Revolutionary and Napoleonic Wars. Cruveilhier felt a calling to the Roman Catholic priesthood, but his father refused to allow it, insisting that he study **medicine** instead. He completed his secondary education at the College of Limoges in 1810, then moved to Paris, where his father had arranged for him to become the student of Guillaume Dupuytren, the most prominent French surgeon of the era.

Dupuytren struggled to turn his friend's son away from religion toward medicine and finally succeeded in awakening his interest in pathology. After taking his M.D. degree in 1816, Cruveilhier sought only the simple life of an ordinary physician in his native town, but, goaded by his father's ambitious plans for him and failing, perhaps because of his father's machinations, to gain a staff position as hospital surgeon in Limoges, he returned to Paris in 1823. Dupuytren secured him a professorship in surgery at the University of Montpellier. Cruveilhier soon resigned, intending to go back to Limoges, but in 1825 he became professor of descriptive anatomy in Paris, where he spent the rest of his career.

By 1826, Cruveilhier was on the staff of most hospitals in Paris and had established a small but prestigious and successful medical practice. Charles-Maurice de Talleyrand-Périgord was among his patients. Cruveilhier took advantage of the death of René-Théophile-Hyacinthe Laënnec in 1826 to revive the Anatomical Society of Paris, which Dupuytren had founded in 1803 but which Laënnec, as president, had allowed to become dormant after 1808. Serving as its president until 1866, Cruveilhier broadened and solidified its publishing program.

Dupuytren died in Paris on February 8, 1835. His will stipulated that a chair of pathological anatomy at the University of Paris and a museum of pathological anatomy should both be established with funds from his estate and that Cruveilhier should occupy this chair. These bequests were honored. The toxicologist Mathieu Orfila founded the Musée Dupuytren in 1835; Cruveilhier assumed the professorship in 1836 and held it for the rest of his life. He published a short biography of Dupuytren in 1841.

The National Academy of Medicine elected Cruveilhier a member in 1836 and its president in 1839. Always concerned with medical ethics, he gave an important speech on November 2, 1836, at the public meeting of the Paris medical faculty, "On the Duties and the Morality of the Physician," which was published the following year.

Cruveilhier's first major publication was his doctoral thesis, *Essai sur l'anatomie pathologique en général (Essay on Pathological Anatomy in General)*, which appeared in 1816. He continued on this subject in his 1821 book, *Médecine pratiqueé éclairée par l'anatomie et la physiologie pathologiques (Practical Medicine Clarified by Pathological Anatomy and Physiology)*. In 1830 his textbook, *Cours d'études anatomiques (Course of Anatomical Studies)* appeared. His *Traité d'anatomie descriptive (Treatise of Descriptive Anatomy)* was published in four volumes from 1833 to 1836 and his *Traité d'anatomie pathologique générale (Treatise of General*

Pathological Anatomy) was published in five volumes from 1849 to 1864.

The subtitle of Cruveilhier's greatest work, the *Pathological Anatomy*, which he issued gradually in forty parts from 1829 to 1842, indicates that it contains "descriptions of the various morbid changes to which the human body is susceptible." Its text was quickly translated into English, German, Italian, Arabic, and Spanish and its plates were cheaply and sometimes poorly reproduced by either redrawing or transfer lithography. Cruveilhier's dissection of 54-year-old Louise Bonin, who died of uterine cancer in 1838, resulted in a section of the *Pathological Anatomy* that was long believed to be the first description of multiple sclerosis, but recent scholarship has established that Scottish pathologist Robert Carswell studied this disease before Cruveilhier.

Cruveilhier's contributions to **forensic science** predominantly involved developing precise methods of **autopsy** for determining the specific **cause of death**. His research into phlebitis, embolism, infarction, and other vascular disorders formed the basis of Rudolf Virchow's more significant work on these topics.

Cruveilhier lacked knowledge of chemistry, biology, histology, and several other disciplines that a medical scientist would normally be expected to have mastered. Yet, his observations of gross anatomy and lesions were so meticulous and his descriptions so clear and accurate that even the discerning neurosurgeon Harvey Cushing, a hundred years later, could not find fault with them. Cruveilhier died on March 18, 1876, at his country home near Limoges in Sussac, Haute-Vienne.

SEE ALSO Autopsy; Death, cause of; Pathology.

Cryptology and number theory

Forensic analyses can be concerned with unraveling the true meaning of deliberately convoluted communications. **Forensic accounting** can involve the search of seized financial and other paper and computer records. An examiner may encounter information that has been altered so as to be indecipherable. Understanding the nature of the informational alteration can permit descrambling strategies to be applied, rendering the information understandable.

Cryptography is a division of applied mathematics concerned with developing schemes and formula to enhance the privacy of communications through the use of **codes**. More specifically, cryptography is the study of procedures that allow messages or information to be encoded (obscured) in such a way that it is extremely difficult to read or understand encoded information without having a specific key (i.e., procedures to decode) that can be used to reverse the encoding procedure.

Cryptography allows its users, whether governments, military, businesses or individuals, to maintain privacy and confidentiality in their communications. The goal of every cryptographic scheme is to be "crack proof" (i.e., only able to be decoded and understood by authorized recipients). Cryptography is also a means to ensure the integrity and preservation of data from tampering. Modern cryptographic systems rely on functions associated with advanced mathematics, number theory that explores the properties of numbers and the relationships between numbers.

Encryption systems can involve the simplistic replacement of letters with numbers, or they can involve the use of highly secure "one-time pads" (also known as Vernam **ciphers**). Because one-time pads are based upon codes and keys that can only be used once, they offer the only "crack proof" method of cryptography known. The vast number of codes and keys required, however, makes one-time pads impractical for general use.

Many wars and diplomatic negotiations have turned on the ability of one combatant or country to read the supposedly secret messages of its enemies. The use of cryptography has broadened from its core diplomatic and military uses to become of routine use by companies and individuals seeking privacy in their communications. Governments, companies, and individuals require more secure systems to protect their databases and e-mail.

In addition to improvements made to cryptologic systems based on information made public from classified government research programs, international scientific research organizations devoted exclusively to the advancement of cryptography, such as the International Association for Cryptologic Research (IACR), began to apply applications of mathematical number theory to enhance privacy, confidentiality, and the security of data. Applications of number theory were used to develop increasingly involved algorithms (i.e., step-by-step procedures for solving a mathematical problems). In addition, as commercial and personal use of the Internet grew, it became increasingly important, not only to keep information secret, but also to be able to verify the identity of message sender. Cryptographic use of certain types of algorithms called "keys" allow information to be restricted to a specific and limited audience whose identities can be authenticated.

In some cryptologic systems, encryption is accomplished, for example, by choosing certain prime numbers and then products of those prime numbers as the basis for further mathematical operations. In addition to developing such mathematical keys, the data itself is divided into blocks of specific and limited length so that the information that can be obtained, even from the form of the message, is limited. **Decryption** is usually accomplished by following an elaborate reconstruction process that itself involves unique mathematical operations. In other cases, decryption is accomplished by performing the inverse mathematical operations performed during encryption.

In the late 1970s, government intelligence agencies, and Ronald Rivest, Adi Shamir, and Leonard Adleman, published an algorithm (the RSA algorithm) destined to become a major advancement in cryptology. The RSA algorithm underlying the system derives its security from the difficulty in factoring very large composite numbers. The RSA algorithm was the mathematical foundation for the development of a public two-key cryptographic system called Pretty Good Privacy (PGP).

Applications of number theory allow the development of mathematical algorithms that can make information (data) unintelligible to everyone except for intended users. In addition, mathematical algorithms can provide real physical security to data—allowing only authorized users to delete or update data. One of the problems in developing tools to crack encryption codes involves finding ways to factor very large numbers. Advances in applications of number theory, along with significant improvements in the power of computers, have made factoring large numbers less daunting.

In general, the larger the key size used in a system, the longer it will take computers to factor the composite numbers used in the keys.

Specialized mathematical derivations of number theory such as theory and equations dealing with elliptical curves are also making an increasing impact on cryptology. Although, in general, larger keys provide increasing security, applications of number theory and elliptical curves to cryptological algorithms allow the use smaller keys without any loss of security.

Advancements in number theory are also used to crack important cryptologic systems. Attempting to crack encryption codes (the encryption procedures) often requires use of advanced number theories that allow, for instance, an unauthorized user to determine the product of the prime numbers used to start the encryption process. Factoring this product is, at best, a time consuming process to determine the underlying prime numbers. An unsophisticated approach, for example, might be to simply to attempt or apply all prime numbers. Other more elegant attempts involve algorithms termed quadratic sieves, a method of factoring integers, developed by Carl Pomerance, that is used to attack smaller numbers, and field sieves, algorithms that are used in attempts to determine larger integers. Advances in number theory allowed factoring of large numbers to move from procedures that, by manual manipulation, could take billions of years, to procedures that—with the use of advanced computing—can be accomplished in weeks or months. Further advances in number theory may lead to the discovery of a polynomial time factoring algorithm that can accomplish in hours what now takes months or years of computer time.

Advances in factoring techniques and the expanding availability of computing hardware (both in terms of speed and low cost) make the security of the algorithms underlying cryptologic systems increasingly vulnerable.

These threats to the security of cryptologic systems are, in some regard, offset by continuing advances in design of powerful computers that have the ability to generate larger keys by multiplying very large primes. Despite the advances in number theory, it remains easier to generate larger composite numbers than it is to factor those numbers.

Other improvements related to applications of number theory involve the development of "non-reputable" transactions. Non-reputable means that parties cannot later deny involvement in authorizing certain transactions (e.g., entering into a contract or agreement). Many cryptologists and communication specialists assert that a global electronic economy is dependent on the development of verifiable and non-reputable transactions that carry the legal weight of paper contracts. Legal courts around the world are increasingly being faced with cases based on disputes regarding electronic communications.

SEE ALSO Codes and ciphers; Computer forensics; Computer hardware security; Computer security and computer crime investigation; Computer software security; Decryption.

Culture

One aspect of the forensic examination of samples or of a crime or accident scene can involve determining whether or not a particular microorganism is present. Disease-causing (pathogenic) microorganisms including bacteria and viruses are capable of causing illness and death, or may have contaminated a food or water source.

Modern techniques exist that rely on the detection of the genetic material of the microorganism and do not require the growth of the organism. Indeed, the organism can be dead and still remain detectable. However, the more traditional growth-dependent **identification** techniques are reliable, inexpensive, and are still widely used.

Bacteria require a food source to grow. Depending on the type of bacteria, the liquid or solid food source (growth medium) can be very general or highly specific, requiring the presence of certain types of amino acids, carbon sources, and other compounds. As well, some bacteria require the presence of oxygen (aerobic bacteria), while others require the complete absence of oxygen (anaerobic bacteria).

When the bacteria-containing sample is added to the medium in the step called inoculation, living bacteria will begin to assimilate the nutrients and use them to repair damaged components and construct new components. As a result, the bacteria will begin to grow and divide to produce two progeny bacteria.

Over the course of hours, the cycle of growth and division is repeated thousands of times. With each round of division, cell numbers double (i.e., growth is exponential). This rate of growth quickly leads to huge numbers of bacteria in the liquid medium or on the solid medium. This causes the liquid to become cloudy. On the surface, the countless growth and division cycles lead to the formation of a visible mound of bacteria that is known as a colony.

Bacteria can be cultured in different types of media and the various resulting biochemical reactions can be used to identify the type of organism that is present. Differing appearance of the colonies on the solid medium or the production of various compounds in the presence of specific nutrients can all be clues to the identity of the microoganism. Depending on the type of bacterium, culture-based identification can take from several days to weeks.

Viruses can also be cultured and identified (typically by their shape). However, since viruses cannot grow independently, they require the presence of a host cell. For example, poliovirus is cultured using cells found in eggs. Some viruses known as bacteriophages require a bacterial host.

SEE ALSO Bacterial biology; Bacteria, growth and reproduction; Biosensor technologies; Pathogens.

D

Brian E. Dalrymple

CANADIAN
FORENSIC ANALYST

For twenty-eight years, forensic analyst Brian E. Dalrymple worked for the Ontario Provincial Police, making significant contributions to the advancement of technologies used in its Forensic Identification Services program. Most notably, he conducted research that led to the use of lasers to detect fingerprints and other **evidence**. Dalrymple has since gone on to open his own forensic consulting firm, and has contributed numerous articles to industry magazines and journals as well as provided **training** to private investigators, attorneys, and police agencies.

In 1972, Dalrymple began working for the Ontario Provincial Police (OPP) as a forensic analyst. He excelled at **fingerprint** and footwear identification, forensic **photography**, computer enhancement, and body examination. In 1977, Dalrymple collaborated with the Xerox Research Centre to develop a method of using an argon **laser** to create a luminescent quality in fingerprints. The OPP became the first police agency in the world to regularly use this new technology. While the laser technique did not work on all fingerprints, it was often able to identify prints that could not be detected using conventional means. The technique was also non-destructive, allowing for other fingerprint identification techniques to be used afterwards.

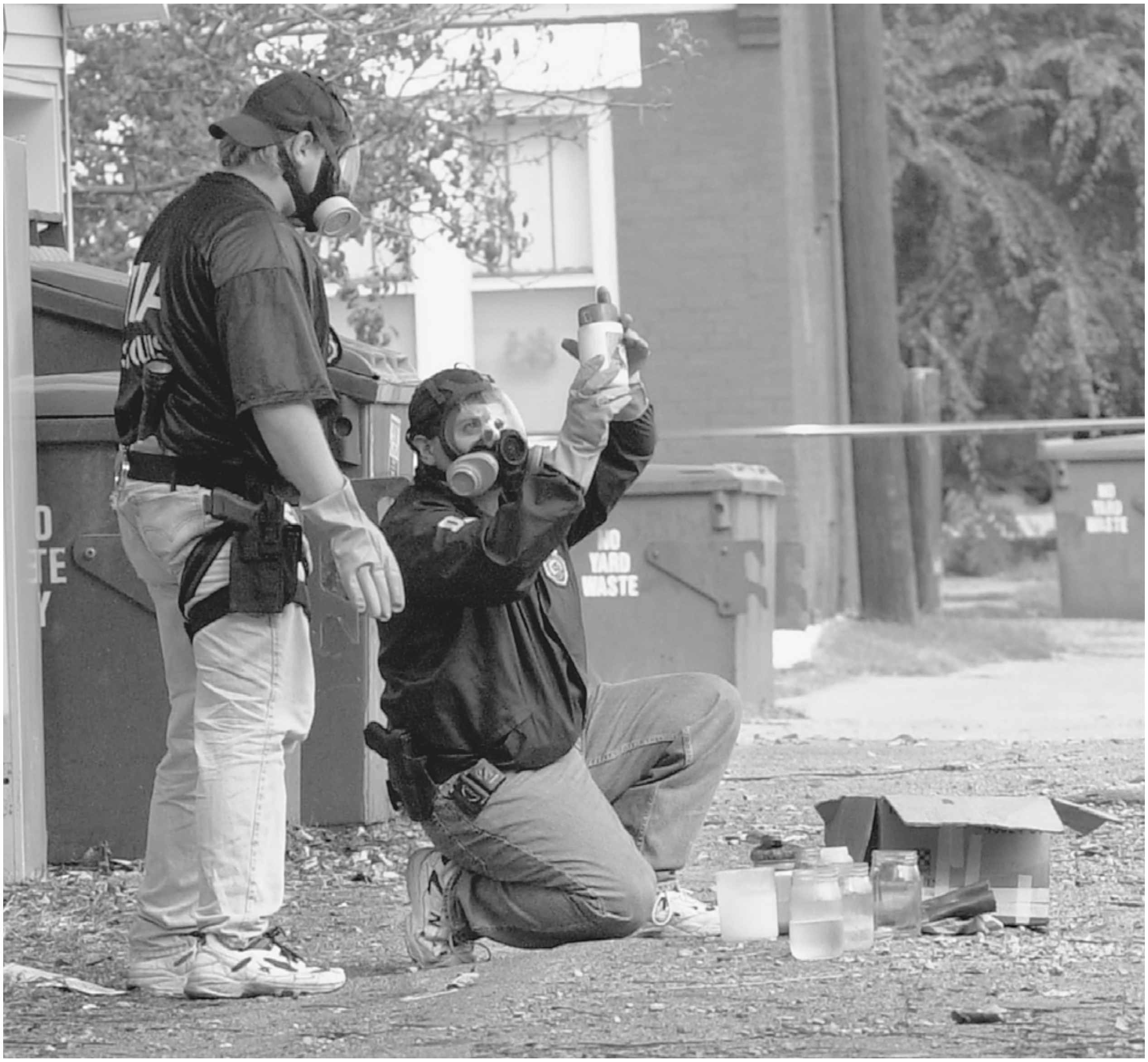
In 1990, after ten years of research, Dalrymple again made an important advancement in technology with the application of computer enhancement technology to evidence images. Through computer enhancement, he found he could detect crucial details of evidence that traditional photographic and analog techniques couldn't reveal. His findings and their subsequent applications again made the OPP leaders in the field of **forensic science**.

Dalrymple retired from the OPP in 1999 to pursue forensic consulting work. He opened Brian Dalrymple & Associates, a firm that assists in computer enhancement techniques, fingerprint detection, forensic light source technology, and photographic evidence analysis for clients in Canada and the United States. He also has written articles for many industry journals, including the *Journal of Forensic Identification* and *Advanced Imaging*. In 1980, Dalrymple won the John A. Dondero Award from the **International Association for Identification**. He also earned the 1982 Foster Award from the Canadian Identification Society and the 1984 Lewis Marshall Award from the Fingerprint Society of the United Kingdom.

SEE ALSO Fluorescence; Technology and forensic science.

DEA (Drug Enforcement Administration)

The Drug Enforcement Administration (DEA) is the lead agency of the United States government for the enforcement of federal statutes on narcotics and controlled substances. Created in 1973, it is a division



Drug Enforcement Agency agents inspect chemicals removed from a home after St. Louis firefighters discovered items used to make methamphetamines in the house after responding to a small fire. © BILL GREENBLATT/CORBIS SYGMA

of the Department of Justice, with offices throughout the United States and in 56 countries. The DEA has numerous enforcement, education, and interdiction programs, an array as varied as the range of illegal drugs and the variety of groups to which they appeal.

Although it exists to enforce the drug laws of the United States, the DEA operates on a worldwide basis. It presents materials to the U.S. civil and criminal justice system, or to any other competent jurisdiction, regarding those individuals and organizations involved in the cultivation, production, smuggling, distribution, or diversion of controlled substances appearing in or destined for illegal traffic in the United States.

The DEA's job is to immobilize those organizations by arresting their members, confiscating their drugs, and seizing their assets. Among its responsibilities are investigation of major narcotics violators operating at the interstate or international levels; seizure of drug-related assets; management of a national narcotics intelligence system; coordination with federal, state, and local law enforcement authorities, as well with counterpart agencies abroad; and **training**, scientific research, and information exchange in support of prevention and control of drug traffic. Part of these duties involves **forensic accounting** and forensic investigations of crime scenes.

Exemplifying this role, from its beginning, the DEA was concerned with the collection, analysis, and dissemination of drug-related intelligence through its Operations Division, which supplied federal, state, local, and foreign officials with information. Originally, the agency had just a few intelligence analysts, but as the need grew, so did the staff, such that by the end of the twentieth century, the DEA's intelligence personnel—both analysts and special agents—numbered nearly 700.

Along the way, demand for drug-related intelligence became so great that the DEA leadership, recognizing how overtaxed the operations division was, in August 1992, created the Intelligence Division. The latter consists of four entities: the Office of Intelligence Liaison and Policy, the Office of Investigative Intelligence, the Office of Intelligence Research, and the Electronic Privacy Information Center (EPIC). The last of these, located in El Paso, Texas, served as a clearinghouse for tactical intelligence (intelligence on which immediate enforcement action can be based) related to worldwide drug movement and smuggling. Eleven federal agencies participate at EPIC in the coordination of intelligence programs related to interdiction.

The DEA also creates, manages, and supports domestic and international enforcement programs aimed at reducing the availability and demand for controlled substances. Among its dozens of programs is Demand Reduction, a program operated by 22 special agents at 21 domestic field divisions to educate youth and communities as a whole, to train law-enforcement personnel, and to encourage drug-free workplaces.

Demand Reduction falls under the heading of the first of three goals the DEA established late in the twentieth century, and toward which it continued to work in the early twenty-first. That first goal is to educate and enable America's youth to reject illegal drugs as well as alcohol and tobacco products. Among the programs in the service of the second goal—to increase the safety of America's citizens by substantially reducing drug-related crime—are the Mobile Enforcement Teams, which work to dismantle drug organizations. The third goal, to break foreign and domestic drug sources of supply, places the DEA in collaboration with foreign governments and agencies through programs such as the Northern Border Response Force. The DEA also works with other federal agencies, including the Department of Justice National Drug Intelligence Center. DEA intelligence itself serves this third goal.

SEE ALSO Evidence; Illicit drugs.

Death, cause of

Cause of death is the generic term that refers to the conditions that lead to the death of a person or an animal. It is paramount to accurately determine the cause of death of an individual as part of crime investigation activities or when death is suspected to have been caused by a condition that has a strong genetic component. The determination of the cause of death is commonly the role of the death investigator, **coroner**, or forensic pathologist in collaboration with crime scene investigators and detectives. It is a complicated process that may require a lengthy period of time. In 2004 there were approximately 2.5 million deaths in the United States, including approximately 27,000 infants less than one year old. Autopsies to determine the precise cause of death were conducted in only about 10% of this group who died.

From a forensic perspective, there are four main categories of causes of death: homicide, suicide, accidental, and natural. Often, it is important to determine the cause of death for judicial reasons. If a homicide occurred, the perpetrator is ideally swiftly identified, arrested, and prosecuted. If a suicide took place, then documentation is necessary to alleviate the need for a criminal investigation. If an accident occurred, it is important to take preventive measures to ensure no further accidents will occur and to determine any legal repercussions. In some instances, a criminal will try to cover a homicide by making it looking like a suicide, but the reverse situation can also occur.

Homicide deaths include all the deaths that were deliberately carried out by an individual, or were due to an individual's negligent behavior. The number of homicides varies greatly from one country to another and from one region to another. In rural locations, homicide rates are usually lower, while in large cities, more homicides are likely to occur. In the United States, homicide represents slightly less than one percent of the total number of deaths. In 2003, the Federal Bureau of Investigation recorded 16,503 homicides in United States, which corresponds to 5.7 homicides per 100,000 inhabitants. Homicide deaths are further classified as caused by a particular condition such as by **firearms**, blunt injuries, sharp injuries, asphyxia, drowning, poisoning, or fire.

Suicide deaths include all deaths that were carried out by the deceased. Men are four times more likely to die from suicide than women. However, women are more likely to attempt suicide. The number of suicides also varies greatly from one country to another. In the United States, the rate of suicide is approximately double that of homicides, or 30,000 per year.

There are approximately 100,000 accidental deaths per year in the United States, which represents about 4% of the total number of deaths. Almost half of all accidental deaths are motor vehicle accident related.

Natural causes account for most of the deaths in the United States, accounting for approximately 90% of all deaths.

SEE ALSO Crime scene investigation; Crime scene staging; Autopsy.

Death, mechanism of

Death is defined as the complete and permanent cessation of all vital functions, such as lack of blood pressure and cardiac activity, absence of reflex response to stimuli, and cessation of spontaneous breathing. However, since some clinical pathological conditions may mimic some death characteristics, the certainty of death is achieved through the observation of the following negative vital signs: loss of consciousness, loss of sensibility, absence of motility or muscular tonus, cessation of blood circulation, and ultimately, absence of cerebral activity. Once all these criteria are met, an individual is declared dead.

From the biologic perspective, however, dying is a gradual process, with different organs and tissues halting their respective functions at different moments. Cells of the central nervous system need greater amounts of oxygen to survive than other cell types. Therefore, neurons in the brain can only live for three to seven minutes in the absence of oxygen, whereas epidermal cells (skin cells) can survive much longer, up to 24 hours or, depending on environmental conditions surrounding the corpse, even longer. Bone cells may survive for several days.

When the heart stops beating, blood is no longer pumped through the veins and arteries to be oxygenated by the lungs and further transported to cells. The blood is drained from the capillary vessels into the larger veins present near the surfaces of the body, due to the collapse of arterial pressure (blood pressure). Therefore, cells no longer receive oxygen and muscle cells start the respiratory process known as anaerobic catabolism, whereby they break down complex chemical substances into simpler ones, in order to extract energy. Through anaerobic respiration, cells of some tissues and organs such as the heart, internal muscular fibers, and limb muscles are able to survive for a while after a heart failure. Anaerobic catabolism, also known as anaerobic glycolysis, causes the buildup of lactate in the muscular tissues that leads to lactic acidosis (high levels of lactic acid). High concentrations of lactic acid in the muscles cause muscular contraction and the body stiffens, losing all flexibility. This state is known in forensics as **rigor mortis** and occurs within three or so hours after death. The body remains in this state for approximately 36 hours. When muscle cells finally die, the rigor mortis ceases and the process of cellular **decomposition** begins. After death, the body tends to progressively lose heat, with the extreme parts such as feet, hands, and the face cooling first. However, the internal organs remain warm for about 24 hours. Environmental temperatures may accelerate or slow down the cooling process.

The above biological data, in combination with other information such as characteristics of the site where the corpse was found, environmental temperature, and presence or absence of insects, is used in forensic investigation to estimate the **time of death** in suspicious cases.

SEE ALSO Crime scene investigation; Death, cause of; Decomposition; Entomology; Time of death.

Death, time of SEE Time of death

Decomposition

The biological and chemical changes undergone by a body after death are known as decomposition. Decomposition is the continual process of gradual decay and disorganization of organic tissues and structures after death. Some tissues, such as bones, teeth, and hair, are more resistant to the action of microorganisms and other environmental factors and may last for centuries. Fossilized bones from animals and hominids, extinct millions of years ago, are studied today by paleontologists and anthropologists, thanks to such resilience.

Forensic **medicine** and forensic **anthropology** investigate the sequence and types of changes that affect decomposing bodies under different conditions and environments. A number of variables may affect both the rate and sequence of decomposition. Therefore, the estimation of time elapsed since death, known in forensics as the postmortem interval, takes into consideration the particular conditions associated with the decomposing body, such as temperature, level of humidity, and medium, such as exposure to preservatives, water, or soil.

For centuries, pigs were the animal model used to study both anatomy and the decomposition process due to their internal structural similarities to the human body. However, in 1980, the University of Tennessee at Knoxville began a research project on human decomposition with cadavers donated by the families of deceased persons or by the individuals who willed their bodies to science. In an area known as the Anthropological Research Facility, human bodies were laid to decompose in several different controlled conditions. These controlled experiments have significantly contributed to the better understanding of human decomposition and to new levels of accuracy of forensic reconstruction techniques, such as the circumstances of death, time and **cause of death**, and determination of age, race, and gender. The data collected from several types of experiments and the measurements of each skeleton are recorded in a computer data bank named ForDisc (Forensic Discrimination).

A general description of postmortem changes due to decomposition basically includes two stages of autolysis, and four stages of putrefaction, besides some conservative phenomena such as saponification or **adipocere**, natural mummification, calcification, etc. However, these latter events only occur in specific conditions. Autolysis consists of the fast and intense spontaneous self-destruction of tissues by the body enzymes present in the cells, without any bacterial interference. Once cells stop receiving nutrients and oxygen via blood circulation, they start anaerobic (without oxygen) "breathing", breaking ATP (adenosine tri-phosphate) into ADP (adenosine di-phosphate) to obtain energy. Anaerobic respiration lasts for a few hours, until all ATP reserves are exhausted. The anaerobic respiration induces the accumulation of lactic acid in cell tissues that disrupts cell function. Enzymes then collapse the cell nucleus and cell breakdown (necrosis) occurs.

Tissues rich in blood vessels (more dependent on oxygen and energy) are the first ones to suffer autolysis, whereas those poorly irrigated or deprived from blood vessels, like the ocular corneas, are not immediately affected by decomposition. Putrefaction (or breakdown by microorganisms) follows autolysis. With the exception of fetuses and newly born babies, the main source of these microorganisms in corpses is the right part of the large intestines. Microorganisms then invade the abdominal cavity, the chest, head, and limbs. The first visible signs of such activity are the greenish abdominal stains, accompanied by the initial odors of rotting flesh. The stains gradually expand to other parts of the body (thorax, head, and limbs) and change from light to dark green, then beginning to blacken. In people who have drowned, the greenish coloration starts on the face, progresses toward the thoracic area, and then to other parts, due to the position that drowned bodies assume in water, which facilitates putrefaction of the upper respiratory pathways first. In newly born infants, putrefaction agents (bacteria, fungi, etc.) invade the body through all cavities, especially through the respiratory pathways. The greenish stains appear in newly born babies first on the face, neck, and chest due to bacterial activity in the upper and lower respiratory pathways, and because their intestines are sterile. This phase of decomposition is known as the chromatic period.

Bacterial action destroys the structure of cells and soft tissues, releasing in the process body **fluids** in internal cavities such as chest, abdomen, and oral tract. Anaerobic microorganisms produce methane, hydrogen sulphide, and other gases responsible for the increasing stench that surrounds rotting organic matter. As gases accumulate inside the body, it starts to swell, forcing more fluids from organs to internal cavities and blood to the periphery of the body. This phase of decomposition is called the gaseous period.

Subcutaneous (under the skin) blisters containing a mixture of plasma, **hemoglobin**, and gases appear and a marbled-like pattern spreads through the skin. The outer layers of the skin (epidermis) begin to detach from inner layers of the skin (dermis) as the gaseous period progresses. The subsequent phase involves the process of liquid putrefaction, in which the soft tissues are gradually dissolved. The body loses its shape as tissue mass decreases and the separation of skin layers is completed. During this liquefaction period, gases are released and a putrefied creamy substance covers the skeleton. The next phase is known as skeletonization, with

Volunteer rescue workers deliver a decomposed body to Wat Ban Muang temple in southern Thailand for identification after the tsunami of December 2004.

the environmental elements (e.g., larvae, worms, and sometimes insects) separating the skeleton from ligaments, which causes the detachment of the **skull**, the mandible, and long bones, with bones eventually collapsing apart. Bones become increasingly fragile and lighter over the years, and acidic **soils** eventually dissolve them.

Adipocere (a waxy substance formed after death by fatty tissues) formation is not a universal phenomenon during decomposition. It is more common in remains of children, women, and overweight people, requiring both adipose (fatty) tissues and contact with humidity in the soil, or immersion in water, or the prevention of body water evaporation. Collective burial graves, were bodies are piled together, are also favorable to adipocere formation. Adipocere is very rare in remains of slim individuals because it results from the spontaneous chemical transformation of fatty tissues into a grayish-white waxy matter. Coroners have a special interest in adipocere because of its preservation properties of other tissues underneath. Adipocere-conserved body parts allow the performance of several forensic tests some months (and even years) after death. Examples are, the study of facial or neck lesions, toxicological tests, or the study of perforations caused by bullets.

Unborn fetuses that die between the sixth and the ninth months of pregnancy undergo a different process, known as maceration, due to prolonged exposure to the amniotic fluid. Fetal maceration external signs resemble in some ways those found in corpses immersed in water. However, the precise sequence of internal changes in fetal maceration is unique and offers three different well-defined phases or maceration degrees that allows the forensic determination of postmortem interval.

SEE ALSO Adipocere; Autopsy; Bacterial biology; Body Farm; Crime scene reconstruction; Death, cause of; Drowning (signs of); Entomology; Exhumation; Immune system; Medical examiner; Mummies; Osteology and skeletal radiology; Toxicology.

Decontamination methods

A crime or accident scene often contains **fluids**, including **blood**. These fluids could also contain noxious biological or **inorganic compounds**. It is necessary to carefully handle fluids when collecting **evidence** to avoid contamination. Additionally, after the survey of the crime or accident scene is complete, steps must be taken to decontaminate the site in order to remove any potential danger to others.

Human decontamination can involve removal of a contaminant from the skin. Usually such decontamination must be done quickly, since the contaminant may be absorbed through the skin where it can cause internal damage. Washing with regular hand soap or the antiseptic soap used in hospitals allows for the rapid removal of personal spills. Portable emergency response personal decontamination kits can also be carried to the scene.

Decontamination of an investigation scene often utilizes a variety of physical and chemical decontamination methods and strategies. The method selected depends on the nature of the contaminant. For example, vacuuming up a spill of a powdery chemical can be a prudent step, while the same technique might be inappropriate for a liquid spill.

Liquids such as blood are removed from inert surfaces or living surfaces (i.e., skin) by the use of sorbents. The sorbent can be a natural material, such as soil, diatomaceous earth, or activated charcoal, or can be synthetic (i.e., Amberlite XAD-2 and XAD-7 resins). Absorption involves the concentration of a substance from the liquid phase onto the surface of the adsorbent material due to the chemistry of the surface molecules.

The most recognizable solid absorbent is a clay material known as Fuller's Earth. This material is commonly found in cat litter. When solid absorbent materials like Fuller's Earth, soil, or diatomaceous earth are used, the contaminant is usually not altered. For example, petroleum products are readily absorbed, but are not changed in their character. Thus, the sorbent material becomes toxic and so must be collected and disposed of afterwards. Caution needs to be taken during the collection process, as fine dust or particles can be inhaled or stuck to exposed skin.

A different type of physical decontamination involves washing the contaminant away using another fluid like water, an alcohol, or freon. The aim here is to dilute the contaminant in the wash fluid, which should itself be collected for proper disposal. Washing is not a complete decontamination. Residual contaminant can remain behind in cracks or other hiding places. However, the use of high-pressure sprays can be an effective and rapid means of decontaminating surfaces like walls and floors.

Chemical decontamination goes further than merely removing a contaminant from the environment. Rather, in chemical decontamination the adsorbing chemical neutralizes a contaminant. One example of chemical neutralization is the adsorption of a contaminant by material that is impregnated with an alkaline chemical. Another general example is the use of chemically reactive compounds that interact with the contaminant and change its structure into a form that is non-toxic.

A popular chemical decontamination strategy relies on the use of oxidizing agents. Bleach is a well-known example of an oxidizing agent. The use of oxidizing compounds such as calcium hypochlorite or sodium hypochlorite inactivates a variety of chemical compounds as well as dangerous microorganisms such as bacteria and viruses.

Oxidizing agents can be wiped onto a spill and collected in an absorbent material. As well, some oxidizing agents can be incorporated into topical lotions, which are smeared onto the skin to help inactivate a chemical or biological spill.

A recent innovative example of an oxidizing agent is L-Gel. Developed at Lawrence Livermore National Laboratory, L-Gel uses potassium peroxymonosulfate to deactivate a variety of biological agents, including **anthrax spores** and *Yersinia pestis* (the bacterium that causes plague). The thick gel is able to cling to surfaces better than water, especially to steeply sloping surfaces like walls, which keeps the decontaminant in contact with the target longer than using a straight water-based decontaminant.

Strong bases, such as hydroxide forms of calcium, sodium hydroxide, and potassium, are other useful chemical decontaminants. These agents disrupt chemical bonds in the contaminant and so destroy the offending compounds' noxiousness.

Water is an ideal fluid for decontamination because a variety of chemically different detergents and soaps readily dissolve in water. These compounds can loosen or bind contaminants and so remove them from a surface. The friction of scrubbing also aids in decontamination of the skin during hand washing.

The different tendencies of chemicals to dissolve in water (a property known as solubility) affect the efficiency of a decontaminant. For example, a longer

An FBI team member is assisted by firefighters in the decontamination process at American Media, Inc. in 2001, a biohazard crime scene where federal agents gathered information into the death of a worker who died from exposure to anthrax. © REUTERS/CORBIS

period of decontamination is needed when using a compound that is not readily soluble in water. This problem can be somewhat overcome by the use of micro-emulsions, which are essentially very small droplets of the decontaminant. The droplet coat is a material that is less water-soluble. The effect is best seen when oil is added to water. Then, a sheen of oil appears on the water, rather than a homogeneous oil-water mixture. If a contaminant is not water soluble, it will quickly partition into the hydrophobic ("water-hating") decontaminant portion of a micro-emulsion. This can speed up the action of a decontaminant. Micro-emulsions can be applied to a contaminated surface as a spray, which can be washed off later.

SEE ALSO Anthrax, investigation of 2001 murders; Biohazard bag; Crime scene cleaning; L-Gel decontamination reagent; Pathogens; Toxins.

Decryption

Forensic analysis, in particular **forensic accounting** (the utilization of accounting, auditing, and investigation to assist in financial legal matters), can involve dealing with information that has been altered so as to be unreadable and impossible to understand without using decryption to convert it into readable material.

This scrambling of information is done in a controlled fashion, according to a pre-determined pattern. If this pattern can be understood, then the meaningless scramble can be reconverted to intelligible text.

Decryption is simply the reverse of encryption, the process by which ordinary data, or plain text, is converted into a cipher. A cipher, often incorrectly identified as a code, is a system in which every letter of a plain text message is replaced with another letter so as to obscure its meaning. To decipher a message requires a key, an algorithm that provides the method by which the message was encrypted.

Decryption operates in everyday life when financial information is sent over the Internet. During the electronic passage, the information is encrypted to make it meaningless if intercepted. At the other end of the electronic journey, the application of the decryption algorithm renders the message meaningful to those for whom it is intended.

In one of the earliest and simplest **ciphers**, Julius Caesar sent messages in which each letter was substituted by the letter three places after it in the alphabet. In place of *A*, then, one would use a *D*. The key for such a cipher would be simply, "Shift right by three," or something similar.

A key is an algorithm, or a method for solving a mathematical problem by using a finite number of computations, usually involving repetition of certain operations or steps. An excellent example of an algorithm is $f(x) = y$, a formula by which a relationship between two elements is shown on a Cartesian coordinate system. It is said that "y is a function of x," meaning that for every value of x, there is a corresponding value of y. Suppose it is established that $2x = y$; then the key for the function has been established, and all possible values of x and y can be mapped.

This is what occurs in decryption in a simplified form. The example shown is one that could easily be solved by what are called "brute-force" means. Brute force is a method of decryption in which a cryptanalyst, lacking a key, solves a cipher by testing all possible keys. This tends to be impractical for most ciphers without the use of a computer, and for the most sophisticated modern ciphers, brute force is all but impossible.

Suppose, however, one were shown a graph with the following coordinates for x and y: 1, 2; 2, 4; 3, 6; and so on. It would be fairly easy to determine from these values, using brute force, that $2x = y$, even if one did not have the key. This is an example of "weak" encryption. By contrast, some of the systems in use today for encryption of bank transactions or cellular phone communications and other purposes are extremely "strong". The ultimate example of strong encryption would be a situation in which decryption would be impossible without knowing the key.

Strong encryption is a controversial matter, due to the concerns of law-enforcement and intelligence authorities that such ciphers could be used by terrorists or other illegal groups. This has led to a move on the part of several governments, including that of the United States, to set up "key-escrow" arrangements, whereby all developers of ciphers would be required to give authorities a "back door" or key into the cipher. The government would maintain decryption keys in a secure location, and use them only when given a court order.

Forensic professionals can now use commercially available decryption software. Of course, updating of the software is vital to keep pace with newly devised ciphers. Many forensic officials will also have access to the state-of-the-art decryption software and expertise via organizations such as the Federal Bureau of Investigations and **Interpol**.

SEE ALSO Codes and ciphers; Computer forensics; Cryptology and number theory; Forensic accounting.

Defensive wounds

Defensive wounds are any type of injuries that result from an attempt, or repeated attempts, to defend against an assailant using such sharp edged weapons as knives or blunted instruments such as fists and clubs. Such wounds are usually deeply indented stab wounds, but can be either blunt or sharp in nature. Violent crimes involving defensive wounds can include criminal homicides, rapes, and robberies. Although defensive wounds can appear anywhere on the victim's body, they are generally found on the upper extremities of the human body including the back of the hands, the inside of the palms, and the inner side of the forearms. The different positioning and angles of the wounds indicate to the forensic examiner the exact way that the victim was trying to ward off and protect themselves against the attack.

In many cases, the victim will hold up hands and forearms in front of the body in a defensive, posturing position in order to protect the face and chest from injury during the assault inflicted by the perpetrator. In such a case, the victim may receive lacerations on the forearm when an assailant uses a sharp weapon such as a knife or multiple groupings of abrasions and bruises to both hands and forearms when fists or other blunt objects are used during the attack.

In a stabbing case, for example, slashing wounds on the hands of the victim may indicate that the victim grabbed the knife during the struggle only to have it pulled back by the assailant, thus inflicting more injuries to the victim. These wounds will usually be deep and focused around the palms and the undersurface of the fingers. Superficial cut and stab wounds to the back of the head, neck, and scalp, which are delivered at appropriate angles and positions with respect to both people, are indicative that the victim turned away from the attacker. In another example, a shotgun attack may show the presence of small, round pellets lodged within the hands or forearms of a victim, once again showing the victim was attempting to protect vital parts of the body against injury.

SEE ALSO Knife wounds.

Henry P. DeForrest

1864–1948
AMERICAN
PHYSICIAN

Henry Pelouze DeForrest (also deForest) is an important figure in the history of fingerprinting. Born in 1864, in Futon, New York, DeForrest was educated at Cornell University and received his medical degree from Columbia University. He became a surgeon and obstetrician in New York City. He was a surgeon with the New York City Police Department from 1902 to 1912, and was also the Chief Medical Examiner for the city's Municipal Civil Service Commission from 1912 to 1919. From 1903 to 1921, DeForrest was an associate professor of obstetrics at the New York Post Graduate Hospital and Medical School.

In 1902, while with the police department, DeForrest was asked to devise a system to scrutinize potential civil service employees to lessen the practice of having a person substitute for the actual candidate in the qualifying civil service exam. Drawing on the knowledge of the unique **identification** power of the **fingerprint**, DeForrest recommended the use of fingerprint identification. Beginning on December 19, 1902, the first person was fingerprinted in the new fingerprinting system that was subsequently complied.

This was actually the second use of fingerprinting in the United States. But DeForrest's accomplishment is significant, as it represented the first fingerprint file established in the United States, and the first use of fingerprinting by a U.S. government agency.

In 1903, spurred on by the success of the Civil Service experience, the systematic use of fingerprinting in criminal identification began in the United States, when the New York State Prison adopted the fingerprint system.

DeForrest's pioneering fingerprinting efforts paved the way for the subsequent widespread adoption of fingerprinting as an identification (and subseqently as a forensic identification) tool. In modern times, databases such as the **Integrated Automated Fingerprint Identification System** (IAFIS) maintained by the Federal Bureau of Investigation (**FBI**) houses millions of fingerprint patterns, which are available to law enforcement agencies worldwide.

DeForrest also invented the dactyloscope, a machine that records fingerprint patterns. The dactyloscope has found widespread use in fingerprint-based identification systems in airport customs facilities and in other applications where admittance or credit acceptance requires personal identification. DeForrest died in 1948.

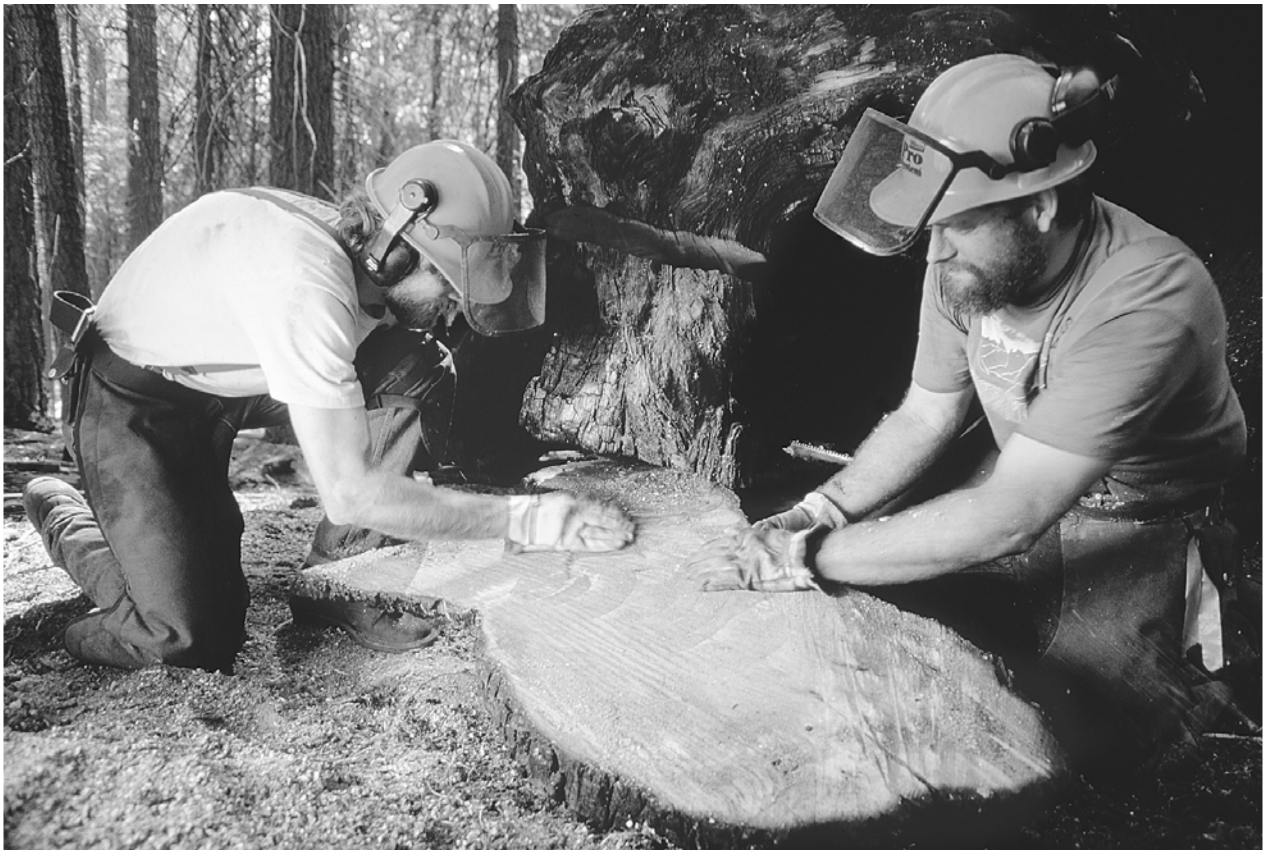
SEE ALSO Fingerprint; Integrated automated fingerprint identification system.

Dendrochronology

Dendrochronology is the science of dating events and variations in environment in former periods by comparative study of growth rings in trees and aged wood. In scientific terminology, tree growth rings are used as proxy indicators for past environmental variations. The term dendrochronology is derived from the Greek terms *dendron* for tree, *chronos*, meaning time, and *logos* meaning the science of.

Dendrochronology is governed by a set of principles or scientific rules. These principles have their roots as far back as 1785 (the Principle of Uniformitarianism) and have continued to evolve as recently as 1987 with the Principle of Aggregate Tree Growth. Some are specific to dendrochronology, such as the Principle of Aggregate Tree Growth, while others, like the Principle of Replication, are basic to many disciplines. All tree-ring research must adhere to these principles, or else the research that results could be flawed.

Dendrochronology is an important technique in a number of disciplines, including archeology, paleontology, paleobotany, geomorphology, climatology,



A logger cuts pieces or samples from a fallen giant sequoia. Scientists study the tree rings to discover the sun cycles, amount of rainfall, the climate, and any fires during the lifetime of the tree. © JIM SUGAR/CORBIS

and ecology. Forensic applications concern the dating of wooden objects and matching objects with crime scenes using the wood's morphological features.

Plant anatomical features have long been used by archeologists and paleontologists to date and to characterize archeological sites. Since the 1930s they have become increasingly more common in forensic applications. The cell wall is particularly important for two reasons: it is not easily digested by most organisms and, therefore, persists when other plant features are destroyed, and the size, shape, and pattern of cell walls is often specific according to species.

Annual growth rings occur because the xylem cells become gradually smaller in radius as the growth season proceeds into the dormant season. There is an abrupt change in size from small, late season cells to the large, early season cells of the following spring. The approximate age of a temperate forest tree can be determined by calculating the annual growth rings in the lower part of the trunk. The variation in ring width reflects environmental conditions. Wide rings signify favorable growing conditions, absence of disease and pests, and favorable climatic conditions. Ring patterns of several samples from a given geographic area subject to similar environmental conditions are cross-dated, giving standardized chronologies (curves) for different species in different areas, to which specimens of unknown origin can be compared. Tree rings record responses to a wider range of climatic variables, over a larger part of the Earth, than any other type of annually dated proxy record.

Tree ring analysis is a common technique for dating masterworks by European painters, many of which were painted directly on wood. If the samples are in good condition, analysts can pinpoint the exact year when the tree from which the wood for the painting was taken was cut down. For example, a Peter Paul Reubens painting originally dated 1616 was shown to be at least 10 years younger, and a painted wall panel recovered from a house in Switzerland in the 1970s was determined to have been painted on spruce harvested in 1497.

Likewise, dendrochronology techniques are useful in determining the provenance of wooden art objects and musical instruments. In one case, two violins forming part of an inheritance were purported to have been made by Antonio Stradivari. The sounding boards of the instruments were x-rayed and compared to standard curves for spruce from the Alpine region of northern Italy, where Stradivarius is known to have worked. The oldest rings from the samples dated to 1902 and 1894 respectively for the two violins. Furthermore, these oldest rings were not the outermost rings of the wood from which the violins were constructed. Allowing for a period of seasoning before the wood could be used to make the instruments, analyses showed that the violins could not have been made before 1910. Given that Stradivari did his best work at the turn of the 17th century, the instruments were deemed to be fakes.

It can be a challenge to estimate the time since death for a body when only bones remain. Plant roots, like their above-ground counterparts, exhibit annual growth rings that can be useful in pinning down the postmortem interval, or at least the time since the body came to be at the location where it was found.

In one criminal case, the discovery of human remains lying across a black spruce (*Picea mariana*) leader (branch) that subsequently grew up around the remains provided an opportunity to use the growth ring pattern to estimate the postmortem interval. These remains were discovered in an advanced state of **decomposition**, and it was clear that relevant insect **evidence** was not forthcoming. The asymmetrical growth of the leader resulted in a correspondingly asymmetrical pattern of its growth rings. As the date of cutting the leader was known, it was possible to evaluate the asymmetrical growth pattern to provide an estimation of the postmortem interval. Fine polishing of the cross section and computerized quantification of ring widths enabled an estimation of the displacement of the leader, and hence the time the decedent's body was so positioned. By charting the ring-width differential for the leader, the actual date of disappearance was confirmed.

SEE ALSO Crime scene investigation; Decomposition; Identification; Paint analysis.

Dial tone decoder

In the investigation of a crime, many experts are consulted, including forensic investigators and law enforcement agencies. All aspects of the crime are reviewed; in addition, investigators may dust for fingerprints, interview potential suspects, and wiretap telephones.

Telephone conversations are sometimes surreptitiously taped using microphones or other bugging devices. These devices run the risk of being detected. In some intelligence-gathering tapings, however, the contact telephone number may yield information that is as valuable as the actual conversation. If the content of a conversation is not essential, the contact telephone number can be obtained with a device called a dial tone recorder.

In a touch-tone telephone, each digit from 0 through 9 produces two tones when the particular key is pressed. Each tone has a particular wavelength (i.e., height of the peak and trough of the wave) and a frequency (i.e., the number of waves and troughs per unit area). One of the tones is from a low group, which represents the rows on the telephone keypad. The other tone is from a high group, which represents the columns on the keypad. The function of the dial tone decoder is to decipher the tone pairs and match up the combination with the row and column location on the telephone keypad. In an operating phone, this information is passed to a switch, which routes the signal to the phone line, allowing the call to proceed.

A dial tone decoder is also a standard feature of touch-tone telephones, and makes the phone capable of converting the numerical and symbolic information that is entered using the phone's keypad into a signal that can complete the transmission.

A decoder can also detect a busy signal. Dial tone decoders can also route the dial tones to a personal computer equipped with an infrared port, as the electrical impulses of the tones can be converted to infrared radiation. Thus, a computer can be used to record the activity of a telephone over time, including the numbers dialed during that period.

Instances of **assassination** via cellular telephones equipped with a decoder and an explosive device occurred in contested areas of the Middle East in the late 1990s. When the subject answered the telephone, a code was entered that triggered a blast. Detection of the code by the dial tone decoder triggers the explosive device. In this way, attacks were carried out from remote locations. Hamas, an Islamist militant group, orchestrated such an attack in July 2002, killing five Americans and four Israelis at the Hebrew University in Israel after a bomb placed in a backpack in the university cafeteria was remotely detonated by cell phone.

In police investigations, dial tone decoders are routinely used for intelligence gathering, and are also used by telephone repair crews to verify phone numbers.

SEE ALSO Bomb detection devices; Bomb (explosion) investigations; Telephone caller identification (Caller ID); Telephone recording system; Telephone tap detector.

Park Dietz

AMERICAN
FORENSIC PSYCHIATRIST

Park Dietz is one of the most well known forensic psychiatrists in the United States, and possibly in the world. Dietz earned an M.D. degree, a Master's in Public Health, and a Ph.D. in Sociology from Johns Hopkins University. Dietz's approach to forensic **psychiatry** is that of the rigorous scientist; he utilizes extensive and detailed study of the subject matter at hand in an effort to develop an understanding of the underlying patterns, whether the subject is serial killing, sexual sadism, spree killing, psychopathic crime, celebrity stalking, or **product tampering**. His case preparation style is somewhat unique. Dietz not only employs minutely detailed inspection and analysis of employment documents, such as military records; journals, diaries, books, and letters, photos, police reports, and crime-related information, he frequently examines the murder and burial sites as well. Dietz has earned a reputation as an expert who is able to relate information in layman's terms, comprehensible to the media, to juries, and to law enforcement personnel.

Some of the more high-profile cases in which he has been involved are the trial of Presidential shooter (and would-be assassin) John Hinckley, Jr., the trial of Unabomber Theodore (Ted) Kaczynski, the investigation of Tawana Brawley, the sieges at Waco and at Ruby Ridge, the trials of serial murderers Jeffrey Dahmer and Charles Ng, and the search for the Atlanta Olympics bomber. In the latter case, Dietz was able to tie the blast to two other explosions in Atlanta (one at an abortion clinic and one at a nightclub frequented by lesbians), and to one at a clinic in Birmingham, Alabama. Dietz developed a sufficiently detailed profile of the bomber that it helped lead to the **identification** of Eric Rudolph as a suspect; he later confessed to the crimes.

Park Dietz continues his work as a noted forensic psychiatrist through two different forums. Park Dietz & Associates (PD&A) is a large forensic consulting firm whose specialty is a team approach to case evaluation and assessment; the Threat Assessment Group (TAG) is an expert **training** and consultation and firm dedicated to the prevention of school and workplace violence.

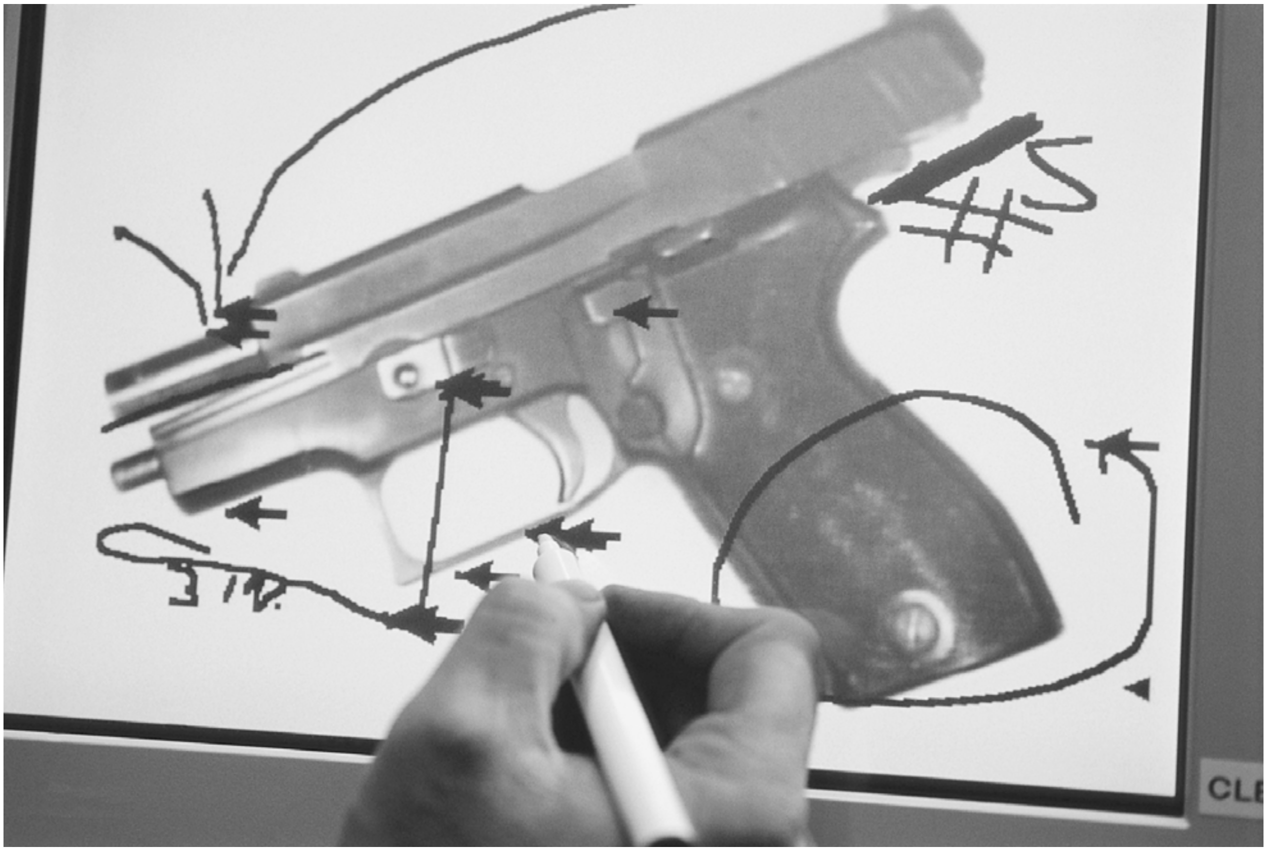
SEE ALSO Accident reconstruction; Autopsy; Criminal responsibility, historical concepts.

Digital imaging

Digital imaging is the electronic recording, processing, enhancement, and storage of visual information. Its applications in **forensic science** range from documenting crime scenes to enhancing faint or indistinct patterns such as partial fingerprints. Although digital imaging is often considered to be synonymous with digital **photography**, digital imagery can also be obtained by conventional x-ray radiography, computed tomography (CT or CAT scans), magnetic resonance imaging (MRI), **laser** scanning, and infrared photography.

Both digital and film photography employ lenses to focus light rays into a sharp image, with the size of the image controlled by the focal length of the lens. Lenses with long focal lengths produce larger images than those with short focal lengths, although the magnitudes of long and short are relative to the film or sensor size. Focal lengths are generally given in millimeters. A diaphragm within the lens (in combination with shutter speed) controls the amount of light entering the camera as well as the depth of focus in the image. In place of the film used in a digital camera, however, a digital camera uses a light-sensitive electronic sensor. Two sensor types are commonly used: CCD, or charged coupled device sensors, and CMOS, or complementary metal oxide semiconductor sensors. Both types of sensors are composed of rows and columns of photosites that convert light into an electronic signal. Each photosite is covered with a filter so that it is sensitive to only one of the three (red, blue, or green) components of visible light. Digital image processing techniques can also be applied to film negatives or positives if they are digitized using a high-resolution scanner that operates in much the same way as a digital camera.

Two primary measures are used to characterize digital images: resolution and size. Resolution refers to the ability of a sensor to represent details, and is generally specified in terms of pixels per inch (ppi).



Digital demonstration of a gun. © ROYALTY-FREE/CORBIS

Image size refers to the total number of pixels comprising an image, and is typically given in terms of megapixels. A pixel is the smallest possible discrete component of an image, typically a small square or dot, and one megapixel consists of one million pixels. As of early 2005, the best commercially available digital **cameras** had resolutions of approximately 20 megapixels and many professional quality digital cameras had resolutions of 5 or 6 megapixels.

Regardless of its origin, once an image is available in digital form it can be modified or enhanced using digital image processing techniques. Common image processing techniques include contrast stretching to expand the tonal range of an image, edge detection to outline areas possessing similar textural or tonal properties, and unsharp masking to increase sharpness. Unsharp masking derives its unusual name from a film photography technique in which an original negative was combined with a deliberately blurred negative to produce a sharp print. Although these image processing techniques can do much to enhance subtle features of an image, they cannot create information that does not already exist.

One of the aspects that distinguishes forensic digital imaging from non-forensic digital imaging arises from legal considerations. Images that are destined for use in a court of law must be obtained and processed using carefully documented procedures if they are to be allowed as **evidence**. The documentation typically includes the name of the photographer, the date the image was obtained, the names of anyone who had access to the image before it was introduced in court, the names of anyone who enhanced or altered the image, and the details of any enhancement procedures. One issue that is a particular concern when an image is obtained with a digital camera is originality. Whereas traditional photography produces a film negative or positive that cannot be easily replaced without detection, digital cameras produce electronic files that can be modified and overwritten either accidentally or deliberately. It is possible to open a file, make modifications, and then save it with the same file name even though the image has been altered. Computer systems used to store forensic digital imagery must therefore be secure enough to prevent accidental modification of or deliberate tampering with original files.

The possibility of image tampering was raised during a 1995 **murder** trial in Seattle. The only evidence that linked the defendant to the crime scene consisted of a digitally enhanced image of a bloody palm print taken from a mattress pad. Prosecutors used a digital image that had been sharpened and filtered to remove the fabric texture, and the defense unsuccessfully claimed that the image could have been altered by the computer operator. The possibility of image manipulation was also raised in the O.J. Simpson murder trial, during which the Simpson defense suggested that photographs of him wearing a particular brand of shoes had been fabricated.

SEE ALSO Automated Fingerprint Identification System (AFIS); Cameras; Crime scene investigation; Evidence; Forensic science; Geospatial imagery; Photo alteration; Photography; Remote sensing; Simpson (O. J.) murder trial.

Disappeared children of Argentina

Between 1976 and 1983, Argentina was governed by a repressive military dictatorship. This government considered students, intellectuals, and politicians as dissidents and the dictatorial government severely censored and brutalized members of these groups. An estimated 30,000 people were kidnapped, tortured, and killed during these years. Because of these atrocities, the time period is often referred to as the "Dirty War." After people marked as dissidents were kidnapped from their homes, the government usually denied any information regarding their whereabouts; as such, the murdered people were referred to as "the disappeared."

A particular aspect of the terror involved kidnapping pregnant women and taking them to secret detention centers where they were held until they had their babies. After giving birth, the mothers were killed and the babies were given to families that wanted children and that had close ties to the government. The children of people deemed subversive by the government were also kidnapped. Approximately 220 babies were raised in adopted homes as a result of these brutal practices.

In 1977, a group of mothers and grandmothers of disappeared children began demonstrating in the Plaza de Mayo, which houses the capital building in Buenos Aires. Their peaceful march around the Plaza de Mayo with white headscarves eventually brought the attention of international aid groups, as well as reporters and journalists. This group became known as the grandmothers of the Plaza del Mayo (Abuelas de Plaza de Mayo). Although many of them believed that the government had killed their children, they hoped that their efforts would help them locate grandchildren.

In 1980, one of the Abuelas read an article describing a method for determining family relationships using biochemical markers on **blood** cells. She speculated that it might be possible to develop a test to prove that the Abuelas were the grandparents of children who had been adopted during the dirty war. They eventually enlisted the help of Mary-Claire King, an American geneticist from the University of California, Berkeley. King, in collaboration with Argentinean geneticist Ana Maria Di Lonardo, developed genetic tests to identify grandchildren of some of the Abuelas.

Political pressures removed the military government from power in 1983 and the newly elected president established a commission to investigate the fates of the disappeared and to prosecute those who committed crimes under the dictatorship. Part of the commission provided a structure for any children who were adopted under suspicious conditions during the period of the military government to have his or her **DNA** checked with the National Genetic Data Bank, which was run by Ana Maria Di Lonardo for the purpose of providing genetic **identification** for Argentinean citizens.

Four different types of genetic tests were developed that allowed grandparents to identify their grandchildren: HLA typing, Y-chromosome analysis, **mitochondrial DNA analysis**, and autosomal **STR (short tandem repeat) analysis**. HLA typing, or histocompatibility typing, was developed in the late 1980's and it was the original test used by King and Di Lonardo. HLA typing relies on identifying the genes that code for special molecules called antigens that are found on the surface of white blood cells. Since the Y-chromosome is inherited from the father, Y-chromosome analysis is used to determine paternity, or in the case of the children of the disappeared, grandpaternity. Mitochondrial DNA is inherited strictly from the mother, so mitochondrial DNA analysis is used to determine the identity of a mother or maternal grandmother. Autosomal **STR analysis** involves studying specific regions on the DNA found in the nucleus of a person's cells. These regions contain large numbers of repeating nucleotides, which are the building blocks of DNA. These repeating sequences are usually between two and five nucleotides long, and STR analysis often focuses on

Argentine forensic anthropologists exhume bones in 2002. The bones are suspected of belonging to children considered missing during Argentina's Dirty War dictatorship of the 1970s. © REUTERS/CORBIS

tetramers, which are four nucleotides long. The number of times these tetramers are repeated in a specific location on a **chromosome** will vary from person to person and will be inherited from a parent or a grandparent. Thus, the number of short tandem repeats in a certain location on a chromosome can be used to identify familial relationships.

As of 1996, 175 families and 2100 people provided genetic samples to the National Genetic Data Bank. Legislation passed in 1997 invalidated these adoptions and provided access to adoption records for these children. In all cases where identity of adoptive children was established, the courts considered the best interest of the child. In some cases, children remained with their adopted families; in others they returned to live with their grandparents, and in some cases the biological family was integrated into the life of the adopted family. By 2002, genetic tests proved the identities of 59 children who had been kidnapped and adopted during the military rule; 31 of the children were returned to their biological families.

SEE ALSO Gene; Mitochondrial DNA typing.

Distal SEE Anatomical nomenclature

Disturbed evidence

Evidence presented in court is only relevant if it can be shown to have been involved in a crime and to have survived intact until considered by the judge and jury. For example, if a gun, said to be a **murder** weapon, bears the fingerprints of an investigating police officer, then its value to the investigation is lost. Disturbed evidence refers to any item of evidence that has been interfered with in some way, whether intentionally or unintentionally. It is up to the crime scene investigators and the forensic analysts to make sure that none of their actions lead to a disturbance of evidence.

Before the investigators even arrive at the scene, however, there is already plenty of opportunity for perpetrators and witnesses to interfere with or dispose of evidence. They may carry out some form of **crime scene staging** to try to disguise what has really happened.

A common form of staging is trying to make a murder look like an accident or suicide. Perhaps a gun will be carefully placed in the victim's hand or beside the body. However, generally the pathologist will know that the nature of the wounds is not consistent with being self-inflicted. A murderer sometimes moves a body into the bathroom and pretends the victim fell after getting out of a bath or shower. Another type of staging is trying to blame a non-existent intruder for an attack. A man who murders his wife, for instance, may break a window, turn over jewelry boxes and drawers, and remove valuable items. Staged burglaries may also be set up as part of an insurance fraud; the owner removes an item and pretends it has been stolen.

Blood is, of course, one of the most significant forms of evidence. The pattern and nature of a bloodstain is not only revealing of the nature of the attack, it may also identify the perpetrator if there is blood on his or her clothing or if there has been a struggle in which his or her blood is left behind. Attackers may be surprised and panicked by the amount of blood some attacks can generate. They may assume that washing it away with a cleanser such as bleach will remove this most telling form of evidence. In fact, it is hard to remove all traces of blood, especially if the perpetrator is in a hurry to get away, and invisible traces nearly always remain. These can be visualized using a **luminol** spray, which fluoresces in ultra-violet light when it is sprayed on blood.

The first responder, that is, the first officer on the scene of a crime, may well find someone has tried to hide or destroy evidence. It is the officer's job to stop this from happening. Once the investigation team arrives, it becomes a case of ensuring that none of its actions destroy or compromise evidence. Establishing a common approach path or an agreed way of accessing and leaving the scene minimizes traffic of personnel at the scene. A policed cordon around the scene ensures that only those who really need to be there actually enter the scene, reducing the possibility of contaminating or destroying evidence.

Some items of evidence are, by their very nature, fragile, and the investigators must capture them as soon as possible by **photography**. Examples include **shoeprints** in snow or tire marks that could be washed away by rain. Sometimes evidence is destroyed by insects or predators. Insects will feed upon a body or lay their eggs in body tissues within hours of death. While their actions may provide valuable information on **time of death**, they may also render the body less amenable to pathological investigation. When **decomposition** is advanced, predators may scatter remains and bones, making it harder for a forensic pathologist or anthropologist to work out the identity of the deceased.

Once the investigators are on the scene, they must bear in mind that they are an intrusion and do their best not to degrade or destroy evidence. According to **Locard's exchange principle**, everyone involved in a crime scene takes something from the scene, such as mud or blood, away with them, and leaves something of himself behind, like a **fingerprint**. This is as true of the investigators as it is of the perpetrator and witnesses. If they touch areas that are likely to bear fingerprints of suspects, they could contaminate them with their own fingerprints. Accordingly, investigators will wear gloves, masks, protective bodysuits, and overshoes. Evidence should be collected, if possible, on one occasion, which means it is better to collect too much evidence than too little. Returning to the crime scene to collect further evidence sometimes raises questions in court as to whether it was placed there since the crime occurred.

The possibility of cross-contamination is always a big issue when it comes to evaluating evidence. **Trace evidence**, like hair, **fibers**, paint, and blood, is by its very nature readily transferred from one item to another. If **cross contamination** occurs, the source of trace evidence found on a significant item is uncertain. It may have landed there during the crime itself, in which case it is significant and meaningful evidence. However, it is also possible that the evidence was transferred to the item via a third party during the investigation. The only way of avoiding cross contamination is to follow strictly controlled procedures during an investigation.

For instance, suppose hairs or fibers from a victim are found on the clothing of a suspect. Such trace evidence could be highly incriminating. However, an officer may come to the suspect's home from the scene of the crime after having had contact with the victim. Here the officer may pack up the suspect's clothes for examination. Should the suspect come to court, the defense will say that this officer picked up the hair or fibers from the scene of the crime and acted as an intermediary, transferring it to the clothing of the suspect. The investigating team must have procedures in place that ensure this does not happen. Ideally, officers would not attend more than one scene linked to the crime—in this case, the scene itself or the suspect's home—to avoid cross-contamination of this kind. Given there is a finite number of personnel available for each crime investigation, sometimes the same officer will be involved at more than one scene. In such cases, he or she must follow a strict decontamination process between attending different scenes. The cross-contamination charge can always be answered if careful records are kept of the movements of investigators between different scenes.

Once evidence has been collected, it must be handled, packaged, and transferred with scrupulous care to ensure it is not disturbed from its original state. Each piece of evidence is packaged separately in an unused container and then sealed into an outer container and labeled. Obvious sources of cross-contamination should always be kept well separated. For instance, the clothing of the suspect would never been packaged or handled in the same room as that of the victim and the investigators should be able to prove this. Only by following such procedures to prevent cross-contamination can the true value of trace evidence be revealed in court.

Perhaps the most powerful defense against evidence having been disturbed is the **chain of custody** protocol. Evidence found at the scene of a crime must eventually be presented and questioned in the courtroom. For the evidence to be of use in a trial, it must make the journey from crime scene to court in a validated and secure manner, so that all involved can be assured that it has not been contaminated and that it really is relevant to the crime investigation. That is why crime investigators must follow a routine commonly known as the chain of custody when it comes to collecting and handling evidence.

The first officer to collect an item of evidence, be it a fiber or a bullet, will sign and date either the item itself or its packaging. Clearly, marking an item ensures there is no ambiguity, as packaging could be separated from the evidence itself. However, some types of evidence, such as bullets, may be altered if someone marks them. Bloodstains and fingerprints, among the most valuable items of evidence, often cannot be collected directly, so it is a case of officers signing photographs or transfers and recording what has been done.

Evidence usually goes from the crime scene to the forensic laboratory for examination. The chain of custody does not end here, however. The receiving officer will sign for and date the evidence packages. Everyone who handles the evidence at any stage in the laboratory does likewise until the analysis is complete. After all, there are as many opportunities for compromising evidence in the laboratory as at the crime scene. Evidence may be stored at the wrong temperature or a label could go missing.

The analysis itself may disturb the evidence. Some experiments actually destroy evidence, so care must be taken that all other necessary tests, such as microscopy, have been done before, for instance, pyrolysis, which heats up a paint sample. Ideally, only a tiny sample would be taken for analysis, but if the evidence is only available in minute amounts, sampling may destroy it. Once laboratory investigations have been completed, the evidence will be handed over to the police for storage until its presentation in court.

The receiving police officer will sign for the evidence and it should be stored in a secure area to minimize the risk of interference or loss. The prosecuting lawyer is responsible for the evidence once the case arrives in court. He or she will sign to that effect, and is the last link in the chain of custody. The investigators should have been aware of any disturbance to the evidence before they arrived at the scene. Once they began work, they would have taken every care to protect fragile evidence and minimize any chance of cross-contamination. The chain of custody involves everyone with an interest in investigating the crime. If it has been followed correctly, then the case can proceed with all involved being aware of the precise journey the evidence took from crime scene to the court. This allows the court to judge the case on the basis of the evidence, assured that it has not been disturbed.

SEE ALSO Bindle paper; Control samples; Crime scene investigation; Cross contamination; Evidence; Evidence, chain of custody; Fibers; Quality control of forensic evidence; Trace evidence.

Bruce W. Dixon

AMERICAN
PHYSICIAN, EMERGENCY RESPONSE AND PUBLIC HEALTH EXPERT

Since the 1960s, Dr. Bruce W. Dixon has been working to improve the health and safety of the state of Pennsylvania. As a physician and professor, Dixon has treated patients and mentored medical students. As the director of the Allegheny County Health Department, he has instituted innovative health programs and made key moves to ready Pennsylvania for potential terrorist threats through disaster planning. Dixon also writes and lectures on **forensic science** and medical subjects.

Dixon attended the University of Pittsburgh, earning a B.S. degree in chemistry and then an M.D. After working and teaching at Duke University for a number of years, he returned to the University of Pittsburgh in 1975. In 1979, he became an associate professor, continuing to teach and practice **medicine**. He earned a reputation there for his approachability and enthusiasm for teaching. Dixon has also been a lecturer at the Cyril H. Wecht Institute of

Forensic Science and Law, at Duquesne University School of Law in Pittsburgh, speaking on subjects like the detection of biological and chemical weapons threats.

In 1992 Dixon was appointed as the director of the Allegheny County Health Department, in addition to his duties at the University of Pittsburgh. In the health department post he manages all health programs, including those affecting human health and environmental quality. He has seen to it that the state has been a leader in disaster planning and preparedness, creating an environment where emergency response workers can share knowledge and cooperate with each other. In 2000 Dixon helped form the Allegheny Correctional Health Services, Inc., a nonprofit organization that provides inmate medical services at the Allegheny County Jail. He was also involved with the Pennsylvania **smallpox** vaccination program, a preventative measure taken in 2003 when public health workers were vaccinated for the disease in response to the potential threat of terrorism.

In addition to his other achievements, Dixon contributes to journals and books on the subject of medicine and disaster response. He is a contributing author of *Forensic Aspects of Chemical and Biological Terrorism*, which is written for public health and safety workers, and addresses the roles and responsibilities of these officials in the event of a terrorist attack.

SEE ALSO Bioterrorism.

DNA

The deoxyribonucleic acid (DNA) of every human is unique. Furthermore, DNA is ubiquitous. These properties have made DNA an important tool for the **identification** of individuals, both in forensics and security applications.

DNA consists of two twisted strands of polymers, made up of mononucleotide units. Each nucleotide is composed of a 2-deoxyribose sugar ("2-deoxy-" because the hydroxyl or -OH group of the ribose sugar is missing from the second carbon position on the sugar ring), a phosphate, and one of the four bases: adenine (A), guanine (G), cytosine (C), thymine (T). The deoxyribose sugar and phosphate are linked by phosphodiester bridges in such a way as to form an unbranched polynucleotide chain.

According to the Watson-Crick model, which was published in 1953, the DNA molecule consists of two such polynucleotide chains which are complementary but not identical and which spiral around an imaginary common axis. The two strands are antiparallel, meaning that the phosphodiester links between the deoxyribose units read in opposite directions designated $5'$ to $3'$ on one chain and $3'$ to $5'$ on the other. The bases, which are perpendicular to the helix axis, protrude at regular intervals from the two spiral sugar phosphate strands, and reach into the interior of the helix. The strands are annealed together by hydrogen bonds between the bases of opposite strands. For correct annealing to occur, a purine (adenine or guanine) on one strand must pair with a pyrimidine (thymine or cytosine) on the other. Within the constraints of the double helix, hydrogen bonds can only form between adenine and thymine (A:T) and between guanine and cytosine (G:C). Through this pairing, the arrangement of bases along one strand determines that of the other, and the genetic information is thus coded in these base sequences.

The most commonly described DNA structure is that of the right-handed Watson-Crick double helix, also known as B-DNA, which has a diameter of 20å. The double helix is not symmetrical and has a broad groove (major groove) and a narrow (minor) groove between the chains. Adjacent bases are separated by 3.4å along the helix axis and related by a rotation of 36° which causes the helix structure to repeat after 10 residues on each chain; at intervals of 34å. DNA is, however, a dynamic molecule whose structure can vary and there are two other commonly found DNA conformations, each with slightly different dimensions.

Within a cell, DNA is organized into long strands called chromosomes. Each **chromosome** contains many thousands of different genes. A **gene** is a functional segment of DNA that codes for a specific protein. During protein synthesis, a portion of DNA is translated into a complementary strand of ribonucleic acid (RNA), which is further transcribed into a sequence of amino acids. A sequence of three nucleotides is required to code for one amino acid and chains of amino acids are further modified outside the nucleus of the cell into the proteins.

The **sequencing** of the human genome established that there are only about 30,000 different types of genes (and so proteins) encoded by the human genome. These proteins either perform tasks directly or synthesize molecules required for the biological activity that sustains life.

The DNA molecule is inherited by every cell and every individual. In asexual reproduction, the DNA in chromosomes is unwound and duplicated before the cell divides. Both daughter cells receive exact copies of the parent cell's DNA. In sexual reproduction, a portion of the DNA is inherited from both the female and the male parent. In humans, there are 23 pairs of chromosomes in the genome. During meiosis, which forms the sex cells or gametes (the egg in females and the **sperm** in males), the chromosomal pairs separate and each gamete receives 23 unpaired chromosomes. When a sperm fertilizes an egg, its 23 unpaired chromosomes are paired with the 23 unpaired chromosomes in the egg and the resulting zygote contains a unique set of paired chromosomes.

SEE ALSO Analytical instrumentation; Biological weapons, genetic identification; Chemical and biological detection technologies; DNA profiling; RFLP (restriction fragment length polymorphism); STR (short tandem repeat) analysis.

DNA banks for endangered animals

DNA banks for endangered animals consist of samples of **sperm**, ova, embryos, tissue samples, and **serum**. These biological materials are frozen in liquid nitrogen at −196°C or −373°F, where they can be maintained indefinitely. About a dozen zoos and conservation groups around the world have begun collecting genetic material from endangered animals and preserving it. The goal of this type of collection is to preserve information stored in the genetic material of animals that may not exist in the future. This material contains information about the biochemistry, **physiology**, and even the environment in which the animals existed.

The material in DNA banks for endangered animals is usually collected during surgical procedures or soon after an animal dies. For example, before breeding season every year, veterinarians examine captive giant pandas to assess their health. At these times, gamete (sperm or ova) samples can be taken and stored in DNA banks. In instances when gametes cannot be obtained, tissue samples from skin cells or **blood** samples may be banked.

One of the challenges facing biologists building DNA banks for endangered animals is determining the best way to freeze, store, and then recover biological samples. Because animal cells are mainly composed of water, when they are frozen, ice crystals destroy much of the cell. Therefore, the water in the cells must be removed and replaced with a cryoprotectant fluid, which protects the cellular structures and molecules. Scientists must develop special protocols to infuse the cells with this cryoprotectant, and these protocols vary from species to species. In addition, the rate at which genetic material is frozen and thawed may vary from species to species. In some species, special treatments may be needed after thawing occurs. Development of these sensitive procedures requires careful experimentation.

A variety of zoos and conservation groups have collected and stored genetic material from endangered species. The largest DNA bank for endangered animals is housed at the San Diego Zoo and is called the Frozen Zoo®. Between its establishment in 1975 and 2005, the Frozen Zoo collected samples from more than 7,000 threatened and endangered species, including more than 13,000 samples of **semen**, oocytes (eggs), and embryos. The Cincinnati Zoo and Botanical Garden holds genetic material for more than 60 animal species and 150 plant species. The Audubon Society maintains a DNA bank for at least 35 different animal species, most of which are endangered. In 2004, three British institutions, the University of Nottingham, the Institute of Zoology, and London's Natural History Museum, announced the formation of the Frozen Ark project, the purpose of which is to develop a genetic repository of all endangered species on the World Conservation Union's (IUCN) Red List, a list that totals more than 7,200 species.

Most of the DNA banks for endangered animals are focused on conservation. A major use for the genetic material stored in these banks is to increase the genetic diversity of species at risk of becoming extinct. As populations of endangered animals shrink, the gene pool of the animals becomes more limited. This leads to inbreeding, which increases the population's risk of disease, birth defects, and the inability to survive natural disaster. Material from DNA banks can be used to infuse small populations with new genetic material, increasing their chances of survival. Another goal of DNA banks is to increase the population size of endangered species by producing new individuals. In 1999 at the Audubon Center for Research of Endangered Species, a domestic housecat gave birth to an African wildcat kitten that had been frozen as an embryo in a DNA bank. This was the first example of interspecies birth. In 2000, the Center produced test-tube Caracal cats from

A Yacare caiman in Brazil. Forensic scientists provided DNA evidence that handbags and shoes imported through Kennedy Airport in New York were made from the skins of the endangered reptile. © STAFFAN WIDSTRAND/CORBIS

sperm that had been stored in their DNA bank. Material stored in DNA banks for endangered animals can also be used to understand animal physiology by analyzing the blood serum and tissue samples for hormones and other biochemical indicators. Information regarding the environment in which the animal lived may also be understood from biochemical markers, trace metals, and compounds from the environment found in tissue samples.

DNA banks are also used for forensic work with endangered animals. Between 1999 and 2001, researchers at the University of Trent in Ontario, Canada, developed DNA banks of endangered animals that are listed on the CITES (Convention on the International Trade of Endangered Species) list. They have developed a DNA bank of Gyrfalcons and Peregrine falcons so that wild birds can be distinguished from birds that have been bred in captivity. A DNA bank that includes genetic information of Amazon parrots helps to identify birds that are illegally traded. Genetic material from various species of sturgeon is also being deposited in DNA banks in order to identify caviar that is from fish on the CITES list. DNA banks of tigers have also been developed to identify materials found in Asian medicines. Finally, DNA banks of North American endangered duck and goose species are used for **identification** and for population management.

SEE ALSO Gene; Wildlife forensics.

DNA databanks

With the advent of significant biotechnological advances in molecular biology, particularly with the completion of the human genome sequence, a better understanding of the genetic material that we inherit (**DNA**) has allowed scientists to utilize this information in a variety of applications. One of these ways has been to initiate and establish large-scale DNA databanks. A DNA databank is essentially a storage facility that maintains DNA extracted from a variety of sources from an individual including **blood**,

The Armed Forces Pathology Institute DNA Repository holds the DNA of all active Service men and women and civilians who work with the military in positions in which they might be killed. © KAREN KASMAUSKI/CORBIS

saliva, hair, skin, or other kinds of tissue (muscle, liver, etc). Since DNA in the proper storage conditions can be maintained indefinitely, creating DNA databanks can serve a variety of purposes that include screening for disease genes, paternity testing, identity matching for criminal investigations, and research-related studies.

The initial incentive for creating DNA databanks was to have a repository to send out samples for molecular genetics testing to screen for genetic predispositions to disease or inheriting disease genes. Currently, the United States lacks a DNA databank with a national, centralized repository system. Other countries such as Iceland, the United Kingdom, and Estonia have established large, centralized DNA databanks on a national level. An essential method to better understanding disease as it relates to the human genome has been to link DNA databanks to clinical information so that researchers can elucidate the mechanisms of heritable disease, susceptibility to disease, and identify ways to use the genome for therapeutic applications.

A national DNA databank in the United States has been controversial due to the ethical, legal, and social implications. These issues revolve around the fear that a national DNA databank will compromise an individual's privacy and give law officials too much accessibility to an individual's genetic information. Furthermore, having DNA stored in a national DNA databank risks misuse of the DNA in the future, even if initially there are carefully considered restrictions and the appropriate informed consent. Genetic information is analogous to anthropometric or biometric medical information. However, it is much more robust in terms of the information it contains.

Although a national DNA databank does not exist in the United States, most states collect DNA from convicted murderers or sex offenders. All states have a law regarding the storage of specific DNA information from any individual arrested or convicted of a **felony** in a database and a small percentage of states require the DNA profiles of all felons to be in this database. DNA has linked murderers to the crimes they committed retrospectively, in some cases decades after the **murder** was committed. In these cases, a national DNA databank would have significant ramifications in law enforcement. DNA identified at the scene of the crime could be matched to an individual within hours after the sample is analyzed. This would only be possible if the entire country underwent DNA fingerprinting and these findings were stored in a centralized database that law enforcement officers could use to match to DNA found at a crime scene. This would allow rapid **identification** of suspects and lead to a larger number of arrests. The cost for such a large-scale endeavor is considerable.

Currently, DNA databanks for forensic purposes utilize a standard DNA-typing system based on the Federal Bureau of Investigation (**FBI**) panel (13) of specific DNA markers called short tandem-repeat loci, or STRs. STRs are DNA sequences that are repeated a different number of times in different individuals. These repetitive sequences are inherited and can be used to identify an individual with a high degree of certainty. The DNA data is processed using a universal system known as the Combined DNA Index System, or **CODIS**. All states are expected to comply with this system and criminals who cross state lines, if their DNA information is stored in the database of genetic profiles, can be identified by any referral center that has the expertise and access to the system. The DNA information that stored is predominantly for the purposes of identification, no other genetic information is stored on the databases. CODIS DNA profiles are used for a dual law enforcement purpose. While one purpose is to store profiles of convicted felons based on states' requirements, the other is to collect and store unidentified DNA profiles that are from specimens obtained at crime scenes. Although the states maintain their own databanks, the FBI coordinates crosstalk between states through a searchable National DNA Index System, or **NDIS**.

CODIS is responsible for making over 500 matches, leading to arrests by establishing a connection between different violent crimes or by matching a suspect's DNA to DNA obtained from a crime scene using known convicted felons genetic profiles from the database. Over 1,000 crime investigations have benefited from CODIS since its inception. There are over 104 laboratories in 43 states and the District of Columbia. NDIS has assisted the FBI to link six sexual assault cases occurring in the District of Columbia to cases in Florida that otherwise would likely have remained unsolved. It is important to recognize that a significant percent of matches are linked to genetic profiles obtained from criminals arrested for crimes that are not felonies, suggesting that minor crimes are repeated with an increasing magnitude of offense.

SEE ALSO DNA fingerprint; DNA profiling; DNA sequences, unique; DNA typing systems; Mitochondrial DNA typing.

DNA evidence, cases of exoneration

When available and properly utilized, **DNA** is a powerful component of the **forensic science** and criminal justice systems; it can link seemingly unrelated crimes, resolve cold cases, track violent offenders both in and out of the penal system, solve crimes which would have been previously unsolvable, and prevent innocent people from going to prison. Currently, DNA is also being used to exonerate the innocent. Many people who were convicted of violent crimes and sentenced to lengthy periods in prison have continuously stated their innocence. DNA technology now makes it possible, in some cases, to prove or disprove their claims.

At present, there are more than 30 Innocence Projects headquartered at law and journalism schools across the United States, the goals of which are to overturn cases based on the introduction of compelling new **evidence** (frequently DNA-related). Attorney Barry Scheck started the first Innocence Project in New York in 1992; his goal was to be "the last word" for impoverished clients who maintained their innocence but had run out of other legal options. As of early 2005, nearly 160 people have been exonerated by the work of these groups. In addition to their goal of exonerating the wrongfully convicted, the Innocence Project is working to require states to pass legislation mandating that case evidence be preserved, and DNA testing be made readily available to those accused of crimes.

A parallel project was commissioned by the National Institutes of Justice and carried out by the Institute for Law and Justice in Alexandria, Virginia, in 1995. This project involved the study of cases in which post-conviction DNA analysis led to exoneration, as well as an in-depth investigation of DNA laboratories and testing processes. In her commentary on the release of the original report in 1996, former United States Attorney General Janet Reno said, "...DNA aids the search for truth by exonerating the innocent. The criminal justice system is not infallible, and this report documents cases in which the search for truth took a tortuous [twisting] path. With the exception of one young man of limited mental capacity, who pleaded guilty, the individuals whose stories are told in the report were convicted after jury trials and were sentenced to long prison terms. They successfully challenged their convictions, using DNA tests on existing evidence. They had served, on average, 7 years in prison."

DNA testing can be done on **blood**, **semen**, **saliva**, skin and tissue (buccal cells, or inner cheek scrapings, are frequently used), and hair. In one of the earlier recorded cases of the forensic use of DNA technology, in 1986 police in the United Kingdom requested that Alec Jeffreys of Leicester University verify the confession of a suspect in a case involving two rape-murders. DNA testing exonerated the suspect.

In 1987, Robert Melias was the first person in the United Kingdom to be convicted of a crime (rape) on the basis of DNA evidence. Also in 1987, one of the first uses of DNA technology to obtain a criminal conviction was reported in the United States; Tommy Lee Andrews was convicted of rape as a result of a DNA match between his blood sample and semen found in a victim.

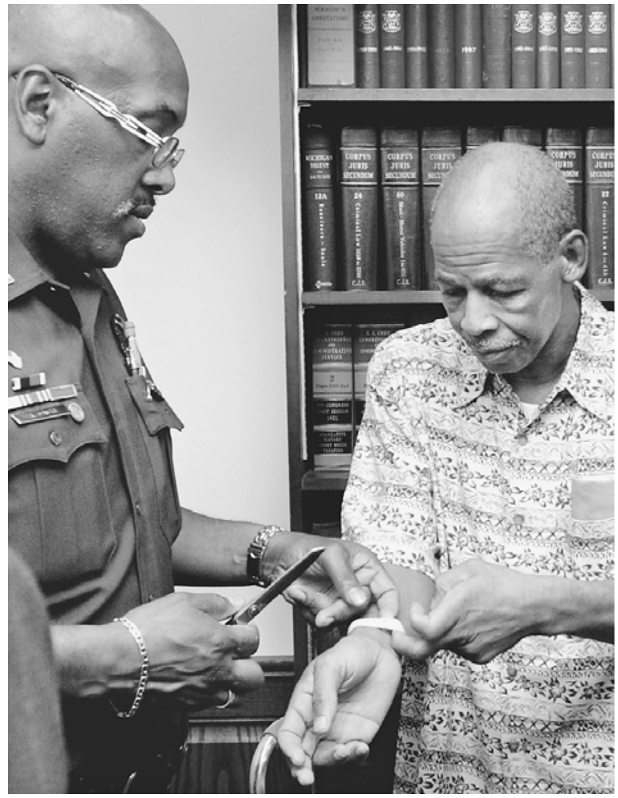
One of the earliest recorded cases of DNA exoneration in the United States was that of Gary Dotson. On July 9, 1977, as she was walking home from work, the complainant alleged that she was abducted, forced into the back seat of a car, raped, assaulted, and pushed from the car onto the street. In July 1979, Gary Dotson was convicted of aggravated kidnapping and rape, and sentenced to 25–50 years in prison. The prosecution's evidence presented at trial was a police-drawn composite sketch of the defendant, with which the complainant had assisted; results of the victim's **identification** of Dotson from a book of mug shots and from a police line-up; testimony that a pubic hair removed from the victim's underwear was dissimilar to her own and similar to Dotson's; and the state serologist's report that semen on the woman's underwear came from a Type-B **secretor** (an individual who secretes the ABH antigens of the ABO blood group in saliva, semen, vaginal, and other bodily **fluids**), and that Dotson was a Type-B secretor. In 1985, the victim recanted her testimony and stated that it had been a fabrication to cover up a sexual encounter with her boyfriend. Dotson's attorneys contended that this recantation constituted grounds to vacate the original conviction. The judge hearing the motion (the same judge who presided over the original trial) refused to grant a new trial, because he felt that the original testimony was more compelling than the recantation. In 1988, Dotson's new attorney (Dotson was released from prison in 1985, and was arrested several subsequent times for other infractions) had DNA tests conducted by Jeffreys of the United Kingdom and by Forensic Sciences Associates in California. These tests did not exist at the time of the original rape conviction. The DNA results indicated that the semen stains on the alleged victim's underwear could not have come from Gary Dotson, but could have come from her (alleged victim's) boyfriend. The chief judge of Cook County (Illinois) Criminal Court ruled that Dotson was entitled to a new trial. The State Attorney's office decided not to prosecute because of the DNA test results and the lack of credibility of the alleged victim. Dotson's conviction was overturned on August 14, 1989, after Dotson served eight years in prison as a result of the wrongful conviction.

Edward Blake, a noted forensic scientist from northern California, was the first to work with **PCR (polymerase chain reaction)**, which, in 1985, revolutionized the process of DNA testing. According to Blake, DNA testing as it is now done, strongly aids in the corroboration of the facts of a case, and the credibility of DNA evidence lies not just in the act of analysis, but also in the manner in which biological samples are collected, stored, processed, and transported. If there are any flaws in the process, it calls the final results of the DNA analysis into question.

One of the cases of exoneration to which Blake often refers is that of Earl Washington. Washington was a mildly retarded African-American farm hand from rural Virginia, who was convicted of rape and **murder**, and sentenced to die in the electric chair. In the spring of 1983, Washington had spent an evening drinking with friends, and got into a fight with his brother over a girl. The intoxicated Washington, angry and deeply distressed, ran next door to a neighbor's house to steal a gun with which to challenge his brother. When the elderly female neighbor attempted to prevent him from taking the gun, Washington hit her with a chair, took the gun, and ran back to his house (where he eventually shot his brother in the foot). When he was arrested soon after, he immediately confessed to shooting his brother and assaulting the neighbor. The police also questioned Washington about a number of unsolved crimes, including three rapes; he confessed to all of them. Next, the police questioned him about the rape and murder of Rebecca Williams, a 19-year old Caucasian mother of three small children. By that point, Washington was in tears, and he confessed to her rape and murder as well. The charges for the first three rapes were all dismissed when the victims came in and stated that Earl Washington was not the perpetrator. However, he was charged with capital murder in the Williams case, as there was no available witness. A primarily Caucasian jury heard Washington's case at trial; he was convicted after only 50 minutes of deliberation. An hour and a half later, the same jury recommended the death penalty.

The Virginia Supreme Court denied Earl Washington's appeal, and an execution date was set. Washington decided not to pursue the appeals process further, as he was not able to represent himself, as required, in a Habeas Corpus petition. In order to represent himself, he would have had to read the entire trial transcript, do his own research, write his own legal brief, and then represent himself before the hearing judge. A fellow death row inmate, with the help of the NAACP, successfully filed a civil rights suit charging that death row inmates who sought appeals should be entitled to free legal representation, and Washington's execution was stayed nine days before it was scheduled to occur, so that he might have the opportunity to pursue the appeal process. A Virginia defense attorney named Robert Hall took on Earl Washington's case, who argued that his client had been coerced by the police into making false confessions. Hall suggested that Washington had responded to the initial police questioning with answers based on the information supplied in their questions. When asked if the victim was white or black, he responded "black" (she was white); when asked if she was tall or short, he responded "kind of short" (she was tall). When the police asked him how many times he had stabbed her, he stated "once or twice," when she had died of multiple stab wounds. His responses to virtually every question were inaccurate.

When Hall examined the forensic reports, he noted that the genetic markers from the crime scene did not match those of Earl Washington. Even in the face of all of this information, it did not meet the criteria for reasonable doubt, and Washington was again facing the death penalty. As time went on, the hope for overturning Washington's conviction was shifted to the state crime lab and its ability to perform DNA analysis. Ten years after his arrest (1993), DNA testing done on a vaginal swab from Rebecca Williams indicated no link whatsoever to Earl Washington. His attorneys petitioned then-Governor Douglas Wilder for clemency and, on his last day in office, he offered Washington and his lawyers a deal: he could either accept life in prison without parole, or take his chances with the incoming governor George Allen, who would have the authority to sign the death warrant. Washington opted to accept the deal that guaranteed him the ability to continue to live. Seven years later, another round of DNA testing conclusively exonerated him. Virginia Governor Jim Gilmore finally granted Earl Washington a full pardon and he was released from prison in 2001.



A Michigan man, Eddie Joe Lloyd, was freed with exonerating DNA evidence in 2002, after spending 17 years in prison.

The Innocence Projects have encouraged the public to accept that fact that mistakes are made, and innocent people are sometimes convicted and imprisoned. Prosecutors, as well as defense attorneys, have begun to acknowledge a responsibility to find and free those who have been wrongly convicted. Thus far, DNA testing has resulted in thousands of convictions of guilty individuals, and the exoneration of more nearly 160 innocent people.

SEE ALSO Circumstantial evidence; Composite drawing; DNA fingerprint; DNA sequences, unique; Mitochondrial DNA analysis; *Frye* standard.

DNA evidence, social issues

The use of **DNA evidence** is a controversial issue from a social and ethical viewpoint. Although the techniques are widely understood by scientists and criminal investigators, the public in general does not have a deep understanding of the technology. Gone are the days of heated interrogations resulting in guilt or innocence and basic crime scene evidence. Investigations are now much more complex, using DNA evidence and trace samples. DNA databasing as an investigative tool is new (late 1990's), and the actual techniques of molecular biology are fairly recent (late 1970's). Thus, the vast majority of the population has yet to receive education on these topics. Uncertainty accompanies this lack of understanding, which can also be fuelled by sensationalism in news stories and coverage of trials where DNA evidence is utilized.

As with any new technology, a certain amount of speculation accompanies **DNA profiling** and databasing. Many people are concerned it is a fine line between developing a DNA database and violating civil liberties. DNA contains a wealth of information about not only an individual, but also can give information about family and ethnic background. Inappropriate use of DNA profiles in databases could lead to discrimination, so the proper degree of protection of the databases is essential.

There are two types of forensic DNA databases: the convicted offender database and the crime scene database. The convicted offender database is a log of STR (short tandem repeat) profiles. STR profiles utilize variability in the number of repeats at a given locus to differentiate among individuals. There are three major forensic DNA databases of individuals convicted of a crime: **CODIS** (Combined DNA Indexing System), which is maintained by the **United States Federal Bureau of Investigation**; the ENFSI (**European Network of Forensic Science Institutes**) DNA database; and the ISSOL (Interpol Standard Set of Loci) database maintained by Interpol. The type of offenses for which DNA is stored differs among countries and states. Initially, these databases contained only samples from violent offenders, those convicted of aggravated assault, rape, or **murder**. However, the value of obtaining DNA from offenders of less severe crimes has been recognized, as many small time criminals become repeat offenders and also more violent offenders. The power of a large bank of DNA samples extends to the possibility of it acting as a deterrent. A match of DNA evidence from a crime scene (which would then be logged in the crime scene database) to one in the convicted offender database rapidly solves the crime, saving time, effort, and money. Conversely, the use of DNA evidence can immediately prove a suspect's innocence.

There are groups of people fervently opposed to DNA profiling for ethical and social reasons. Now that the complete human genome is sequenced, population genetics and other studies are ongoing that have linked genes to phenotypes, predisposition to disease, and predicted response to drug therapy. Should research establish a link between a particular genotype specific to offenders or violent criminals, this could potentially be used to profile potential criminals. In a world where one is guilty until proven innocent, what is the consequence of possessing a genetic profile suggesting that you may one day commit a crime? In society, this individual could potentially be convicted of a crime that he has never even committed. Thus, the opponents of DNA profiling argue, the use of databases to profile individuals for behavior types such as sex offender or violent criminal could affect human rights and civil liberties.

The potential for the criminal justice system to become more genetics-based is another concern. STR loci are based on non-coding sections of the human genome. There are several reasons for this; these regions of the genome tend to be highly variable and thus differ considerably among individuals. The result is a near impossible probability that when all STR loci are taken into account that the profile could belong to more that one human being. Secondly, by using non-coding regions, the STR profiles are not linked to any phenotype or human trait. However, if the genotype of other loci are utilized for analysis additional to STR database uses, it is possible that genetic-based profiling could occur.

Civil rights advocates are concerned that the DNA databases could one day be extended beyond that of criminal offenders to the point where genetic analysis or profiling could be used in a discriminatory manner. It is their intent to protect what exists currently in databases to ensure the DNA is not exploited in any manner that is unethical or violates human rights.

The cause for concern here is the fact that although STR profiles only are logged into the DNA database, be it CODIS, ENFSI, or ISSOL, if the sample is stored, it does include all other genetic information on that individual. Additionally, data obtained from a crime scene that would be entered into the crime scene database could first be utilized to provide a profile of the assailant. For example, DNA evidence left at the scene of a crime may not match any suspect in the criminal database. However, this DNA could potentially be used to obtain the person's sex, height, hair, and eye color and other such traits that may allow the police to generate a physical profile of the perpetrator. Thus, anyone matching this profile could become a potential suspect.

Further analysis of the STR profile via a DNA sample provided by a person under suspicion would easily rule that individual out if he was indeed innocent. However, this too, generates questions of human rights, as although the person is shown to be innocent, any negative consequences or publicity surrounding the investigation could be shown to violate that individual's human rights. Proponents of using genetics to generate a profile of the felon argue that constitutional rights are not violated as no particular group is singled out in such a profile. Furthermore, using such a method could actually decrease racial profiling, as disproportionate finger pointing toward a particular group would be avoided.

Legal implications are constantly considered in courts of law to assure adherence to the respective governing guidelines. In October 2004, President Bush signed into law the Justice for All Act. This law, part of the Advancing Justice Through DNA Technology Act of 2003, provides additional support for victims' rights, ensuring funding for victim's assistance programs. It also extends the DNA databases by providing funds to analyze samples in backlog and sets guidelines for the use of DNA testing post conviction for those who maintain their innocence. The Innocence Protection Act is part of the Advancing Justice Through DNA Technology Act of 2003 (HR 3214/S 1700), and is a United States Government initiative to utilize DNA and forensic evidence to prove the innocence of those wrongly convicted of a crime. It allows convicted individuals access to DNA evidence in order to demonstrate their innocence. Numerous people convicted of crimes, including some on death row, have been exonerated based on DNA evidence that either wasn't available or did not exist as an admissible courtroom technology at their time of conviction.

In Europe, Article 8 of the European Convention of Human Rights defines guidelines for the protection of individual rights. The use of forensic DNA databases has come into question under this law, but the proper use of DNA databases was shown not to be in violation. As the value of using forensic DNA databases across borders is realized, especially across Europe, human rights discussions become even more complex. Although most all European countries are governed by the European Convention of Human Rights, each individual country has its own additional guidelines and regulations when it comes to privacy rights, confidentiality of genetic information, and **crime scene investigation**. In order to address these concerns on a European basis, several councils and agencies are devoted to these tasks; examples include the Council of Europe convention for the protection of human rights with regard to the application of biomedicine, the United Nations outline for an International Declaration on genetic data, and the European Data Protection Commission.

The diversity of countries across Europe requires consideration of many social and ethical topics regarding forensic DNA databases. Some European Union member countries do not currently have a DNA database in existence. Different opinions exist across Europe concerning which crimes warrant taking a DNA sample. In addition, some countries require consent first, while others do not; and the length of time samples may remain in the DNA databank may be different from country to country. The Interpol DNA Monitoring Expert Group is committed to the development of a consolidated forensic DNA database across Europe as well as internationally. Part of this initiative includes promoting awareness of social, privacy, and **ethical issues**.

Clearly, social and ethical issues regarding DNA evidence will continue to be a topic of debate. Through education, legislation, and proper use of DNA forensic technologies and databases, the use of DNA evidence will continue to convict the appropriate offender and demonstrate the innocence of others.

SEE ALSO CODIS: Combined DNA Index System; DNA; DNA profiling; European Network of Forensic Science Institutes; Privacy, legal and ethical issues; Standardization of regulations; STR (short tandem repeat) analysis.

DNA fingerprint

DNA (deoxyribonucleic acid) represents the blueprint of the human genetic makeup. It exists in virtually every cell of the human body and differs in its sequence of nucleotides (molecules that make up DNA, also abbreviated by letters, A, T, G, C; or, adenine, thymine, guanine, and cytosine, respectively). The human genome is made up of 3 billion nucleotides, which are 99.9% identical from one person to the next. The 0.1% variation, therefore, can be used to distinguish one individual from another. It is this difference that can be used by forensic scientists to match specimens of **blood**, tissue, or hair follicles to an individual with a high level of certainty.

The complete DNA of each individual is unique, with the exception of identical twins. A DNA fingerprint, therefore, is a DNA pattern that has a unique sequence such that it can be distinguished from the DNA patterns of other individuals. DNA fingerprinting is also called DNA typing.

DNA fingerprinting was first used for sample **identification** after the geneticist Alec J. Jeffreys from the University of Leicester in Great Britain discovered that there are patterns of genetic material that are unique to almost every individual. He called these repetitive DNA sequences "minisatellites." The two major uses for the information provided by DNA-fingerprinting analysis are for personal identification and for the determination of paternity.

DNA fingerprinting is based on DNA analyzed from regions in the genome that separate genes called introns. Introns are regions within a **gene** that are not part of the protein the gene encodes. They are spliced out during processing of the messenger RNA, which is an intermediate molecule that allows DNA to encode protein. This is in contrast to DNA analysis looking for disease causing mutations, where the majority of mutations involve regions in the genes that code for protein called exons. DNA fingerprinting usually involves introns because exons are much more conserved and therefore, have less variability in their sequence.

DNA fingerprinting was originally used to identify genetic diseases by linking disease genes within a family based on the inheritance of the segregating markers and the likelihood that they would be in close proximity, but it also became used for criminal investigations and forensic science. In general, the United States courts accept the reliability of DNA analysis and have included these results into **evidence** in many court cases. However, the accuracy of the results, the cost of testing, and the misuse of the technique have made it controversial.

In forensics laboratories, DNA can be analyzed from a variety of human samples including blood, **semen**, **saliva**, urine, hair, buccal (cheek cells), tissues, or bones. DNA can be extracted from these samples and analyzed in a lab and results from these studies are compared to DNA analyzed from known samples. DNA extracted from a sample obtained from a crime scene then can be compared and possibly matched with DNA extracted from the victim or suspect.

DNA can be extracted from two different sources within the cell. DNA found in the nucleus of the cell, also called nuclear DNA (nDNA) is larger and contains all the information that makes us who we are. It is tightly wound into structures called chromosomes. DNA can also be found in an organelle within the cell called the mitochondria, which functions to produce energy that drives all the cellular processes necessary for life. Mitochondrial DNA (mtDNA) is much smaller, contains only 16,569 nucleotide bases (compared with nDNA, which contains 3.9 billion) and it is not wound up into chromosomes. Instead, it is circular and there are many copies of it.

Nuclear DNA is analyzed in evidence containing blood, semen, saliva, body tissues, and hair follicles. DNA from the mitochondria, however, is usually analyzed in evidence containing hair fragments, bones, and teeth. **Mitochondrial DNA analysis** is typically performed in cases where there is an insufficient amount of sample, the nDNA is uninformative, or if supplemental information is necessary.

Unlike nDNA, where one copy of a **chromosome** comes from the father and the other from the mother, mtDNA is exclusively inherited from the maternal side. Therefore, the maternal mtDNA should be the same as her offspring. This can be helpful in cases where it is not possible to obtain a sample from the suspect but it is possible to obtain a sample from one of the suspect's biologically related family members. By doing so, the suspect can be excluded as the culprit of a crime if the results indicate that the relevant family member's mtDNA does not match the mtDNA fingerprint from the sample.

Mitochondrial DNA can be informative in a different way than nDNA. Less than 10% of the mitochondrial genome is noncoding and localized in a region called the D-loop. In this region, there are sequence variations that are inherited that can be used for forensic purposes. These regions, called hypervariable regions, are broken down into two sections: HV1 and HV2. It is within these regions that inherited sequence variations can be identified.

One of the main reasons mtDNA analysis can be helpful to forensic scientists is that in some tissues, mitochondrial DNA is in excess compared to nDNA. As nDNA exists in chromosomes and there are only two copies of each chromosome (one inherited maternally, the other paternally) per cell, the nDNA copy number is much smaller. The mitochondrial genome can have a copy number of 2–10 per organelle and in some cases the number of organelles can reach the hundreds. For example, in muscle tissue, where the demand for energy is highest, there are a larger number of copies of the mitochondrial genome. Analysis of mtDNA, therefore, can be particularly helpful in forensic cases where sample integrity or size is compromised or when confirmation is needed.

There are many methods that forensic scientists use to determine the sample's DNA fingerprint. Once DNA is extracted, it can then be analyzed using a variety of molecular genetics techniques. In some cases, there is not enough DNA to directly evaluate it. If this occurs, a technique called the **polymerase chain reaction** (**PCR**) is used to amplify the genomic DNA from a sample. This procedure allows a scientist to amplify a specific sequence of DNA in the genome exponentially, so that it is in large enough quantities to be analyzed.

DNA analysis can be performed by **sequencing** the amplified DNA fragment using fluorescently labeled nucleotides and a **laser** that will recognize the nucleotide based on the fluorescent label to which it is attached. This technique is expensive, may not be informative, and is generally not the best approach to DNA fingerprint a sample.

If there is enough DNA, the DNA extracted from the sample can be cut or segmented using specific enzymes (proteins that speed up chemical reactions) called restriction endonucleases that act as molecular scissors by cutting specific sequences that they recognize. By cutting in the same sequence that is present in different locations throughout the genome, a pattern of fragments can be formed. Differences in the sequence patterns between two samples can be due to inherited variations in the DNA that can distinguish two different samples.

Once the DNA is cut, the segments are arranged by size using a process called **electrophoresis**, whereby an electrical field is generated, pulling the negatively charged DNA toward the positively charged end through a gel-like matrix. The segments are marked with radioactive probes and exposed on x-ray film, where they form a characteristic pattern of black bars. This pattern is called the DNA fingerprint. If the DNA fingerprints produced from two different samples match, the two samples are likely to have come from the same person.

DNA can also be processed and cut with restriction enzymes. If there is a variation in a particular sequence that results in the enzyme no longer recognizing and cutting the DNA (or a loss of the cut site), a larger fragment will be observed when running the DNA in a gel by electrophoresis. Using a chemical that binds to DNA (called ethidium bromide) and fluoresces when it is excited by ultraviolet radiation, the fragments can be observed on a gel based on size. Bigger fragments will migrate more slowly in the gel. An individual with the sequence variation in which the enzyme does not cut would have a longer size fragment than the individual with the variation the enzyme does cut.

The original DNA fingerprinting procedure used Variable Number Tandem Repeats (VNTR), which are repetitive DNA sequences that are spread throughout the genome in noncoding regions. These targets are large, with repeat numbers that are variable from person to person and have a repeat size composed of hundreds of nucleotides which can be repeated a hundred times.

The biggest problem with using the VNTR-fingerprinting approach is that DNA extracted from samples in a crime scene, such as from a dried blood stain, is often broken up into tiny pieces due in most cases to natural DNA-degrading processes. This can make DNA analysis difficult, unless informative fragments remain intact. Additionally, the smaller the sample, the more likely it will be degraded. For example, a plucked hair might contain up to 30 nanograms (30 ng, or 30 billionths of one gram) of genomic DNA, but a hair shaft without the root might maximally only contain 0.1 ng of DNA. The integrity of the sample as well as the quantity, therefore, can make reliable and definitive identity determination difficult.

More recent approaches have circumvented the problem associated with degraded DNA. Shorter repetitive sequences, or short tandem repeats (STR), were later identified and found to contain repeat core units of three, four, or five nucleotides long and have a complete length of only 80–400 nucleotides. Due to the shortness of these sequences, only 50 pg of DNA (which is almost a 1000 times less than that found in a hair shaft without the root) is required. The discriminating power, when analyzing STRs at multiple locations with the genome, can match persons with a probability of 1 in 10^{15} to a stain. The DNA fingerprint using **STR analysis** can, therefore, be an extremely powerful technique in forensic sciences.

With the completion of the human genome sequence and the rapid post-genomic characterization of the sequences, it has become easier to analyze samples pertinent for forensic applications. In fact, forensic scientists have been able to link a suspect to the scene of a crime using dried chewing gum, the cells in the saliva from the butt of a cigarette, and cells found underneath fingernails. DNA fingerprinting, therefore, has revolutionized the forensic sciences by its use in investigations and prosecutions of active criminal cases, missing persons investigations, re-examining dead-end cases, post-conviction exoneration, and studies where maternal relatedness is in question.

SEE ALSO Analytical instrumentation; Chemical and biological detection technologies; DNA profiling; DNA recognition instruments; RFLP (restriction fragment length polymorphism).

DNA indexing SEE CODIS: Combined DNA Index System

DNA isolation methods

Deoxyribonucleic acid (**DNA**) isolation is an extraction process of DNA from various sources. Methods used to isolate DNA are dependent on the source, age, and size of the sample. Despite the wide variety of methods used, there are some similarities among them. In general, they aim to separate DNA present in the nucleus of the cell from other cellular components.

Isolation of DNA is needed for genetic analysis, which is used for scientific, medical, or forensic purposes. Scientists use DNA in a number of applications, such as introduction of DNA into cells and animals or plants, or for diagnostic purposes. In **medicine** the latter application is the most common. On the other hand, **forensic science** needs to recover DNA for **identification** of individuals (for example rapists, petty thieves, accident, or war victims), paternity determination, and plant or animal identification.

Presence of proteins, lipids, polysaccharides and some other organic or **inorganic compounds** in the DNA preparation can interfere with DNA analysis methods, especially with **polymerase chain reaction** (**PCR**). They can also reduce the quality of DNA leading to its shorter storage life.

Sources for DNA isolation are very diverse. Basically it can be isolated from any living or dead organism. Common sources for DNA isolation include whole **blood**, hair, **sperm**, bones, nails, tissues, blood stains, **saliva**, buccal (cheek) swabs, epithelial cells, urine, paper cards used for sample collection, bacteria, animal tissues, or plants.

It is quite clear that the extraction methods have to be adapted in such a way that they can efficiently purify DNA from various sources. Another important factor is the sample size. If the sample is small (for example sperm, or a single hair) the method has to be different to the method used in isolating DNA from a couple of milligrams of tissue or milliliters of blood. Another important factor is whether the sample is fresh or has been stored. Stored samples can come from archived tissue samples, frozen blood or tissue, exhumed bones or tissues, and ancient human, animal, or plant samples.

The isolation of DNA usually begins with lysis, or breakdown, of tissue or cells. This process is essential for the destruction of protein structures and allows for release of nucleic acids from the nucleus. Lysis is carried out in a salt solution, containing detergents to denature proteins or proteases (enzymes digesting proteins), such as Proteinase K, or in some cases both. It results in the breakdown of cells and dissolving of membranes.

While the lysis of soft tissues or cells is easy, DNA also has to be isolated from hard tissues, such as bone, wood, and various plant materials. Most plant samples require freezing in liquid nitrogen and subsequently pulverizing the tissues to a fine powder. On the other hand, bones are highly mineralized and the ions have to be removed from the samples before extraction so they do not later interfere with PCR. Once the samples are partly processed they are then homogenized in lysis buffer using a mechanical homogenizer.

DNA isolation is a simple process and can be performed in a kitchen using household appliances and chemicals. Vegetables or meat can be homogenized with salt and water. After that, by application of a detergent, cellular proteins and lipids are separated away from DNA. Enzymes found in meat tenderizer or pineapple juice allow precipitation of proteins and free DNA into the solution. By adding alcohol to the mix, nucleic acid is brought to the top of the container and can be spooled onto a stick as a visible white string.

A number of commercial DNA purification kits use the very same principles as this household method, but different reagents. In a commercial kit the common lysis solutions contain: sodium chloride; tromethamine (also known as Tris), which is a buffer to retain constant pH; ethylenediaminetetraacetic acid (EDTA), which binds metal ions; and sodium dodecyl sulfate (SDS), which is a detergent. A common enzyme used in DNA extraction is Proteinase K.

The oldest methods of DNA purification in laboratories, still often used also by the **FBI**, rely on a mix of organic solvents. Lysed samples are mixed with phenol, chloroform, and isoamylalcohol for separation of DNA and protein. Proteins are denatured by the organic mixture. When the sample is centrifuged, DNA is retained in the aqueous (water) layer, phenol is at the bottom of the tube, and denatured proteins form a cloudy interface. This method is very efficient, but unfortunately it can only be used if the quantity of starting material is reasonably abundant. Moreover, the organic solvents used carry health and safety problems. The quality of the DNA from this procedure is usually not adequate for some more sensitive analytical techniques (especially **sequencing** and occasionally PCR).

A modification of the method uses high salt (sodium chloride, NaCl) concentration to bring down DNA. After the denaturation of cellular proteins using detergents and a protease for a few hours or overnight, salt is added and mixed with the solution. As a result, salt of nucleic acid is formed and in presence of alcohol can be recovered by centrifugation.

Occasionally, alkaline denaturation of the sample is used to release DNA from the cells. Buccal swabs and occasionally blood stains can be placed in small plastic tubes (eppendorfs) and subjected to denaturation with sodium hydroxide (NaOH). The solution is then re-equilibrated to neutral pH with a more acidic buffer solution and is ready for PCR. Although it is a quick and simple method, the quality of DNA is not always adequate for all applications.

A method similar to alkaline denaturation is heat denaturation, achieved by boiling samples. Heating of a sample to 100°C releases DNA into the solution but also denatures it by separating the two strands. In some cases this procedure gives adequate nucleic acid that can be amplified by PCR, however, most of the time there are remaining inhibitors in the form of degraded proteins, other **organic compounds**, or ions.

A related method used commonly in forensic laboratories utilizes Chelex ion exchange resin that binds multivalent metal ions and is particularly useful in removing inhibitors from DNA. It can be used with any type of sample, including whole blood, bloodstains, seminal stains, buccal swabs, or hair. The only difference from the previous method is the presence of resin, which binds the impurities from the solution, while DNA is being left in the solution. By centrifuging the samples, the resin is brought to a pellet and separated.

Another method similar to Chelex relies on the use of paramagnetic beads with DNA binding capacity. Samples are lysed and then the solid material is treated with Proteinase K. The lysates are then applied to the beads. Resin is subsequently washed and DNA is eluted of it at 65°C, magnetic beads are separated from the sample on a magnetic stand.

Other methods of DNA purification involve columns of various sorts, which are packed with ion exchange, or silica based resins or matrices. Ion exchange columns are generally positively charged to bind the negatively charged DNA; silica matrices are also charged and can also retain DNA. In such applications DNA from the cellular lysates is expected to bind to the column. These columns are then washed using salt solutions to remove unbound material. Nucleic acid is then recovered by applying water or a neutral pH salt solution to break down the resin-DNA bonding.

The use of columns allows increased throughput of samples, shorter time of isolation in comparison to traditional solvent based extraction, increased yield of recovered DNA, and improved quality of purified DNA.

In addition to columns and the previously described resins, there are also liquid resins that are used. The principle is the same as for magnetic beads, but at the final step the samples have to be spun to separate DNA from the resin.

All of these methods so far have dealt with simple, single samples. In some cases a sample consists of a mixture of cells, for example sperm cells and non-sperm epithelial cells. This extraction is based on differential properties of the two cell types. Sperm cells resist Proteinase K lysis; therefore the non-sperm cells are lysed first in its presence. When the tube is centrifuged, the solution contains epithelial DNA, while the pellet contains sperm cells. Sperm cells are subsequently lysed by adding dithiothreitol or DTT with Proteinase K. Any of the techniques mentioned before can be used to isolate the DNA from those differential lysates.

Although plants are not a common source of DNA for forensic investigation, analysis of their DNA is very common in science. Plants are more difficult to work with than many other materials for a couple of reasons. First, plant cells have a cell wall, which has to be at least partly destroyed before the cytoplasm with the DNA can be accessed. Second, plants often have high levels of sugars (for example starch or fructose) in their tissues or other organic compounds such as polyphenols.

Grinding of the samples in liquid nitrogen helps to destroy the cell wall, but the organic compounds including sugars still remain. As a result, methods were developed that use chloroform-octanol mix, hexadecyltrimethylammonium bromide (CTAB) with high salt to remove polysaccharides, and polyvinylpyrrolidone (PVP) to remove polyphenols.

All of these methods are successfully used in various laboratories and with various samples. The methods have to be properly selected to optimize the yield and quality of the DNA extracted.

SEE ALSO DNA; DNA profiling; DNA typing systems.

DNA mixtures, forensic interpretation of mass graves

War crimes are most often committed during conflicts between nations. Crimes against humanity, such as summary executions of civilians, are also not uncommon in situations of national armed conflicts, revolutions, or in totalitarian regimes. All of these events result in missing persons and often in undiscovered mass graves. Both are searched for and processed by forensic experts in the aftermath of the conflict. Legal **medicine** has greatly benefited from the development of molecular biology and its new analytical techniques, in particular **DNA** analysis, in the **identification** of highly decomposed human remains.

Terrorist attacks on densely populated areas or against large human gatherings, such as the 2001 attack on the World Trade Center and the 2002 Bali nightclub bombing, or mass disasters, such as the 2004 Indian Ocean earthquake and tsunami, also yield a tragically large amount of bodies to be identified. In some situations, such as after the conflict in Kosovo in the 1990s, the identification of human remains was possible in many cases by comparing medical and dental records of missing persons with findings at **autopsy** in cadavers rescued from mass graves. Mass graves containing a large amount of highly decomposed bodies and skeletal remains do pose specific challenges for forensic experts, especially when dental and medical records are not available, or when the grave is a secondary one, containing parts of bodies who were purposely removed and mixed by the perpetrators. The recent development of new DNA **sequencing** and profiling technologies, as well as the understanding of the uniqueness of certain DNA sequences among individuals, has become greatly useful for human identification in situations of mass casualty.

Discrete genetic variations among individuals in the population and among races are known as polymorphisms. The word polymorphism originates from the Greek *poly*, meaning several and *morphos*, meaning shape. Single nucleotide polymorphisms (SNP) are mutations of one base pair in the sequence of certain genes. Several polymorphisms are present in regions of DNA known as microsatellites, as well as in some types of repeated DNA sequences. Polymorphisms are of special interest in forensic investigation because they allow the identification of a person or suspect through the DNA extracted from a bloodstain by comparing it with another sample from the suspect, or the identification of a baby's mother or father, or of a murder victim through a bloodstain or **saliva** left at a crime scene, or the identification of unknown human remains by matching the DNA with that of a living relative. The latter procedure was frequently applied in the aftermath of the Asian tsunami in December 2004.

Most genes are inherited in two copies: one from the father and the other from the mother, which are respectively known as paternal and maternal alleles. Allelic comparison of certain genes is one of the identification techniques used in forensics. Conversely, DNA from cell organelles, the mitochondria, is only inherited from the mother (mtDNA), allowing the comparison of the mtDNA collected from a sibling, or from the mother with the mtDNA of a deceased person, to establish whether those remains belong to that family. The remains of an American soldier who served in Vietnam, for instance, were identified 24 years after his death through the mtDNA extracted from the bone marrow of his skeleton and samples donated from living relatives. Mitochondrial DNA does not identify an individual in particular, however, if more than one sibling is missing. When several members of a family are missing, other genetic and forensic tests may help to determine the identity of the remains found in a disaster area or in a mass grave.

Some specific repeating DNA sequences are also used for human identification. They are classified according to their characteristics, such as LINES (long interspersed sequences), SINES (short interspersed sequences), LTR (long terminal repeats), STR (short tandem repeats), and VNTR (variable number of tandem repeats, or microsatellite DNA). Short tandem repeats are used in tests of paternity and VNTR is used to identify victims and suspects.

Sir Alec Jeffreys, an English professor at Leicester University, was the first scientist to use DNA polymorphism tests in a forensic identity investigation in 1985. He chose a region of DNA known as VNTR because of its great variability (polymorphism) among individuals, which can only yield a perfect sequence match in cases of identical twins. Additionally, if two individuals do present a high degree of similarities (but not a perfect match) in their VNTR sequences, this indicates that they are related.

However, postmortem transformations quickly degrade DNA of soft tissues due to bacterial activity. Hochmeister and colleagues (Journal of Forensic Science, 1991;36:1649–1661) were the first to isolate DNA from the marrow of the human femur from a mummified body of an 11-year-old child and from a corpse that had been submerged in water for 18 months. They utilized two DNA analysis techniques to sequence VNTR from the bones: VNTR amplification by **PCR (polymerase chain reaction)** and **RFLP** (restriction fragment length polymorphisms), thus demonstrating that DNA is relatively well preserved in the marrow of long bones. In 1994 another group identified the Romanov family (the last Russian czar, his wife and three children killed in 1918), also using DNA extracted from their bones. Studies conducted by other researchers in 1996 found that even in bones DNA degrades differently in certain conditions, being best preserved in dry or arid environments such as deserts and worst degraded when the bone fragments were immersed in water. Teeth and dried **blood** stains however, even almost 100 years old, were found to be a good source of well preserved DNA for forensic identification of human remains.

Crime scenes, disaster areas, and mass graves often produce mixed biological samples containing genetic material from two or more individuals, such as mixed body **fluids**, bloodstains, or blood pools. In the 1994 murder case of Nicole Brown Simpson, for instance, the blood pool around the body of Nicole Simpson contained blood (and DNA) of both Nicole and her former husband, O. J. Simpson, who was charged and acquitted in criminal court and later found liable in civil court for her murder. When male and female cells are present in the same sample, the cells can be sorted by using a **laser** technique or **DNA profiling**. In mass graves or bombing scenes however, samples may contain DNA of several victims, rapidly degrading in tropical climates or due to moisture and soil conditions, all of which affect the STR sequences and other DNA loci used in human identification. Until recently, this constituted a serious obstacle to forensic interpretation. With the rapid evolution of genetic screening technologies, however, new test kits and software are being constantly developed. Some of these kits are more sensitive to low, degraded concentrations of DNA found in mixed samples than others.

Additionally, matches from DNA mixtures are also assessed against scientific profiles and probability or frequency estimates in order to establish the statistical significance of the match. These statistics serve to inform courts and jurors of the odds that a match can be common to more than one individual. In degraded DNA mixtures, the margin of error for minor STR components can be 10–33%, and the burial of several relatives with similar alleles in a mass grave can make individual identification of DNA from a mixture even more difficult. Statistical evaluation of DNA mixtures takes into account the match probability.

The International Commission on Missing Persons installed a forensic laboratory in Tuzla, Bosnia, in 2000 for the identification of victims of the war in Bosnia. The forensic team has chosen a more direct approach than DNA mixture analysis. Living relatives of missing persons donate blood samples for comparison with DNA extracted from the long bones and teeth of the exhumed human remains. In Bosnia, more than 30,000 people were reported missing, mostly Muslim men and boys. Mass graves were located and exhumed in nearby Srebrenica and other localities, but many mass graves are yet to be located and processed. To identify one corpse, this method requires samples from 3 relatives. Whenever nuclear DNA is not degraded, it is used in the tests, because the maternal and paternal alleles offer a unique profile for each individual. The other option is mtDNA profiling because mitochondrial DNA is usually better preserved and stays unaltered for longer periods than nuclear material.

ICMP is also profiling DNA from other mass graves in Croatia, Kosovo, and other former Yugoslavia territories. In Rwanda however, where more than 500,000 people were massacred in 3 months in 1994, due to the inexistence of automated DNA technologies and the rapid degradation of DNA because of the tropical heat and humidity, this task would have been impossible. In Brazil, collective summary executions occurred during the totalitarian military regime (1964–1985) and the location of many suspected mass graves remains unknown. Some were discovered in the 1990s. Legal physicians working in the identification of the human remains recovered from mass graves were faced with the same problems of DNA degradation common in other tropical countries. Nevertheless, DNA extracted from teeth and the application of other forensic identification techniques led to the successful identification of many of the victims.

A scientist uses blood samples taken from family members of people who disappeared during Chile's Augusto Pinochet's 1973–1990 dictatorship in an attempt to match DNA from people who disappeared during those years and were later uncovered in mass graves. © REUTERS/CORBIS

SEE ALSO Autopsy; Blood; DNA; DNA sequences, unique; DNA typing systems; Exhumation; Gene; Genetic code; Identification of the son of Louis XVI and Marie Antoinette; Laser; Medical examiner; Mitochondrial DNA analysis; Mitochondrial DNA typing; Mummies; Pathology; PCR (polymerase chain reaction); RFLP (restriction fragment length polymorphism); Skeletal analysis; War crimes trials; War forensics; Y chromosome analysis.

DNA profiling

DNA is the material within every cell of the body and represents the blueprint of life. It allows physical traits to be passed on from one generation to the next. Although the majority of the human genome (the complete set of genes for an individual) is the same across all ethnic populations, people differ in their genetic makeup by a minuscule amount, and thus have their own unique DNA pattern. DNA profiling, also referred to as DNA typing, is the molecular genetic analysis that identifies DNA patterns. In **forensic science**, DNA profiling is used to identify those who have committed a crime. It is estimated that roughly one percent of all criminal cases employ this technique; however, DNA profiling has been used to acquit several suspects involved in serious crimes such as rape and **murder** and it has been used to convict individuals of crimes years after investigators closed the unsolved case. Aside from identifying an individual responsible for violent crimes, the judicial system also can use DNA profiling to determine family relationships in the case of disputed paternity or for immigration cases.

DNA molecular analysis has also been used in the diagnosis of clinical disorders. Many genetic diseases are caused by mutations in DNA within regions of the genome that code for protein, and scientist look in these regions for mutations to determine if a patient is affected or is a carrier of a genetic disease. Unlike clinical molecular genetics, DNA typing for forensics takes advantage of locations within the human genome that do not code for protein. These locations typically involve repetitive DNA sequences that are polymorphic, or have a variable number of repeat sizes. Because non-protein-coding DNA is used, **DNA databanks** that contain DNA typing information do not reveal any information about an individual's health status or whether the individual has or is a carrier of a genetic disease.

The sensitivity of DNA profiling tests have dramatically increased over the last two decades. It used to be necessary to have a sample roughly the size of the ink in an ink pen, skilled forensic scientists can now obtain enough DNA from **saliva** left on the end of a cigarette to get a DNA profile result. The speed at which results can be obtained has also dramatically improved. This is all, in part, due to the discovery of the **polymerase chain reaction**, a technique that can amplify large amounts of specific small sequences of DNA from the human genome. It is also due to the advent of various DNA fingerprinting tools. The effect of these advances has broadened the sample size and quality required for analysis.

DNA profiling uses a variety of **DNA typing systems**, including: **restriction fragment length polymorphism** (**RFLP**) typing, short tandem repeat (STR) typing, single nucleotide polymorphism (SNP) typing, mitochondrial DNA (mtDNA) analysis, human leukocyte **antigen** (HLA)-typing, gender typing, and Y-chromosome typing.

The first approach to DNA typing used variable number tandem repeats, or VNTRs. VNTR's are repeating units of a DNA sequence, the number of which varies between individuals. They are analyzed as Restriction Fragment Length Polymorphisms (RFLPs). RFLPs are variations within specific regions of genomes that are detected by restriction enzymes. RFLP analysis originated in the 1970s after the discovery of restriction enzymes, or proteins that can cut DNA into smaller molecules (restriction fragments) based on specific DNA sequence recognition sites. A restriction enzyme recognizes and cuts DNA only at a particular sequence of nucleotides (the components of DNA). VNTR's are 20–50 base pairs (pairs of nucleotides) long per repeat and a person can have anywhere from 50 to several hundred repeats. This repeat length is inherited. This DNA typing approach was first discovered by the British geneticist Alec Jeffreys in 1985 and is the principle behind today's DNA profiling systems.

The advantage of using a RFLP-based analysis for DNA profiling is that VNTR regions are highly variable in copy number from person to person. Therefore, it is highly unlikely that DNA profiles from unrelated individuals would be identical. However, there are also several drawbacks to this technique. Since these regions are large, it is often difficult to clearly separate the fragment using **electrophoresis**, which is a technique that uses a DNA sample loaded into a gel that migrates towards a positively charge electric field based on size. For example, larger fragments migrate slower than smaller fragments. This is problematic when the migration of one VNTR is indistinguishable from another VNTR, even if they differ in length. This is due to limited resolution of the gel matrix (only large differences can be detected). A larger amount of DNA (20 nanograms) of purified, high quality DNA is also required for this technique. Thus, DNA samples extracted from crime scene specimens may be not suitable in quality for this type of analysis. High purity in terms of DNA extractions can be compromised according to the source of the sample. If, for example, the sample is **blood** and is extracted from clothing, the dye from the cloth might alter the mobility of the extracted DNA in the gel, making the analysis difficult.

VNTR analysis has been replaced by Short Tandem Repeat (STR) analysis. STR regions are comprised of 2–4 base pair repeats that are repeated between 5 to 15 times. **STR analysis** is currently the standard approach to forensic DNA profiling. This is mainly because shorter repeat sequences are easier to analyze.

STR analysis is faster, less labor intensive, and can be automated. A single reaction can analyze 4–6 STR regions using very little DNA (only one nanogram is usually sufficient). If only a small amount of DNA is recovered or if it is degraded, it may be possible to use STR analysis, but not VNTR analysis.

Additionally, in VNTR analysis, genomic DNA is digested with restriction enzymes and then run on a gel. The fragments produced are transferred to a membrane and probed with a radiolabeled sequence of DNA that matches the VNTR sequence. The migration of the VNTR fragment on the gel determines their size and generates a pattern. The radiolabeled probe produces dark bands on x-ray film when exposed in a time-dependent and dose-dependant manner. Unlike VNTR analysis, STR analysis uses the polymerase chain reaction to amplify DNA in the region where the STR is located. These **PCR** products can then be run on a gel in the same manner as the VNTR fragment and using sophisticated computer software with **laser** controlled equipment, the migration of the PCR products can be compared to control DNA molecules that have a known size. If run together, the size of the unknown STR can be estimated. In this case, STRs are visualized by adding a DNA intercalator such as ethidium bromide into the gel, which intercalates into the DNA and fluoresces (emits) ultraviolet light.

STR analysis, however, is not without its drawbacks, as well. If very little DNA is recovered from a crime scene and it is degraded, not all regions in the genome will amplify, or there will be discriminatory amplification of DNA in only one chromosomal STR region, rather than both. This can significantly affect the results and lead forensic scientists to draw incorrect conclusions. Additionally, there may be substances in the sample that inhibit the PCR reaction. For these reasons, forensics scientists must use a standardized approach that is reproducible and includes all the necessary positive and negative controls for DNA profiling to be used as **evidence** during a court proceeding.

A significant problem in using DNA profiling as evidence in court proceedings is the possibility that a mistake was made in the sample extraction, preparation, or analysis. For this reason, investigators take precautions to reduce human error. Each forensics laboratory must maintain a high level of quality control and quality assurance standards to prevent this from happening. State and local mandates are being established to standardize these techniques.

Every cell, tissue, or organ in a person's body contains the same DNA pattern, so the United States law enforcement and armed forces has developed databases to collect information related to an individual's DNA identity. This information will be used for **identification** purposes in missing person cases or to identify the remains of deceased individuals. Other techniques previously used to identify individuals such as using dental records, dog tags, or blood typing have been superceded by DNA profiling, which provides more information and is more conclusive. For example, if two samples have the same blood type, it still is not clear that they came from the same person. Even dental records might not be helpful in cases where the integrity of the sample is compromised to a degree that makes it difficult to match it appropriately. In DNA profiling, even if the deceased person was significantly disfigured, it would still be possible to analyze the sample.

SEE ALSO DNA databanks; DNA evidence, social issues; DNA fingerprint; DNA sequences, unique; DNA typing systems; Mitochondrial DNA typing.

DNA recognition instruments

With the advent of molecular detection techniques, the repertoire of forensic tools has grown considerably. The ability to detect deoxyribonucleic acid (**DNA**) and even to match the nucleic acid to its source can allow the forensic scientist to identify an individual, or to determine if the individual was at the scene of a particular investigation.

DNA recognition instruments allow rapid **identification** of the origin of DNA in an environmental or medical sample. Recognition of the source of DNA is important in pathogen (disease-causing agent) identification in various public health, diagnostic, and military forensic applications.

DNA recognition instruments utilize two main methods for detection and identification. These are nucleic acid hybridization and the **polymerase chain reaction** (**PCR**). Hybridization of nucleic acids allows differentiation of sequences that differ by as little as one base pair by using high temperature washes that remove partially matched DNA strands. Hybridization relies on the fact that single stranded DNA reforms a double stranded helix with a complementary strand. The method requires a single stranded target (unlabeled) and probe (labeled with a radioactive or fluorescent tag to detect signal). PCR-based detection in modern instruments is based on the specificity provided by primers required for DNA amplification and fluorescent probes to detect the product in real time.

Engineers and biologists are designing new technologies to make DNA recognition rapid and robust, with increased sensitivity of the assays and improved identification of positive samples. Optical identification methods are primarily used in PCR-based instruments; however, new magnetic and electrochemical methods were developed for hybridization-based assays.

Chip-based hybridization assays, where the target DNA is spotted onto a glass or plastic slide and a single stranded DNA probe is used to detect it, were developed recently by a number of companies. Technology allows placement of thousands of DNA molecules on the slide, but detection of the specific reaction is often lacking sensitivity. As a result, a number of research teams and commercial companies are researching better ways to identify a positive signal.

One breakthrough came with the implementation of electrical conductivity as a detection method. This method relies on the use of electrodes with gaps of 30–50nm in size, containing single stranded DNA molecules (oligonucleotides) immobilized on their surface (capture probes) and gold oligonucleotide nanoparticles allowing detection of electrical currents resulting from hybridization. Both oligonucleotides bind to the target sequence when the electrode is immersed in a solution containing target molecules.

Scientists at Northwestern University produced a modification of this method, called signal amplification, using a photographic developing solution. A salt wash before the addition of photographic developer removes mismatches and the silver coated gold particles can be easily visualized. The chip is then scanned using a flatbed scanner, removing the need for expensive equipment. This method is highly sensitive and very fast. It is able to detect concentrations of DNA (100 times more sensitive than conventional detection methods), in one to three minutes.

A further modification of this method was developed in 2002. It incorporates nanoparticle probes that in addition to gold particles, have Raman dye-label (for example Cy3, Cy5, or Texas Red). Detection of these probes can be either by Raman **spectroscopy** or by using a flatbed scanner to detect silver enhancement. By using multiple labels one is able to design chips detecting multiple target sequences (multiple **pathogens**).

The great advantages of hybridization-based instruments are that they do not require any DNA amplification, are highly sensitive, and give rapid results.

Scientists in industry are currently producing instruments that are based on measuring electrical conductivity. One is known as the eSensor. The system consists of bioelectronic chips, reader, and special software. The chips contain capture probes and signaling probes. After an interaction with a target sequence, signaling probes induce electric current, which is detected and interpreted by the sensor's software. This instrument can perform a number of assays simultaneously. A second instrument is directly based on the technology from the Northwestern University group, using a method of conductivity detection that was modified to amplify the signal from gold particles by using a photographic developer solution to coat the gold particles. Although this instrument currently requires a large space, work is underway to design a hand-held device.

One company has licensed a Strand Displacement Amplification (SDA) method, and has devised an electrical method of binding DNA to silicon chips and performing hybridization. SDA oligonucleotides (probes) are localized to spots on the chip by charge and immobilized on the surface by chemical reaction. The sample is then added to the chip and by applying an electric current, the binding of the test to the probes is highly accelerated (one to three minutes). By reversing the charge, unbound molecules are removed and only perfect matches remain. The entire process takes about 15 minutes.

Chips for identifying pathogens such as the bacteria responsible for **anthrax** are under development.

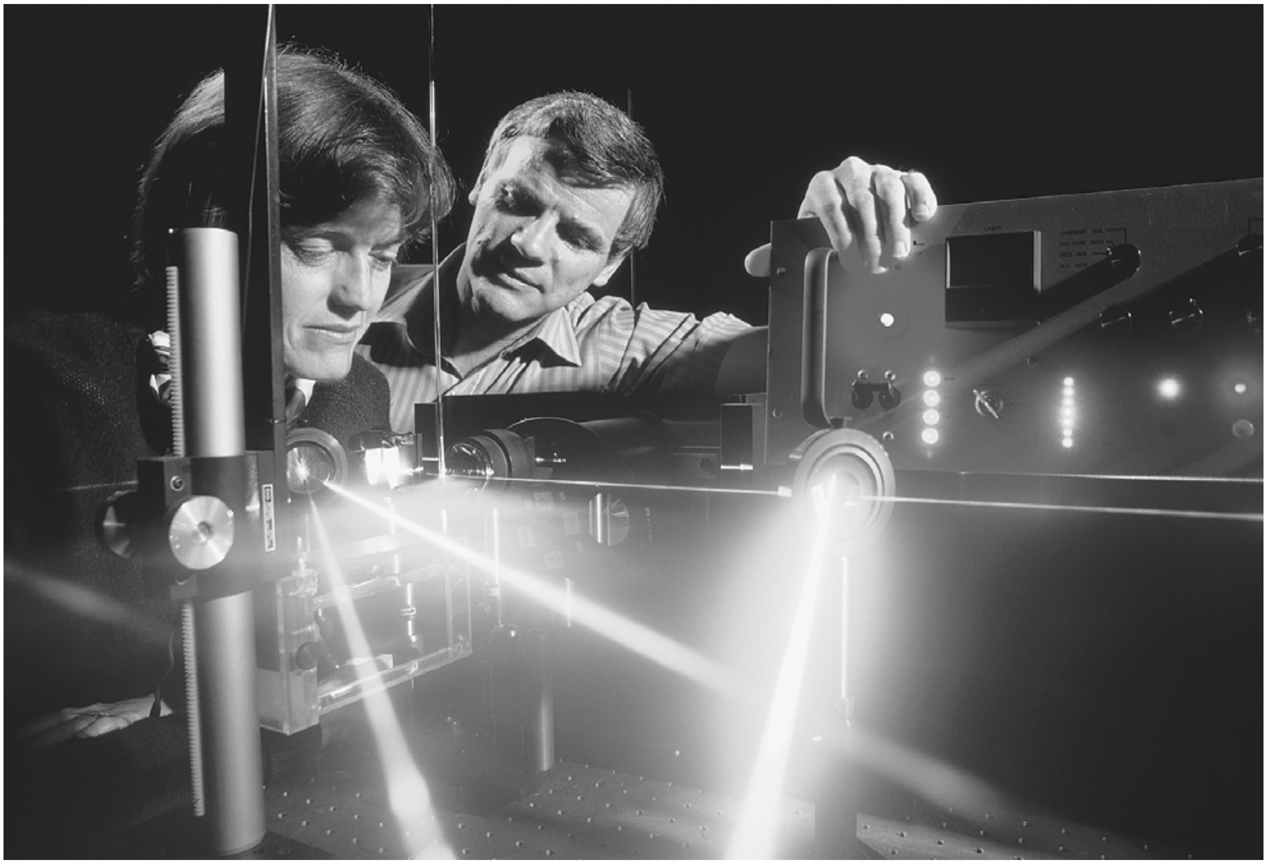
The newest technologies in PCR-based instruments involve instrument miniaturization and methods for handling and detecting multiple pathogens in multiple samples. The ability to prepare clean PCR templates in a field is often difficult or limited. The presence of various chemicals can inhibit the amplification, giving false negative results and, in the case of an attempt to identify a biological threat, possibly endanger people's lives. As a result, a number of companies have started to offer sample preparation units with their PCR instruments.

The advanced nucleic acid analyzer (ANAA), developed in 1997, was the first DNA recognition instrument designed for work in the field. It was portable, but still large and was superseded by a hand-held ANAA (HANAA).

The major differences between the various instruments are in the proprietary heating and cooling systems, detection optics, and sample preparation and handling, as well as size. The speed of most of these instruments is similar to the typical sample analysis taking 7–20 minutes.

A different technology, but still PCR-based, uses a high-performance liquid **chromatography** to separate the PCR products and identify mutations. The advantage of the system is that it can detect mutations in any genes that could have been altered for designing biological weapons, thus, potentially complementing any other detection methods.

DNA recognition instruments are likely to be used in general monitoring of the environment, investigation



Biologists at the California Institute of Technology demonstrate a machine designed to read DNA sequences. The sequenator uses lasers, and is hundreds of times faster than human sequencers. © ROGER RESSMEYER/CORBIS

of suspicious objects, and in diagnostics. In all of these applications, detection must be rapid and accurate in order to introduce prevention measures or rapid treatment. Ease of use and result interpretation are important, as in the majority of cases users will be people with minimal laboratory **training**.

SEE ALSO Analytical instrumentation; Biological weapons, genetic identification; Chemical and biological detection technologies; DNA profiling; RFLP (restriction fragment length polymorphism); STR (short tandem repeat) analysis.

DNA sequences, unique

An increasingly important facet of **forensic science** is the use of techniques that detect and determine the structure of deoxyribonucleic acid (**DNA**). When the aim of the investigation is to identify an unknown person, the exploitation of unique portions of DNA can be very useful.

DNA contains genetic information that is unique to each organism. The entire cellular DNA of any organism, bacteria, plant, virus, or animal represents the genome. A DNA sequence is considered to be unique if it is present in only one copy in a haploid genome (that portion of DNA that contains only a single copy of each **chromosome**). In humans, for example, a haploid number of chromosomes is 23.

Not all of the DNA contained in the genome is unique; there are also various repetitive sequences present.

A DNA strand is composed of a strand of nucleotides (nitrogen-based building blocks of DNA and ribonucleic acid; RNA). Each nucleotide contains a phosphate attached to a sugar molecule (deoxyribose) and one of four bases, guanine (G), cytosine (C), adenine (A), or thymine (T).

It is the arrangement of the bases in a sequence, for example ATTGCCAT, that determines the encoded **gene**. This sequence allows scientists to identify organisms, genes, or fragments of genes.

One of the main characteristics of DNA is the fact that it forms double stranded molecules (helices) by forming hydrogen bonds between the complementary strands inside the helix and a sugar-phosphate backbone outside. This pairing is not random, A always pairs with T, and C pairs with G, therefore a sequence complementary to ATTCCGAT will be TAAGGCTA.

Genes are the sequences of encoded proteins, and, together with the surrounding regulatory sequences, are considered as unique genomic sequences, since they are present as single copies in a haploid genome. In contrast, some sequences are present in multiple copies. These represent repetitive fragments. The simplest genomes of viruses and bacteria contain mostly unique sequences with only a few repetitive regions. However, the proportion of repetitive DNA increases in higher organisms, for example sea urchins have only 38% unique sequences and human just over 50%.

Genes encoding the same protein in bacteria, plants, and humans often display similar genetic sequences and perform the same or similar function across the spectrum of organisms. Such homology between the sequences allows scientists to identify the genes in humans by using fragments of mouse or yeast genes to search for similar DNA fragments. Although most of the genes show some species-dependent differences, not all of them can be used to discriminate between organisms. Only a few genes can be used for this purpose. The two main groups are ribosomal (16S in bacteria and 18S in animals) and mitochondrial genes.

Ribosomal genes are useful for tracing evolution and relationships, especially in bacteria. However, mitochondrial genes have an advantage over the ribosomal genes as they are not encoded by the nuclear DNA, but are present as circular molecules in the cells. As such they are less likely to be degraded with time. This is advantageous for the forensic scientist, since genetic **identification** may be possible using bones, teeth, or tissue fragments even when death occurred a long time before.

The presence of unique DNA sequences allows forensic scientists to identify signature sequences that can be later used as probes to detect individual organisms or to detect a particular gene. Changes of even one base pair can be readily detected by most hybridization techniques and by **sequencing**.

Signature sequences are particularly important for diagnosis of viruses, which are the **pathogens** that lack ribosomal or mitochondrial genes. Their detection and identification is greatly simplified by using these sequences, as traditional methods can take up to a few weeks.

The unique DNA sequences can also be used to design primers (short DNA fragments needed to initiate DNA amplification) for **polymerase chain reaction** (**PCR**). There are sufficient differences between all the genes within one organism, as well as between organisms from different species, to ensure that the selected primers will only amplify the target sequence even if a mixture of different DNA molecules is present. This allows forensic scientists to design diagnostic and identification tests for the common pathogens and diseases and for parts of pathogen's genome.

Although everyone except for identical twins has unique DNA, the identification of an individual is not based on the sequencing of the individual's genome. Instead, analysis of mitochondrial DNA in a region of a displacement-loop (D-loop or control region) or of short tandem repeats (STRs) is used for identification purposes.

D-loop analysis is used for individual identification in forensic analysis. This is possible due to the polymorphisms of such sequences resulting from substitutions of base pairs during DNA replication process (for example, instead of A, DNA polymerase incorporates T).

The D-loop region is 1274 base pairs long and is located between the genes encoding transfer RNA (tRNA) for proline and tRNA for phenylalanine. It contains the regulatory regions of the for replication other genes.

The main method used for the identification of the changes in this region is PCR amplification and sequencing. However, new microarray approaches that analyze patterns of gene expression in miniature environments such as glass slides or silicon wafers are also being developed.

SEE ALSO Biodetectors; DNA profiling;
RFLP (restriction fragment length polymorphism);
STR (short tandem repeat) analysis.

DNA typing systems

Deoxyribonucleic acid (**DNA**) typing is a way to categorize an individual's genetic makeup in order to distinguish one individual from another. This has been made possible due to the rapid acceleration of genomics-based technologies coupled with the fact that human genomic DNA, which is comprised of

3 billion bases (letters in the DNA alphabet), is unique in only 0.1% of its makeup. Therefore, approximately 3 million bases differ from one person to the next, allowing scientists to use these differences to perform identity matches with a high degree of certainty. These variable regions of DNA can be used to generate a DNA profile of an individual, using samples from **blood**, bone, hair, **semen**, and **saliva**, as well as other body tissues.

In DNA typing, there are several systems that can be employed to characterize DNA from a sample. These systems have different applications and purposes. For example, in forensics, scientists may need to obtain DNA from a crime scene in order to analyze a specific set of DNA markers (regions within the genome that are variable) rapidly, yet with good results. DNA typing systems that have previously been used or are currently being used in forensics include **restriction fragment length polymorphism** (**RFLP**) typing, short tandem repeat (STR) typing, single nucleotide polymorphism (SNP) typing, mitochondrial DNA (mtDNA) analysis, human leukocyte **Antigen** (HLA) typing, gender typing, and Y-chromosome typing. RLFP analysis was the first major DNA typing system used in forensics. All of the techniques that followed could not have been developed without the discovery of a revolutionizing methodology called the **polymerase chain reaction**, or **PCR**. PCR allows a scientist to amplify genomic DNA (small sequences up to a few thousand in length) extracted from a sample so that there are sufficient quantities to be analyzed.

RFLP analysis was first developed by Alec Jeffreys. RFLPs can be used to analyze the DNA directly in a way that is fairly inexpensive. In RFLP analysis, genomic DNA is digested with a molecular enzyme that cuts the DNA at specific sequences it recognizes, creating multiple fragments. These fragments can be variable depending on whether the enzyme cuts at a particular site in the DNA. Variable DNA that is inherited (and not mutated) at a site may or may not be cut by the enzyme depending on whether the sequence contains the enzyme recognition site. These sites can be highly variable based on inheritance patterns. For this reason, a pattern of fragments will be produced based on the number of cut sites, separated by gel **electrophoresis**, transferred to a nitrocellulose membrane, and using radio-labeled probes (short sequences of DNA that bind to the complementary sequence from the sample DNA) that bind to specific sequences of interest, they can be identified by audioradiography. Radioactively labeled probes are visualized by audioradiography, or what appears to be film that has burned bands, based on size, that run in the gel during gel electrophoresis. If there is a lack of a restriction site in an individual's DNA at a specific site, the enzyme will not cut it and the fragment will therefore be larger. RFLP analysis is not always applicable because it requires a large amount of high quality DNA. In forensics, samples obtained from a crime scene tend to be degraded. Although RFLP is one of the original applications of DNA analysis that forensic investigators used, newer, more efficient DNA-analysis techniques have replaced this technology.

PCR-based assays followed RFLP analysis because of their greater sensitivity, simplicity, and amenability to analyzing degraded DNA samples. PCR can amplify extremely small amounts of DNA (even DNA from a single cell) to large DNA concentrations (nanograms). Using PCR to amplify a specific sequence of interest, which contains a variable sequence within the amplicon (amplified PCR fragment), **STR analysis** can be performed. STRs are short tandem repeats of 2–5 base pairs that are repeated a few to dozens of times. Identification of the STR can be performed by direct DNA **sequencing**. However, it is most often analyzed using gel electrophoresis (if the difference in tandem repeat is large enough) with ethidium bromide, a carcinogen that inserts DNA and fluoresces with an ultraviolet lamp. As the size of the amplified STR loci is in the range of 200–500 base pairs, it makes it ideal for degraded DNA samples.

The Federal Bureau of Investigation (**FBI**) uses a set of thirteen specific STR regions for **CODIS**, a software program that comes from a database derived from local, state, and national agencies using information collected from criminals or arrested individuals. With these markers, it is estimated that there is approximately a one in one billion chance that two individuals will be the same at the thirteen different marker sites.

Another DNA typing system, which is used most frequently in forensics, is **mitochondrial DNA analysis**. Mitochondrial DNA (mtDNA) is DNA that comes from a source separate from the DNA found in the nucleus. It is much smaller (only 16.5 thousand bases) than nuclear DNA and is important for producing proteins that are important and specific to energy production within the cell. The advantage of using mtDNA is because many tissues (such as muscle) have a much higher copy number of mtDNA compared to nuclear DNA, which only has two copies of genetic information and two sex chromosomes.

For samples with little DNA recovered, mtDNA analysis is the preferred approach. It is also important for samples that do not have nucleus, such as red blood cells, rootless hair, bones, nail clippings, and teeth. For these tissues, STR and RFLP analysis cannot be used. Finally, mtDNA analysis is possible due to a highly variable region (by 1–2% in unrelated individuals) in the mtDNA genome called the "D-loop." Mitochondrial DNA is maternally inherited.

Y-chromosome analysis is only applicable in cases that test for identity matches in males. Y-chromosomes can only be inherited by sons from fathers. It can also be useful in testing male suspects when multiple sample sources have been identified at a crime scene. Gender typing can also be performed by analyzing the X-chromosome and determining if there is one allele (male) or two different alleles (female) at an informative site.

Another DNA typing system, used in particular by forensic scientists, involves designing small pieces of short DNA sequences called "probes" that bind to complementary DNA sequences extracted from a sample found at a crime scene. Much like the radiolabeled probes, these short sequences can be used to create a distinct pattern depending on the DNA source. These patterns can be compared to the sample from a crime scene and determined if a match exists between the DNA from the sample and the DNA from the suspect. These probes can be fluorescently labeled and used to identify Small Nucleotide Polymorphisms (SNPs), which are single base variations that are known to be variable within a given population, are not themselves disease-causing, do not represent spontaneous mutations, and are found throughout the genome. A marker is only informative if there is a difference between two samples. Although a single SNP may not be informative, combining several SNPs is useful and can easily be automated. The more markers that are used, the likelihood that the two samples are identical is greater.

Although six or more probes are usually used in forensics DNA typing, new, more advanced DNA typing systems are being developed. DNA-chip technology is the latest molecular advancement that will considerably speed up analysis and allow forensic scientists to study many sequences at one time in a fully automated manner. DNA chips (also known as microarrays) have small sequences printed or synthesized onto microscopic spots on a tiny chip. When DNA is added to the chip, binding of the sample to the probe occurs when there is a match. The probes are labeled with a fluorescent dye that fluoresces when it hybridizes to a sequence from the sample DNA. Different fluorochromes (colors) can be used to distinguish which DNA base is present in a variable position of the DNA sequence.

Despite its speed, this type of DNA technology is more expensive and probably better suited for applications where a large number of suspects' samples are required for DNA typing. It might also apply DNA typing to identify the remains of many different individuals from a natural disaster. For example, after the tsunami that developed off the west coast of the Indonesian islands in 2004, coastal regions in Thailand and other Asian countries were devastated by its destruction. Many visitors' and residents' remains were found but could not be identified. Microarray-based DNA typing would have been helpful in characterizing the DNA patterns from the remains and matching them to various samples.

After the discovery of PCR, a DNA typing system that was used in forensics was the HLA DQ a / HLA DQA1 system, or Human Leukocyte Antigen (HLA) system. This system is comprised of a 242 base area in the genome that is highly variable in the population. It can be detected using molecular probes that seek out complementary subregions within this genetic region. The probe for HLA DQa set started out with six common sites called DQ alleles that, when combined, produced 21 possible genotypes. With only one locus or region in the genome used, the predictive value was lower than RFLP analysis or other PCR-based assays. The HLA DQA1 system improved the analysis by detecting 28 possible genotypes. The AmpliType PM+DQA1, another HLA-related locus, was developed to expand the HLA DQ system. It uses several markers at different loci (the location of a particular **gene** on a **chromosome**), analyzed simultaneously (also called multiplexing). With five additional markers analyzed, the statistical power increases considerably.

SEE ALSO Analytical instrumentation; Chemical and biological detection technologies; DNA fingerprint; DNA profiling; DNA recognition instruments; DNA sequences, unique; Mitochondrial DNA typing.

Document destruction

Accounting, in particular **forensic accounting** (where accounting and investigative practices are used to trace the sometimes deliberately clandestine movement of finances from person to person and within an organization), can be concerned with paperwork and other documents that can be destroyed. The task of document reconstruction in a forensic investigation may be onerous but is not necessarily impossible.

Even documents stored on a computer may circulate as hard copy, and these, combined with other paper items such as phone messages, notes, memoranda, and other items, can be valuable forensic **evidence**. Those seeking to hide a paper trail have increasingly turned to document destruction, a security solution long applied by government agencies. Document destruction can be achieved with paper shredders, burn boxes, and other forms of technology, often in industrial facilities dedicated to that purpose.

Stories of document destruction by businesses and public officials regularly appear in the media. In 2002, as a scandal erupted around Enron Corporation for falsifying records of earnings, it was revealed that Arthur Andersen LLP, the accounting firm that had helped Enron falsify its books, had shredded literally tons of documents.

Forensic evidence can be obtained from a crude attempt at document destruction such as disposal of paperwork in the trash. Once garbage is placed on the curb for pickup, the discarded information is easily obtained by someone dedicated enough to pick through the garbage.

In the 1990s, garbage-combing thieves earned the colorful appellation of "dumpster diver." Private detectives, for purposes either laudatory or malign, also obtain a great deal of their information from trash. (So, too, do law-enforcement officers, including forensic specialists who take advantage of the fact that material an individual has discarded is open to search without a warrant.).

The best methods of document destruction take place on an industrial scale. The document destruction industry, which primarily serves corporate clients, is estimated to generate $1.5 billion a year in revenue. Whereas only about two dozen companies nationwide were in operation in the early 1980s, by 2002 that number had risen to about 600.

Document shredding, which particularly came to national attention in the wake of the Enron debacle, is only one of many methods of document destruction, though it is the one most frequently used. As a report in the *Wall Street Journal* noted, "For routine destruction work, many companies use shredding services because even heavy-duty office-model shredders tend to choke on anything thicker than about 50 pages—and can be stopped dead in their tracks by a binder clip."

By contrast, the shredders at a facility such as that of American Document Security Corporation (ADS) in Brooklyn, New York, are capable of chewing through 20 tons of documents an hour. Clients of such companies range from law and consulting firms to investment banks, hospitals, and many others.

Though document shredding is probably as old as the concept of written documents, shredding by machine dates back to the 1920s, when an American inventor developed the first shredder from a Bavarian noodle cutter. Today's shredders are far more efficient than those used even in 1979, when the students who took over the U.S. embassy in Tehran, Iran, were able to piece together documents shredded by embassy personnel.

Some shredders are known as disintegrators. Often used for destroying CD ROMs, circuit boards, and other items containing computerized data, the disintegrators chop up materials into a fine dust that can be sifted through a screen at the bottom of the machine. Another variation on the shredder, inasmuch as it destroys documents by purely physical (rather than chemical or electromagnetic) means, is a hammer-and-mill device, which beats paper quite literally to a pulp.

Paper that has been put through industrial shredders and hammer-and-mill devices often is recycled. Waste-to-energy plants burn paper waste at temperatures as high as 2,200°F (1,204°C).

For burning documents on a smaller scale—especially documents for which security is an extremely high concern—a burn box may be used. Actually, the purpose of the burn box is not to destroy documents per se, but to destroy documents discovered by the wrong people. Inside the box, a sturdy metal container, is a volatile chemical mixture attached to a tamper-sensitive switch. If someone opens the box in an unauthorized manner, the chemicals turn the pages to ash.

An intriguing variety of document destruction can be used for electronic media such as CD-ROMs, hard drives, floppies, and so on. This is a degausser, which applies electromagnetic energy to rearrange particles of information contained on a magnetic field. Used either in the form of a stationary box or a hand-held wand, a degausser removes information permanently, leaving the storage device free to be used again.

SEE ALSO Computer forensics; Document forgery; Product tampering.

Document forgery

Information can serve as **evidence** in a forensic investigation. Paperwork, computer files, notes, and more can help piece together the incident under study. However, it is not always guaranteed that the information is genuine. Identifying a deliberately altered document or identifying the manufacture of a fictitious, but convincingly real, document or file is a challenge for the forensic investigator.

Forensic scientists examine paper manufacturers' marks and, if necessary, use radiocarbon dating techniques to verify the age of a document. Handwriting and linguistic style analysis can help determine the document's author. Forgery specialists also make use of ultraviolet lighting and spectography equipment to determine whether a document contains evidence of tampering through erasure or added characters. Inks and dyes are examined through chemistry, and paper fibers are examined microscopically in order to validate or determine their source. When criminals create elaborate forgeries, such as counterfeit currency, sophisticated computerized printers are often used, and examining their encrypted computer files and printer cartridges can help determine the source of the forgery. Evidence from criminal cases of suspected forgery are probed by the Federal Bureau of Investigation's Questioned Documents Unit; the United States Secret Service investigates counterfeit currency.

On September 8, 2004, CBS News anchor Dan Rather aired a news report questioning the service record of President George Bush in the Texas Air National Guard during the Vietnam War. Several weeks later, when the authenticity of one of the key documents used by CBS News was called into question, Rather publicly apologized. CBS News has since been criticized for failing to follow basic journalistic principles; in essence by failing to properly conduct a forensic investigation.

The CBS debacle is one of literally hundreds of examples of forged documents passing scrutiny as the authentic item. On September 17, 1980, White House press spokesman Jody Powell announced that an unidentified group had sought to sow racial discord by circulating a forged Presidential Review Memorandum on Africa that suggested a racist policy on the part of the United States. The first surfacing of the forgery appears to have been in the San Francisco newspaper, *Sun Reporter* (September 18, 1980). The *Sun Reporter's* political editor, Edith Austin, claims in that issue of the paper to have received the document from an "African official on her recent visit on the continent." The forgery was replayed by the Soviet news agency TASS on September 18, 1980, and distributed worldwide.

Former United States Ambassador to the United Nations Jeanne Kirkpatrick was the target of more than one Soviet forgery. On February 6, 1983, the pro-Soviet Indian weekly, *Link* published the text of a supposed speech by U.N. Ambassador Kirkpatrick outlining a plan for the Balkanization of India. The speech was never given, but this forgery was replayed many times by Soviet-controlled propaganda outlets. Its most recent appearance was in the book, *Devil and His Dart*, published in 1986. The author, Kunhanandan Nair, was the European correspondent of *Blitz*, another pro-Soviet publication.

On November 5, 1982, the British magazine, *New Statesman* published a photostat of a letter supposedly from a South African official to Kirkpatrick. He was allegedly sending her a birthday gift. The U.S. Mission to the U.N. wrote the magazine on November 19, branding the letter a forgery. The *New Statesman* countered this by printing another photostat of the forgery with entirely different spacing between the lines. The magazine claimed that the letter was authentic and that they had received it from a source in the U.S. Department of State. A comparison of this forgery with a letter sent by the South African official to a number of U.S. journalists announcing his appointment as Information Counsellor at the embassy revealed that this letter was the exemplar. The real letter had been typed on a computer. The forgery based on it was typed on a typewriter and contained a number of misspellings.

In a particularly bizarre incident, two leaflets were mailed to African and Asian participants in the 1984 Los Angeles Summer Olympics, which were boycotted by the Soviets. Signed by the Ku Klux Klan, they threatened the lives of the athletes. These leaflets later proved to be Soviet forgeries, written in poor English. When the U.S. government exposed them and pointed out that there is no organization in the United States called simply the Ku Klux Klan (the organizations bear individual names like White Knights of the Ku Klux Klan or Invisible Empire of the Ku Klux Klan), TASS, the Soviet official news agency, responded on July 12, 1984, by claiming that the leaflets were signed "the Invisible Empire, The Knights of the Ku Klux Klan." TASS attempted unsuccessfully to correct the error on the leaflets made by the KGB. The forgeries were intended to preoccupy African-American and Asian-American athletes with intimidation, and negatively affect their performance.

Forged Cypriot passport used by Turkish rebel leader Abdullah Ocalan before his arrest in 1999. © CORBIS SYGMA

In the 1980s, before the downfall of the Berlin Wall in 1989 and the Soviet Union in 1991, President Ronald Reagan's signature appeared on a number of forgeries. The last to appear was in May 1987. It was a supposed memorandum to the Secretaries of State and Defense, and the Director of the CIA. In this forgery, which bore the date March 10, 1983, the President was supposedly ordering the establishment of a U.S. military force called the "Permanent Peace Forces" to intervene in Latin America. This forgery received wide circulation in Latin America and was designed to inflame nationalist and anti-American feelings.

These and other examples serve to illustrate how effective a forgery can be. While a typical forensic investigation would likely not have such political ramifications, a forgery could undermine a legal case or lead the investigation in a wrong direction.

SEE ALSO Art forgery; Crime scene investigation.

Dog sniffers SEE Canine substance detection

Dosimetry

A forensic investigation could potentially involve the detection of radiation. In this situation, measuring the amount of radiation present is important, both as **evidence** and to discern whether the radiation presents a potential hazard to the investigators.

Dosimetry measures the amount of radiation energy absorbed over a given period of time by an object such as the human body or a part of that object (e.g., an organ or tumor).

A device that measures cumulative radiation exposure is a dosimeter. A Geiger counter is a radiation detector, but not a dosimeter, because it gives only a moment-to-moment reading of radiation intensity. A strip of photographic film, however, whose degree of exposure indicates how much radiation it has absorbed (up to its saturation limit), can act as a dosimeter. Filmstrip dosimeters are, in fact, still used to measure exposure to ionizing radiation. By grading the sensitivity of a specially formulated film strip from one end to the other, it can be made to indicate net, cumulative radiation exposure as a bar of darkening that grows from the most sensitive end of the film to the least sensitive end. Such "badge dosimeters" are common in the nuclear weapons and nuclear-power industries. However, they have the disadvantage that they must be developed to be read, and so do not give the bearer immediate knowledge of their exposure level.

Another type of dosimeter is the pen ionization dosimeter. These devices contain a long, narrow chamber filled with a few cubic centimeters of nonconducting gas. A metallic contact touches the interior of the chamber at each end. When the dosimeter is to be used, an initial electric charge is placed on the gas tube. This creates an imbalance of electrons between the two ends. Since the gas in the tube is normally nonconducting, electrons cannot pass through it to even out the charge imbalance. However, ionizing radiation passing through the gas forcibly frees electrons from atoms in the gas, and so partially ionizes the gas. The negatively charged electrons are free to flow toward the end of the tube having a positive charge. The more ionizing radiation the pen dosimeter is exposed to, therefore, the more of its initial charge is enabled to leak through the gas tube. The amount of charge lost is a measure of the amount of radiation that has passed through the tube. A pen dosimeter can be read by its bearer at any time, and so gives a current reading of exposure; however, pen dosimeters readings can be affected by mechanical shock or vibration.

A more modern dosimeter design is the thermoluminescent dosimeter (TLD). A TLD contains a tiny crystal of lithium fluoride (sometimes mounted in a finger-ring) that undergoes cumulative structural changes as it is exposed to ionizing radiation. When heated, the crystal glows, giving off an amount of light that is proportional to its radiation exposure. This light is observed by an electronic sensor in a readout unit and recorded digitally. This data can be stored in a central database, a convenient feature if an organization wishes to systematically monitor radiation exposure of a large body of personnel or share data in forensic investigations. Databasing of TLD data has been used, for example, by Canada to monitor the exposure of its troops to radiation from depleted-uranium munitions used by NATO in Bosnia. TLDs, unlike film badges, can be re-used; however, they must be inserted in a reader that heats the crystal and records the light emitted, a process that may take 20 to 30 seconds and erases the data in the crystal.

An even more recent dosimeter design is the optically stimulated luminescence dosimeter (OSLD). In this design, a thin film of crystalline aluminum oxide undergoes cumulative structural changes as it is exposed to ionizing radiation; when an exposure reading is desired, the crystal is exposed to green **laser** light. The amount of blue light emitted by the film in response is proportional to its radiation exposure. Unlike a TLD, an OSLD can supply an instant readout that can be repeated if necessary.

Solid-state devices that measure radiation by detecting ionization leakage current through a transistor device also exist. Radiation detectors and dosimeters based on such solid-state technology have been available since the 1980s, but have not edged out other dosimeter technologies in terms of cheapness, sensitivity, and accuracy.

Dosimetry for laser light, radio waves, and ultrasound is more difficult than dosimetry of ionizing radiation. One method of measuring dose delivered to a volume of tissue is to measure the temperature increase of the tissue; the more increase, the more radio or sound energy has been absorbed. However, these techniques do not work for tissue embedded in living organisms (where temperature measurement is difficult and where heat is rapidly conducted away) or for whole-body exposure, as biologically tolerable doses of laser, radio, and sound energy produce undetectably slight changes in body temperature. Absorption by the body of radio waves is particularly different from absorption of ionizing radiation; the body acts as a complex antenna whose performance is strongly affected by its posture and orientation and by nearby objects. Dosimetry for radio and ultrasound therefore relies heavily on computational models rather than on direct measurements.

SEE ALSO Analytical instrumentation; Isotopic analysis; Radiation damage to tissues; Radiological threat analysis.

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AMERICAN
FORENSIC CONSULTANT

John Douglas, who retired from the Federal Bureau of Investigation (**FBI**) after a more than twenty-five year career, was the founder and head of the FBI's Investigative Support Unit (created in 1980). Douglas is a veteran of the United States Air Force, and he holds a Doctoral degree in Education.

Douglas is a renowned expert on criminal and behavioral **profiling**, and is a prolific and best-selling author on the subject. Among his publications are *Mindhunter: Inside the FBI's Elite Serial Crime Unit* (1996) and *The Cases that Haunt Us* (2001). He continues to be in considerable international demand, both as a public speaker/lecturer and as an expert consultant to police departments, law enforcement agencies, and to prosecuting attorneys.

During his tenure with the FBI, Douglas earned a reputation as a widely known expert on criminal personality profiling. He has been touted as one of the pioneers of modern criminal investigative analysis, and is credited with conducting the first organized study in the United States regarding the methods and motivations of violent serial criminals. As part of that research project, he interviewed such notorious killers as James Earl Ray, Richard Speck, John Wayne Gacy, Ted Bundy, Ed Gein, David Berkowitz, Sirhan Sirhan, and Charles Manson.

John Douglas describes the world of the criminal profiler as arduous, filled with lengthy periods of reading and studying case files, investigator's notes, **autopsy** and crime scene reports, examining crime scene photographs, poring over eyewitness statements, police reports, and, if possible, victim's statements. When the perpetrator's identity is unknown, these forensic scientists seek patterns in the **evidence** that suggest the offender's behavior and character style. They use their composite information to develop a profile of the unknown subject (UNSUB) that may be used to narrow the search for possible suspects.

Over time, the Investigative Support Unit became known as "The Mind Hunters," with John Douglas being the chief Mind Hunter. This elite FBI Unit was involved in some of the most notorious and high-profile serial and sadistic **murder** investigations in American history: the San Francisco Trailside Killer, the Atlanta Child Murderer, Robert Hansen (who hunted and killed prostitutes on his property in Alaska), the Tylenol Poisoner, and the Green River

Killer. John Douglas has been described as a profiler who is adept at understanding the way criminals think, getting inside their minds, understanding the workings of both the predator and his prey (the vast majority of serial and sadistic killers are male). Douglas uses this information, along with examination of the crime scene, to create a profile of the perpetrator, and to attempt to predict his future behaviors. Upon the criminal's apprehension, Douglas' profile could be used to aid in structuring the processes of **interrogation** and prosecution. John Douglas is both a pioneer and a legendary figure in the **forensic science** world of **criminal profiling**.

SEE ALSO Bundy (serial murderer) case; Careers in forensic science; Crime scene staging; Psychopathic personality; Ritual killings.

Arthur Conan Doyle

5/22/1859–7/6/1930
SCOTTISH
WRITER

The British author Arthur Conan Doyle is best remembered as the creator of the famous detective Sherlock Holmes. His fictional crime stories describe the law enforcement and forensic techniques used in crime investigations of his era.

Doyle was born in Edinburgh, Scotland, into an Irish Roman Catholic family of noted artistic achievement. After attending Stonyhurst College, he entered Edinburgh University as a medical student in 1876. He received a doctor of **medicine** degree in 1885. In his spare time, however, he began to write stories that were published anonymously in various magazines from 1878–1880.

After two long sea voyages as a ship's doctor, Doyle practiced medicine at Southsea, England, from 1882–1890. In 1885, he married Louise Hawkins and in 1891, moved his young family to London, where he began to specialize in ophthalmology. His practice remained small, however, and because one of his anonymous stories, "Habakuk Jephson's Statement," had enjoyed considerable success when it appeared in a magazine in 1884, he began to devote himself seriously to writing. The result was his first novel, *A Study in Scarlet*, which introduced detective Sherlock Holmes to the reading public in 1887. This was followed by two historical novels, *Micah Clarke* in 1889 and *The White Company* in 1891. The immediate and prolonged success of these works led Doyle to abandon medicine altogether and launch his writing career.

The second Sherlock Holmes novel, *The Sign of the Four* (1890), was followed by the first Holmes short story, "A Scandal in Bohemia" (1891). The instant popularity of these tales made others like them a regular monthly feature of the *Strand Magazine*, and the famous *Adventures of Sherlock Holmes* series was begun. In subsequent stories Doyle developed Holmes into a highly individualized and eccentric character, together with his companion, Doctor Watson, the ostensible narrator of the stories, and the pair came to be readily accepted as living persons by readers in England and America. But Doyle seems to have considered these stories a distraction from his more serious writing, and eventually grew tired of them. In "The Final Problem," published in 1893, Doyle kills both Holmes and his archenemy, Moriarty. Nine years later, however, Doyle published a third Sherlock Holmes novel, *The Hound of the Baskervilles*, but dated the action before Holmes's literary death. Then, in 1903, Holmes effected his mysterious resurrection in "The Empty House" and thereafter appeared intermittently until 1927, three years before Doyle's own death. All told, Doyle wrote 56 Sherlock Holmes stories and four novels (*The Valley of Fear* [1914], was the last).

Among the other works published early in his career, which Doyle felt were more representative of his true artistry, were *Beyond the City* (1892), a short novel of contemporary urban life; *The Great Shadow* (1892), a historical novel of the Napoleonic period; *The Refugees* (1893), a historical novel about French Huguenots; and *The Stark Munro Letters* (1894), an autobiographical novel. In 1896, Doyle issued one of his best-known historical novels, *Rodney Stone*, which was followed by another historical novel, *Uncle Bernac* (1897); a collection of poems, *Songs of Action* (1898); and two less popular novels, *The Tragedy of Korosko* (1898) and *A Duet* (1899).

After the outbreak of the Boer War, Doyle's energy and patriotic zeal led him in 1900 to serve as chief surgeon of a field hospital near the front lines at Bloemfontein, South Africa. His *The Great Boer War* (1900) was widely read and praised for its fairness to both sides. In 1902, he wrote a long pamphlet, *The War in South Africa: Its Cause and Conduct*, to defend the British action in South Africa against widespread criticism by pacifist groups. In August 1902, Doyle was knighted for his service to England.

After being twice defeated, in 1900 and 1906, in a bid for a seat in Parliament, Sir Arthur published *Sir Nigel* (1906), a popular historical novel of the Middle

Arthur Conan Doyle, British novelist who introduced the famous literary evidence-gathering character, Sherlock Holmes. © HULTON-DEUTSCH COLLECTION/CORBIS

Ages. A year after the death of his wife from tuberculosis in 1906, Doyle married his second wife, Jean Leckie. Doyle then took up a number of political and humanitarian causes. In 1909, he wrote *Divorce Law Reform*, championing equal rights for women in British law, and *The Crime of the Congo*, attacking the exploitation of that colony by Belgium. In 1911, he published a second collection of poems, *Songs of the Road*, and in 1912, began a series of science fiction stories with the novel *The Lost World*, featuring another of his famous characters, Professor Challenger.

After the outbreak of World War I, Doyle organized the Civilian National Reserve against the threat of German invasion. In 1916, he published *A Visit to Three Fronts* and in 1918, toured the front lines. These tours, plus extensive correspondence with a number of high-ranking officers, enabled him to write his famous account *The British Campaigns in France and Flanders*, published in six volumes (1916–1919).

Doyle had been interested in spiritualism since he rejected his Roman Catholic faith in 1880. From 1917 to 1925, he lectured on spiritualism throughout Europe, Australia, the United States, and Canada. The same cause led him to South Africa in 1928 and brought him home exhausted, from Sweden, in 1929. He died in 1930 of a heart attack, at his home in Crowborough, Sussex.

SEE ALSO Crime scene investigation; Literature, forensic science in.

Drawings, composite SEE Composite drawing

Driving injuries

In a disaster, natural or man-made, involving a blast or explosion and resulting in mass casualties, many serious or fatal injuries are caused by driven projectiles (also called driving injuries). Quite often, driving injuries are caused by shards of flying **glass**. The latter part of the twentieth century and the beginning of the twenty-first centuries documented significant increases in the number of terrorist activities resulting in massive serious injuries and loss of life. In the United States, the most notable terrorist activities resulting in driving injuries (among the myriad of other severe and lethal outcomes) occurring during that time period were attacks on abortion clinics, the Atlanta Olympic Park and associated area bombings, the bombing of the Murrah Federal Building in Oklahoma City, and the two attacks on New York's World Trade Towers, with the final attack on September 11, 2001, resulting in the collapse of the buildings. Explosive devices are commonly used both during times of war and in acts of terrorism worldwide. On a lesser scale, driving injuries may also be caused by industrial accidents, fireworks explosions, and motor vehicle accidents.

In the event of a blast, physicians and forensic examiners identify injuries of four types that occur: primary, secondary, tertiary, and quaternary or miscellaneous. Primary injuries are caused by the intense wave of excess pressure emitted immediately after a blast; this generally affects air-filled regions of the body, such as the tympanic membranes (ear drums and middle ear), gastrointestinal tract, and lungs. Secondary injuries are caused by driven objects; debris and shards of glass become high-speed projectiles that are driven into any part of the body. Driving injuries can result in blunt trauma (severe surface and underlying tissue injury that does not result in ruptured skin) or penetrating ballistic fragmentation injuries (shrapnel-like pieces of shattered glass or other blast debris make high-velocity impact with the body and lacerate it, causing surface and underlying tissue damage). A significant number, estimated at around 10% of blast survivors experience driving injuries to the eye. Tertiary damage is caused when humans become projectiles as a result of the concussive effect of a blast (the very strong wind caused by a high pressure explosive), and are injured or killed when they come into contact with other objects, including other humans. Miscellaneous or quaternary injuries are all other blast or explosion-related injuries or complications.

Driving injuries are the most frequent post-explosive occurrences. Blasts in buildings or motor vehicles typically shatter windows, creating driven glass, military **explosives** are generally designed to fragment and create shrapnel, and terrorist bombs often contain small metal objects such as screws, nails, and glass fragments that are designed to maximize secondary blast injuries.

SEE ALSO Bioterrorism; Blunt injuries, signs of; Explosives; Oklahoma bombing (1995 bombing of Alfred P. Murrah building); World Trade Center, 1993 terrorist attack.

Drowning (signs of)

A forensic examiner must consider that a body recovered from water may or may not have been dead when the water was entered. If the person died in the water, there are several possible causes of death, including drowning. It is actually difficult to prove drowning as a **cause of death** with 100% accuracy. The forensic pathologist cannot rely on **autopsy** or laboratory findings alone. Instead, the pathologist may focus on elimination of other causes for the death and on the circumstances surrounding the event.

Immersion of a body in water causes certain characteristic changes that are not necessarily signs of drowning. The skin on the palms and soles becomes white and wrinkled. A similar effect is seen on the tips of the fingers in someone who has their hands in water for extended periods of time. After a few days in water, this macerated skin will begin to separate, and after about a week, it will peel off from the body.

There may also be some evidence of **decomposition** when a body is pulled from water, although this occurs more slowly than it would on land. After about two weeks in water, the rest of the skin and the hair are sloughed, and the face, abdomen, and genitals become bloated with the gases of decomposition. This results in most bodies eventually floating to the surface, unless they have been weighted down to avoid discovery. Predators, such as fish and reptiles, will tend to prey on a corpse in water and this will accelerate decomposition. The body may also knock against objects in the water such as boats, piers, and rocks, and this may cause postmortem injury.

Drowning occurs when water enters the airways and blocks off the supply of oxygen to the body. When this happens, the person will struggle to breathe and will cough, which unfortunately sets off a reflex action that only draws more water into the lungs. The person will generally lose consciousness within a minute or two and then the heart will stop. The brain is the most vulnerable part of the body to oxygen deprivation and it can usually survive for less than four minutes before irreversible damage occurs, along with cardiac arrest. In some cases, however, **hypothermia**, or the chilling of the body that occurs in cold water, has protected the brain by slowing metabolic demands for oxygen, and allowed the person to survive.

The mechanism of drowning differs depending on whether the person was found in fresh water or salt water. Fresh water enters the circulation through the lungs rapidly and dramatically increases the blood volume, creating great strain on the heart. The massive dilution of the blood also causes substantial disruption to its normal chemistry and starts to break down red blood cells. Sea water has an opposite effect. It draws fluid from the blood plasma into the lungs. This does not have the effect of increasing the workload on the heart, so people tend to survive for longer before drowning in salt water.

Postmortem, there may be few obvious signs of drowning on external examination. There may be a copious (visible amount of) froth, perhaps blood-stained, that has come from the lungs and surrounds the nose and mouth. This is a mixture of water and protein from the blood plasma, which froths up as the person struggles to breathe. However, the froth is not always present in cases of drowning and should not be relied on as an indicator.

Internal examination may reveal froth in the windpipe and lungs. Although the lungs are usually swollen, spongy, and full of water on drowning, this can also be seen with other causes of death, such as drug overdose or cardiac arrest upon hitting the water. The struggle to breathe causes great pressure to the sinuses, which often bleed and sometimes leave evidence of hemorrhage.

Laboratory tests may reveal the presence of diatoms in the body. Diatoms are microscopic algae found in both seawater and fresh water. Their silica-based skeletons do not readily decay and they can sometimes be detected even in heavily decomposed bodies. If the person is still alive when entering the water, diatoms will enter the lungs if the person inhales water and drowns. The diatoms are then carried to distant parts of the body such as the brain, kidneys, and bone marrow by circulation. If the person is dead when entering the water, then there is no circulation and diatoms cannot enter the body. Diatoms do not occur naturally in the body. If laboratory tests show diatoms in the corpse that are of the same species found in the water where the body was recovered, then it may be good evidence of drowning as the cause of death. However, the diatom test is now considered very unreliable and would never be used, on its own, as evidence of drowning. The forensic pathologist has to rely on many other sources of evidence to determine cause of death when a body is found in water.

SEE ALSO Death, cause of; Death, mechanism of.

Drug Enforcement Administration SEE DEA (Drug Enforcement Administration)

Drugfire

Drugfire was an electronic database that contained digital images of fired bullets and casings. This system was equivalent to the **Automated Fingerprint Identification System (AFIS)** developed for fingerprints or the Combined DNA Index System (**CODIS**) developed for classifying and storing **DNA** profiles. This system allowed for law enforcement agencies to submit images of crime-related fired bullets and casings to the database. The database then classified the images based on the different characteristics exhibited by the bullet or casing. The database returned to the submitting agency a list of bullets or casings that were present in the database, and could have been fired by the same firearm. The scientist then sorted through the list to identify any matches. This tool was a paramount improvement in the cross-comparison of **firearms**, bullets, and casings. There were 171 state and local law enforcement agencies that participated in the Drugfire program.

As an illustration, imagine that a firearm is used in a **murder** in Washington, D.C., and no suspect was identified in this crime. The crime scene investigators retrieve the bullets from the crime scene and submit them to the laboratory, which in turn, submits them to the Drugfire database. At that point, no hit (match) is found and the crime goes unsolved. Six months later, the same firearm is seized from a suspect in a completely unrelated crime. When the forensic laboratory submits the images to the database, the images from Washington, D.C. are listed as a potential match. The firearms examiner looks at the images and links the firearm to the homicide, which provides assistance to the crime-solving process.

Drugfire was developed by Mnemonics Systems, Inc. for the Federal Bureau of Investigation (**FBI**). It was first implemented by the FBI in late 1989. Similarly, the then Bureau of Alcohol, Tobacco, and Firearms (**ATF**) developed a system called **Integrated Ballistics Identification System (IBIS)**. In 1996 the **National Institute of Justice** assisted the FBI and the ATF in rendering both databases compatible with one another. In 1999 a memorandum of understanding between the FBI and ATF was signed, and the National Integrated Ballistics Information Network (NIBIN) was created to unite Drugfire and **IBIS** under one unique system. The system chosen for this database was IBIS, and Drugfire was then phased out.

SEE ALSO Caliber; FBI crime laboratory; Identification.

Drunk driving SEE Breathalyzer®

DUI SEE Breathalyzer®

DWI SEE Breathalyzer®

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Ear print analysis

Ear print analysis is far more popular as a means of forensic **identification** in Europe than it is in the United States. The European Commission, a scientific arm of the European Union, has launched a program aimed at setting the worldwide standard for ear print analysis and identification research. The assumption among members of the EU **forensic science** community is that forensic analysis of ear prints is more economical than that of **DNA profiling**. It is also thought to be more reliable in legal proceedings, as it is virtually impossible to either tamper with, or accidentally leave at a crime scene, an ear print.

When a human ear is pressed against a surface, materials present on the ear's surface (waxes, skin oils, etc.) are left behind, forming a two-dimensional "ear print." Each ear print is believed to contain specific and individual (unique) anatomical markers, which can be used both to distinguish it from others found at the crime scene, and to compare it to other ear prints on file in forensic databases as a means of identifying suspects or linking crimes/crime scenes, much like occurs with **DNA** profiling at present. It is also possible to take ear prints from suspects under laboratory conditions (akin to those used for **fingerprint** or serological DNA testing and analysis), and compare those prints to ear prints recovered during the **crime scene investigation**. It is believed that ear prints are unique to each individual adult, and are considered difficult to tamper with (fingerprints can sometimes be altered).

It is not uncommon for a perpetrator to put an ear to a door or window prior to entering a crime scene in an effort to determine whether the area is occupied, or for an ear print to be left against a wall or other hard surface during a struggle or when a body is being positioned or moved. This **evidence** can be collected at the crime scene, using methods analogous to those used for the lifting of fingerprints. A benefit to the collection of ear prints along with other crime scene evidence is in its use as confirmatory data: the legal system typically requires two different types of corroborative evidence in order to confirm placement of a suspect at a crime scene. While it is possible to "plant" fingerprints or even DNA material, it is difficult to intentionally place an ear print, particularly before ear prints become a common form of forensic identification, at a crime scene.

At present, there is a paucity of scientific evidence supporting the use of ear prints in forensic investigations. There has not been incontrovertible research evidence that ear prints are unique to each individual; there is a lack of systematization in the collection and analysis of ear print data; and there has not been widespread development or usage of automated ear print matching technology. These issues are being addressed via the European Union's FEARID program, spearheaded by Cornelius van der Lugt at the ICR in the Netherlands, and the United Kingdom's National Training Centre for Scientific Support to Crime Investigation's systematic collection of ear prints in an effort to establish a comprehensive research-based database that is sufficiently large to be able to address the issue of uniqueness.

SEE ALSO Anthropometry; Crime scene investigation; DNA profiling; Evidence; Impression evidence.

Ebola virus

Since the mid-1970s, scientists from organizations that include the **Centers for Disease Control and prevention (CDC)** have periodically been pressed into action to help quell disease outbreaks caused by the Ebola virus. One facet of their responsibilities has been forensic investigations that involve determining the origins of the outbreaks.

Although naturally occurring, the swift and high lethality of the Ebola virus makes it an attractive potential **bioterrorism** agent. This high lethality characteristic can actually work against a large outbreak, as it limits the natural spread of the virus. Deliberate spread of the virus in multiple population areas could counteract the natural limiting factor.

The Ebola virus is one of two members of a family of viruses that is designated as the Filoviridae. The name of the virus comes from a river located in the Democratic Republic of the Congo. It was near this river that the virus was discovered.

The species of Ebola virus are among a number of viruses that cause hemorrhagic fever, which is typified by copious internal bleeding and bleeding from various orifices of the body, including the eyes. The disease can be swift and devastating, resulting in death in up to 90% of cases.

To date, four species of Ebola virus have been identified, based on differences in their genetic sequences and in the immune reaction they elicit in infected individuals. Three of the species cause disease in humans. These are Ebola-Zaire (isolated in 1976), Ebola-Sudan (also isolated in 1976), and Ebola-Ivory Coast (isolated in 1994). The fourth species, called Ebola-Reston, causes disease in primates. The latter species is capable of infecting humans but so far has not caused disease in humans. Ebola-Reston is named for the United States military primate research facility where the virus was isolated during a 1989 outbreak of the disease caused by infected monkeys that had been imported from the Philippines. Until the non-human involvement of the disease was proven, the outbreak was thought to be the first outside of Africa.

The explosive onset of the illness and the under-developed and wild nature of the African region of the virus's appearance has complicated forensic investigations into the origin and natural habitat of Ebola. The source of the Ebola virus is still unknown. However, given that filovirus, which produces similar effects, can establish a latent infection in African monkeys, macaques, and chimpanzees, it seems reasonable that the Ebola virus could reside normally in a similar host. However, direct **evidence** is so far lacking.

Almost all confirmed cases of Ebola from 1976 to 2003 have been in Africa. In the latest outbreaks, which persisted in Gabon through 2003, 122 people were known to have been infected and 96 died, according to data from the CDC. A smaller outbreak killed 7 of 17 infected people in 2004 in Sudan. In the past, one individual in Liberia presented immunological evidence of exposure to Ebola, but had no symptoms. As well, in 1976 a laboratory worker in England developed Ebola fever as a result of a laboratory accident in which the worker was punctured by an Ebola-containing needle.

The Ebola virus produces a high fever, headache, muscle aches, abdominal pain, tiredness, and diarrhea within a few days after infecting a person. Some people will also display bloody diarrhea and vomit blood. At this stage of the disease, some people recover. But for most of those who are infected, the disease progresses within days to produce copious internal bleeding, shock, and death.

Outbreaks of infection with the Ebola virus appear sporadically and suddenly. The outbreak rapidly moves through the local population and often just as quickly ends. The initial infection is presumably by contact between the person and an animal that harbors the virus. Subsequent person-to-person spread likely occurs by contamination with the infected blood or body tissues of an infected person in the home or hospital setting, or via contaminated needles. The fact that infected people tend to be in more under-developed regions, where even the health care facilities are not as likely to be equipped with isolation wards, furthers the risk of spread. The person-to-person passage is immediate; unlike the animal host; people do not harbor the virus for lengthy periods of time.

The possibility of air-borne transmission of the virus is debatable. Ebola-Reston may have been transmitted from monkey to monkey in the Reston military facility via the air distribution system, since some of the monkeys that were infected were never in physical contact with the other infected monkeys.

Mourners look on as Zairean men in protective clothing lower the coffin of an Ebola virus victim into the ground. The 1995 Ebola epidemic killed 245 people in the city of Kikwit over a period of a few months. © PATRICK ROBERT/SYGMA/CORBIS

However, if the other species of the virus are capable of similar transmission, this has not yet been documented. Laboratory studies have shown that Ebola virus can remain infectious when aerosolized. But the current consensus is that airborne transmission is possible but plays a minor role in the spread of the virus.

In the intervening years between the sporadic outbreaks, the Ebola virus probably resides in its natural reservoir. Whether that reservoir is an animal or plant, or resides in the soil or other environment is unknown, although scientists suspect the reservoir is a mammal.

Currently there is no cure for the infection caused by the Ebola virus. However, near the end of an outbreak of the virus in 1995 in Kikwit, Africa, blood products from survivors of the infection were transfused into those actively experiencing the disease. Of those eight people who received the blood, only one person died. Whether or not the transfused blood conveyed protective factor was not ascertained. A detailed examination of this possibility awaits another outbreak.

The molecular basis for the establishment of an infection by the Ebola virus is still also more in the realm of proposal than fact. One clue has been the finding of a glycoprotein that is a shortened version of the viral constituent in the circulating fluid of humans and monkeys. This protein has been suggested to function as a decoy for the **immune system**, diverting the immune defenses from the actual site of viral infection. Another immunosuppressive mechanism may be the selective invasion and damage of the spleen and the lymph nodes, which are vital in the functioning of the immune system.

The devastating infection caused by the Ebola virus is all the more remarkable given the very small size of the viral genome, or complement of genetic material. Fewer than a dozen genes have been detected. How the virus establishes an infection and evades the host immune system with only the capacity to code for less than twelve proteins is unknown.

SEE ALSO Bioterrorism; Hemorrhagic fevers and diseases.

Electrical injury and death

The human body is a good conductor of electricity because it contains a large amount of water and dissolved salts in the form of blood and other body **fluids**. This means that an electric current may pass easily through the body, a process known as electrocution, causing various types of tissue damage and even death. Most cases of electrocution occur by accident, but still need a thorough forensic investigation. Homicidal electrocution, which used to occur mainly by putting an electrical appliance in a bath with the victim, is now relatively rare.

The amount of damage done by electrocution depends upon the size of the current and the length of time for which it is in contact with the body. According to Ohm's Law, the voltage of the source is equal to the current passing through the circuit—in this case, the body—and the resistance to the flow of current it offers. If the skin is wet, it offers lower resistance than dry skin and so currents passing through the body are higher and so cause more damage. Most cases of electrocution occur from contact with a live wire from the public power supply that has voltages of around 200 volts, depending on the country. Contact with overhead power cables,

Dogs being walked by a Lower Manhattan resident walk around a metal electrical service box cover. Many in New York City have become wary of walking over the city's metal manhole and electrical service box covers after the accidental electrocution death of a woman who stepped on one such plate while walking her dogs in 2004. © MIKE SEGAR/REUTERS/CORBIS

which carry thousands of volts, can be far more dangerous. The electricity takes the fastest route through the body which is, typically, from one hand to another or from a hand down to the ground.

If the hand comes into contact with a current of around ten milliamperes, then the person feels pain and usually lets go before any real damage can be done. This is known as an electric shock. Larger currents, up to 30 milliamperes, cause the muscles of the arm to go into spasm and then the person cannot let go of the source of the current. This longer contact could cause serious damage to the body. Fifty milliamperes is enough to cause ventricular fibrillation, a condition in which the heart's upper chambers beat irregularly, which generally leads to cardiac arrest, although it can sometimes be reversed by application of a controlled shock from a defibrillating machine.

Contact with high voltage power supplies does not cause cardiac arrest, but will lead to serious internal burns and organ damage. If the head touches an overhead power cable, a current may pass through the breathing control center in the brain stem, leading to respiratory failure and death.

At **autopsy**, the points of entry and exit of the current may be marked by a burn or a collapsed blister, the latter with a characteristic brown center and pale rim. The hands should always be examined with care, as this is the most common entry point for electrocution. There may, however, be little sign of either external or internal damage, even if the electrocution has been fatal. The pathologist's interpretation may therefore rely much more on the circumstances of the incident rather than on the autopsy findings.

Being struck by lightning is a special case of electrocution. It is always accidental and can give a wide range of findings. Some people do survive a lightning strike, but they are lucky—for they have been exposed to voltages of up to 200 million volts, albeit for just a fraction of a second. A lightning strike causes a range of electrical and thermal injuries to the body, as the victim is exposed not just to high voltage but also an accompanying thermal compression wave like an explosion. Although some people killed by lightning are completely unmarked, an electrocuted corpse may have a bizarre appearance. Sometimes the victim is stripped of clothing by the strike, which may lead investigators to suspect some kind of sexual or homicidal attack. There can be very severe burns, fractures, and lacerations. Metal objects worn on the body, like jewelry or belt buckles, may be completely melted. There is one telling sign of a lightning strike that does not occur in all cases and therefore, cannot be regarded as diagnostic. Lichtenberg figures consist of a red fern-like pattern on the back, shoulders, buttocks, or legs of the victim of a lightning strike. This pattern fades within 12–48 hours without leaving scars or discoloration. The cause of Lichtenberg figures is unclear and they are quite rare. When they are observed, however, it is clear to the pathologist that the person has indeed been struck by lightning.

SEE ALSO Death, cause of; Death, mechanism of.

Electromagnetic spectrum

The electromagnetic spectrum consists of all the frequencies at which electromagnetic waves can occur, ordered from zero to infinity. Radio waves, visible light, and x rays are examples of electromagnetic waves at different frequencies. Every part of the electromagnetic spectrum is exploited for some form of scientific or military activity; the entire spectrum is also key to science and industry. Forensic scientists often use ultraviolet light technologies to search for latent fingerprints and to examine articles of clothing. Infrared and near-infrared light technology is used by forensic scientists to record images on specialized film and in **spectroscopy**, a tool that determines the chemical structure of a molecule (such as **DNA**) without damaging the molecule.

Electromagnetic waves have been known since the mid-nineteenth century, when their behavior was first described by the equations of Scottish physicist James Clerk Maxwell (1831–1879). Electromagnetic waves, according to Maxwell's equations, are generated whenever an electrical charge (e.g., an electron) is accelerated, that is, changes its direction of motion, its speed, or both. An electromagnetic wave is so named because it consists of an electric and a magnetic field propagating together through space. As the electric field varies with time, it renews the magnetic field; as the magnetic field varies, it renews the electric field. The two components of the wave, which always point at right angles both to each other and to their direction of motion, are thus mutually sustaining, and form a wave which moves forward through empty space indefinitely.

The rate at which energy is periodically exchanged between the electric and magnetic components of a given electromagnetic wave is the frequency, ν, of that wave and has units of cycles per second, or Hertz (Hz); the linear distance between the wave's peaks is termed its wavelength, λ, and has units of length (e.g., feet or meters). The speed at which a wave travels is the product of its wavelength and its frequency, $V = \nu\lambda$; in the case of electromagnetic waves, Maxwell's equations require that this velocity equal the speed of light, c ($\cong$186,000 miles per second [300,000 km/sec]). Since the velocity of all electromagnetic waves is fixed, the wavelength λ of an electromagnetic wave always determines its frequency ν, or vice versa, by the relationship $c = \nu\lambda$ The higher the frequency (i.e., the shorter the wavelength) of an electromagnetic wave, the higher in the spectrum it is said to be. Since a wave cannot have a frequency less than zero, the spectrum is bound by zero at its lower end. In theory, it has no upper limit.

All atoms and molecules at temperatures above absolute zero radiate electromagnetic waves at specific frequencies that are determined by the details of their internal structure. In quantum physics, this radiation must often be described as consisting of particles called photons rather than as waves; however, this article will restrict itself to the classical (continuous-wave) treatment of electromagnetic radiation, which is adequate for most technological purposes.

Not only do atoms and molecules radiate electromagnetic waves at certain frequencies, they can absorb them at the same frequencies. All material objects, therefore, are continuously absorbing and radiating electromagnetic waves having various frequencies, thus exchanging energy with other objects, near and far. This makes it possible to observe objects at a distance by detecting the electromagnetic waves that they radiate or reflect, or to affect them in various ways by beaming electromagnetic waves at them. These facts make the manipulation of electromagnetic waves at various frequencies (i.e., from various parts of the electromagnetic spectrum) fundamental to many fields of technology and science, including radio communication, radar, infrared sensing, visible-light imaging, lasers, x rays, astronomy, and more.

The spectrum has been divided up by physicists into a number of frequency ranges or bands denoted by convenient names. The points at which these bands begin and end do not correspond to shifts in the physics of electromagnetic radiation; rather, they reflect the importance of different frequency ranges for human purposes.

Radio waves are typically produced by time-varying electrical currents in relatively large objects (i.e., at least centimeters across). This category of electromagnetic waves extends from the lowest-frequency, longest-wavelength electromagnetic waves up into the gigahertz (GHz; billions of cycles per second) range. The radio frequency spectrum is divided into more than 450 non-overlapping frequency bands. These bands are exploited by different users and technologies: for example, broadcast FM is transmitted using frequencies on the order of 10^6 Hz, while television signals are transmitted using frequencies on the order of 10^8 Hz (about a hundred times higher). In general, higher-frequency signals can always be used to transmit lower-frequency information, but not the reverse; thus, a voice signal with a maximum frequency content of 20 kHz (kilohertz, thousands of Hertz) can, if desired, be transmitted on a signal centered in the Ghz range, but it is impossible to transmit a television signal over a broadcast FM station. Radio waves termed microwaves are used for high-speed communications links, heating food, radar, and electromagnetic weapons, that is, devices designed to irritate or injure people or to disable enemy devices. The microwave frequencies used for communications and radar are subdivided still further into frequency bands with special designations, such as “X band” and “Y band.” Microwave radiation from the Big Bang, the cosmic explosion in which the Universe originated, pervades all of space.

Electromagnetic waves from approximately 10^{12} to 5×10^{14} Hz are termed infrared radiation. The word infrared means “below red,” and is assigned to these waves because their frequencies are just below those of red light, the lowest-frequency light visible to human beings. Infrared radiation is typically produced by molecular vibrations and rotations (i.e., heat) and causes or accelerates such motions in the molecules of objects that absorb it; it is therefore perceived by the body through the increased warmth of skin exposed to it. Since all objects above absolute zero emit infrared radiation, electronic devices sensitive to infrared can form images even in the absence of visible light. Because of their ability to “see” at night, imaging devices that electronically create visible images from infrared light from are important in security systems, on the battlefield, and in observations of the Earth from space for both scientific and military purposes.

Visible light consists of elecromagnetic waves with frequencies in the 4.3×10^{14} to 7.5×10^{14} Hz range. Waves in this narrow band are typically produced by rearrangements (orbital shifts) in the outer electrons of atoms. Most of the energy in the sunlight that reaches the Earth’s surface consists of electromagnetic waves in this narrow frequency range; our eyes have therefore evolved to be sensitive to this band of the electromagnetic spectrum. Photovoltaic cells—electronic devices that turn incident electromagnetic radiation into electricity—are also designed to work primarily in this band, and for the same reason. Because half the Earth is liberally illuminated by visible light at all times, this band of the spectrum, though narrow (less than an octave), is essential to thousands of applications, including all forms of natural and many forms of mechanical vision.

Ultraviolet light consists of electromagnetic waves with frequencies in the 7.5×10^{14} to 10^{16} Hz range. It is typically produced by rearrangements in the outer and intermediate electrons of atoms. Ultraviolet light is invisible, but can cause chemical changes in many substances: for living things, consequences of these chemical changes can include skin burns, blindness, or cancer. Ultraviolet light can also cause some substances to give off visible light (flouresce), a property useful for mineral detection, art-forgery detection, and other applications. Various industrial processes employ ultraviolet light, including photolithography, in which patterned chemical changes are produced rapidly over an entire film or surface by projecting patterned ultraviolet light onto it. Most ultraviolet light from the Sun is absorbed by a thin layer of ozone (O_3) in the stratosphere, making the Earth’s surface much more hospitable to life than it would be otherwise; some chemicals produced by human industry (e.g., chlorfluorocarbons) destroy ozone, threatening this protective layer.

Electromagnetic waves with frequencies from about 10^{16} to 10^{19} Hz are termed x rays. X rays are typically produced by rearrangements of electrons in the innermost orbitals of atoms. When absorbed, x rays are capable of ejecting electrons entirely from atoms and thus ionizing them (i.e., causing them to have a net positive electric charge). Ionization is destructive to living tissues because ions may abandon their original molecular bonds and form new ones, altering the structure of a DNA molecule or some other aspect of cell chemistry. However, x rays are useful in medical diagnosis and in security systems (e.g., airline luggage scanners) because they can pass entirely through many solid objects; both traditional contrast images of internal structure (often termed "x rays" for short) and modern computerized axial tomography images, which give much more information, depend on the penetrating power of x rays. X rays are produced in large quantities by nuclear explosions (as are electromagnetic waves at all other frequencies above the radio band), and have been proposed for use in a space-based ballistic-missile defense system.

All electromagnetic waves above about 10^{19} Hz are termed gamma rays (γ rays), which are typically produced by rearrangements of particles in atomic nuclei. A nuclear explosion produces large quantities of gamma radiation, which is both directly and indirectly destructive of life. By interacting with the Earth's magnetic field, gamma rays from a high-altitude nuclear explosion can cause an intense pulse of radio waves termed an electromagnetic pulse (EMP). EMP may be powerful enough to burn out unprotected electronics on the ground over a wide area.

Radio waves present a unique regulatory problem, for only one broadcaster at a particular frequency can function in a given area. (Signals from overlapping same-frequency broadcasts would be received simultaneously by antennas, interfering with each other.) Throughout the world, therefore, governments regulate the radio portion of the electromagnetic spectrum, a process termed spectrum allocation. In the United States, since the passage of the Communications Act of 1934, the radio spectrum has been deemed a public resource. Individual private broadcasters are given licenses allowing them to use specific portions of this resource, that is, specific sub-bands of the radio spectrum. The United States Commerce Department's National Telecommunications and Information Administration (NTIA) and FCC (Federal Communications Commission) oversee the spectrum allocation process, which is subject to intense lobbying by various telecommunications stakeholders.

In summary, it can be said that the manipulation of every level of the electromagnetic spectrum is of urgent technological interest, but most work is being done in the radio through the visible portions of the spectrum (below 7.5×10^{14} Hz), where communications, radar, and imaging can be accomplished.

SEE ALSO DNA fingerprint; DNA profiling; Electromagnetic weapons, biochemical effects; Fluorescence; Laser; Ultraviolet light analysis.

Electromagnetic weapons, biochemical effects

Exposure to electricity and electromagnetic radiation, while relatively uncommon, can be a factor in a forensic investigation. Because the effects of exposure to electromagnetism leave no visible signs such as bruises or cuts, the cause of a disability or death can be difficult to unravel without knowledge of the phenomena.

Forensically, an encounter with electromagnetic radiation would likely be due to the deliberate use of an electromagnetic weapon.

Electromagnetic weapons—also known as E-bombs—are designed to release a high-power flash of radio waves or microwaves. Depending on the energy of the electromagnetic pulse, effects can range from the disabling of electronic circuitry to physiological effects in those exposed to the electromagnetic pulse.

The pulse released by an electromagnetic weapon lasts for an extremely short time, around 100 picoseconds (one ten-billionth of a second). The absorption of this blast of high energy by anything capable of conducting electricity, including nerves and neurons, overwhelms the recipient.

Research and development into the effects of electromagnetic weapons on human beings and animals was underway in the 1940s. The Japanese spent considerable sums of money on the development of a "Death Ray" between 1940 and 1945. A review of these studies by the United States military concluded that it was possible to develop a weapon that would produce an electromagnetic ray capable of killing humans five to 10 miles away from the source.

Animal studies have demonstrated the lethal nature of electromagnetic radiation. In the studies, wavelengths ranging from 60 centimeters destroyed the lung cells of mice and groundhogs. Wavelengths less than two meters also destroyed brain cells.

Electronic stimulation can have other, non-lethal effects on humans. Secret research conducted in the United States following World War II demonstrated that electronic stimulation of different regions of the brain of test subjects could produce extreme emotions of rage, lust, and fatigue. Another research program, dubbed "Operation Knockout," operated at the Allan Memorial Institute in Montreal, Canada, with funding from the Central Intelligence Agency. The study's director, Dr. Ewen Cameron, discovered that electroshock treatments caused amnesia. Memories could be erased, and the subjects reprogrammed. Once these "psychic driving" experiments became public, Cameron—then a pre-eminent psychiatrist—received harsh public and professional criticism.

In the 1960s, the U.S. Defense Advanced Projects Research Agency (DARPA) studied the health and psychological effects of low energy microwaves for weapons applications. The ability of microwaves to damage the heart, create leaks in blood vessels in the brain, and to produce hallucinations was demonstrated.

Many scientists assume that research into the debilitating effects of electromagnetic radiation has continued up to the present day. However, increasing restrictions on the information obtainable through the U.S. Freedom of Information Act have made verification difficult. A 1993 U.S. Air Command and Staff College paper entitled "Non Lethal Technology and Air Power" documented low frequency, "acoustic" and high power microwave weapons that could deter or debilitate humans.

Low frequency electromagnetic waves, also known as acoustic waves, have been commonly used for decades in functions such as ultrasound machines. However, acoustic waves can also cause internal organs of humans to vibrate. The result can be nausea, diarrhea, earache, and mental confusion. The discomfort increases as one gets closer to the source.

Shorter wavelength electromagnetic radiation produces different effects. A common example is microwave radiation, which in a microwave oven can be used to heat up foods and liquids. When directed at humans, a microwave weapon causes atoms to vibrate, which in turn generates heat. At 200 yards away, body temperature increases from the normal 98.6°F to 107°F. At closer range, the temperature increase can be even higher, and is lethal.

Microwave electromagnetic weapons can also stun a victim. This is the result of the stimulation of peripheral nerves. The simultaneous activity of many nerves overwhelms the capacity of the brain to process the incoming information, and can induce unconsciousness.

The biochemical effect of microwave exposure is dependent on the distance from the source, as electromagnetic fields become much weaker as the distance from the source increases.

Experiments with very low frequency electromagnetic radiation have demonstrated that the radiation can induce the brain to release chemicals that induce slumber, or to release a chemical called histamine. In human volunteers, the histamine release produces flu-like symptoms, which dissipate when the radiation stops.

Not all electromagnetic weapons are cloaked in military secrecy. A device called the Pulse Wave Myotron is commercially available. The Myotron emits rapid pulses of electromagnetic radiation. The pulses incapacitate the movement of voluntary muscles by overriding the electrical pulse that normally flows from nerve to nerve within the muscles. Involuntary muscles, such as the heart and the muscles that operate the lungs, are unaffected. Thus, a victim is rendered incapable of movement or speech. The effect lasts until the muscles can repolarize; approximately 30 minutes.

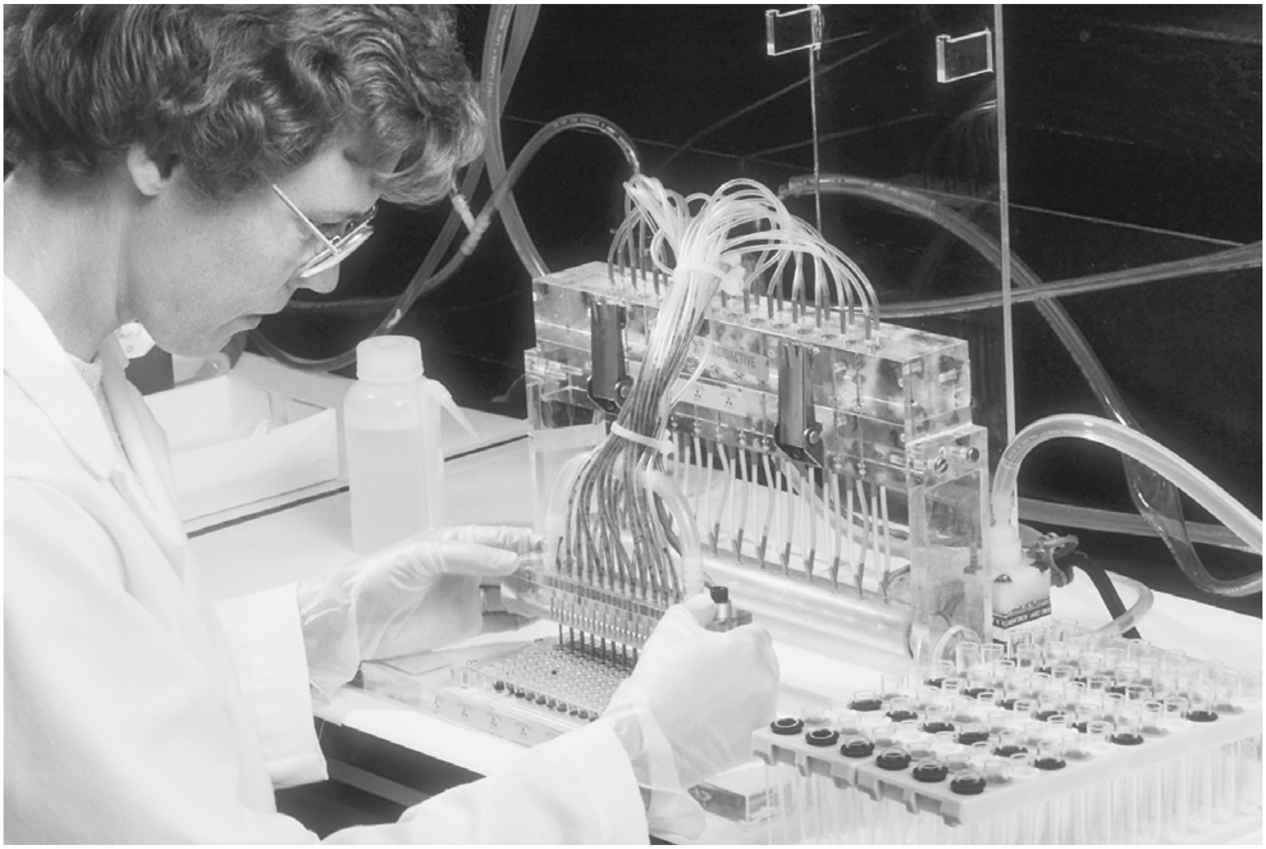
SEE ALSO Electrical injury and death; Radiation, electromagnetic radiation injury.

Electrophoresis

Electrophoresis is a valuable approach to fighting infectious disease. Electrophoretic analysis allows the identification of bacterial and viral strains and is finding increasing acceptance as a powerful forensic tool.

Diseases caused by microorganisms are a threat to national security. One strategy is to examine the relevant microorganisms, particularly to find out the component(s) that are responsible for the infection. For many microbes, proteins are an important factor in the development of a disease. Proteins can function as receptors, to allow the microorganism to adhere to the surface of a host cell. As well, the **toxins** produced by microbes such as ***Escherichia coli*** O157:H7 and *Vibrio chlorerae* are proteins. Methods that can dissect microorganisms into their components, and that can compare a non-disease-causing strain of a microbe to a disease-causing strain to see where they differ, are a valuable approach to fighting infectious disease. Electrophoresis is especially well suited to this role. Furthermore, specialized types of electrophoresis (i.e., pulsed field electrophoresis) allow the genetic material of the microorganism to be examined. Thus, electrophoresis can reveal much detail at the molecular level.

Electrophoresis is a sensitive analytical form of **chromatography**. Under the influence of an electrical



Lab technician performs electrophoresis. © ROYALTY-FREE/CORBIS

field, charged molecules can be separated from one another as they pass through a gel. Gel electrophoresis is a method that separates macromolecules—either nucleic acids or proteins—on the basis of size, electric charge, and other physical properties. The term electrophoresis describes the migration of charged particle under the influence of an electric field. Electro refers to the energy of electricity. Phoresis, from the Greek verb phoros, means "to carry across." Thus, gel electrophoresis refers to the technique in which molecules are forced across a span of gel, motivated by an electrical current. Activated electrodes at either end of the gel provide the driving force. A molecule's properties determine how rapidly an electric field can move the molecule through a gelatinous medium. Gel electrophoresis makes it possible to determine the genetic difference and the evolutionary relationship among species of plants and animals. Using this technology it is possible to separate and identify protein molecules that differ by as little as a single amino acid.

The advent of electrophoresis revolutionized the methods of protein analysis. Swedish biochemist Arne Tiselius was awarded the 1948 Nobel Prize in chemistry for his pioneering research in electrophoretic analysis. Tiselius studied the separation of **serum** proteins in a tube (subsequently named a Tiselius tube) that contained a solution subjected to an electric field.

In electrophoresis, the electric charge often is passed through one of various support mediums. In general, a medium is mixed with a chemical mixture called a buffer. The buffer carries the electric charge that is applied to the system. The medium/buffer matrix is placed in a tray with molecule samples to be separated. As electrical current is applied to the tray, the matrix takes on this charge and develops positively and negatively charged ends. As a result, molecules that are negatively charged, such as deoxyribonucleic acid (**DNA**), ribonucleic acid (RNA), and protein, are pulled toward the positive end of the gel.

Intact DNA is so large that it cannot move through the pores of a gel (although the technique of pulsed field electrophoresis does allow very large pieces of DNA to be examined). When DNA is subjected to electrophoresis, the DNA is first cut into smaller pieces by restriction enzymes. Restriction enzymes recognize specific sequences of the building blocks of the DNA and cut the DNA at the particular site. There are many types of restriction enzymes, and so DNA can be cut into many different patterns. After electrophoresis, the pieces of DNA appear as bands (composed of similar length DNA molecules) in the electrophoresis matrix.

Electrophoresis can be combined with the prior addition of a radioactive food source to the **culture** of bacteria. The bacteria will use the food to make new proteins, which will be radioactive. Following electrophoresis, the gel can be placed in contact with x-ray film. The radioactive bands or spots will register on the film, and so will determine what proteins were being made at the time of the experiment.

There are many other variations on gel electrophoresis, with wide-ranging applications. These specialized techniques include Southern, Northern, and Western Blotting (blots are named according to the molecule under study). In Southern blots, DNA is cut with restriction enzymes, then probed with radioactive DNA. In Northern blotting, RNA is probed with radioactive DNA or RNA. Western blots target proteins with radioactive or enzymatically tagged antibodies.

Modern electrophoresis techniques now allow the identification of DNA sequences that are the same. They have become an integral part of research into **gene** structure, gene expression, and the diagnosis of heritable diseases. Electrophoretic analysis also allows the identification of bacterial and viral strains and is finding increasing acceptance as a powerful forensic tool.

SEE ALSO Chemical and biological detection technologies; Chromatography; DNA; DNA recognition instruments; DNA sequences, unique; DNA typing systems; Thin layer chromatography; Toxins.

Endothermic reaction

In a chemical reaction, reactants are converted into products by the breaking and making of chemical bonds. An example is the burning of carbon in oxygen to make carbon dioxide. Bond breaking requires energy, while bond making releases energy. The balance between the two gives a positive or negative energy change for the reaction. Chemical reactions are classed as being either endothermic, with a positive energy change, or exothermic, with a negative energy change. In an endothermic reaction, more energy is taken breaking bonds than is released making them, so the reaction proceeds with a net absorption of energy. In an exothermic reaction, the reverse is true and energy is released. The issue of whether a reaction is endothermic or exothermic is important in the forensic investigation of explosions.

Endothermic reactions are in the minority—most chemical reactions release energy. An endothermic reaction usually needs some energy to get it going. However, some endothermic reactions occur without this boost; the dissolving of ammonium nitrate in water occurs spontaneously with a marked decrease in temperature due to heat being taken in from the surroundings. Compounds formed by endothermic reactions have stored or potential chemical energy in their bonds, which may be released spontaneously in an explosion. Such compounds include chlorates, perchlorates, and nitrates. These may explode spontaneously, which makes them dangerous to handle whether or not there is any criminal intent. If combined with other components, they will make a high explosive mixture. Explosions of endothermic compounds typically produce a lot of gas, creating a destructive pressure wave spreading through the surrounding area.

The explosion of an endothermic substance is in itself exothermic, with the chemical potential energy of the compound being released in the form of heat, light, and sound. Endothermic explosions are possible too, but need some kind of primer explosive to give them the energy required to set them off. A knowledge of the chemistry of **explosives** can help the forensic investigator understand the devastation that occurs at the scene of an explosion.

SEE ALSO Exothermic reactions.

Energy dispersive spectroscopy

Energy dispersive **spectroscopy** (also called energy dispersive x-ray spectroscopy) is an analysis technique that can be of great value in the forensic examination of samples. The technique utilizes a scanning electron microscope, a type of high magnification microscopy in which the sample is bombarded by electrons. The resultant pattern of electron reflection by the sample is used to generate a detailed three-dimensional appearing surface view.

At the heart of energy dispersive spectroscopy are x rays. During electron bombardment, electrons are also ejected from surface atoms of the sample. The resulting electron vacancy is filled by a higher energy electron. To maintain the energy balance of the atom, some energy must be released. The energy is released as x rays.

Released x rays are gathered by a detector positioned above the sample. Because the energy of the x rays will vary, depending on the element from which they were released, analysis of the x-ray spectrum can permit the various elements comprising a sample to be identified.

The x-ray spectrum is graphically displayed as a series of peaks. The pattern of peaks is a fingerprint of the specific elements in a specimen. Thus, **blood** will produce a different and characteristic pattern of peaks from gasoline.

Fluid samples such as the aforementioned cannot be examined directly. This is because the electron microscope operates in the absence of air, which would otherwise deflect the electron beam from the sample. During sample preparation, **fluids** can be dried down onto the surface. This residue is sufficient for analysis and **identification**.

Fluids can thus be identified and differentiated from each other using the spectroscopy technique. Furthermore, solids can also be analyzed, as the electron beam of the microscope can be focused to a small point on the sample surface. Indeed, various areas of a solid can be independently analyzed. This is advantageous when trying to identify the presence of a component on a solid object (i.e., blood on a knife tip). As well, different types of solid materials can be differentiated from one another.

Energy dispersive spectroscopy requires a dedicated laboratory equipped with a scanning electron microscope and ancillary equipment to conduct the x-ray analysis, as well as trained personnel. Thus, the analysis is typically done at regional or state facilities that will accept samples from local agencies.

SEE ALSO Analytical instrumentation; Fourier transform infrared spectrophotometer (FTIR); Scanning electron microscopy.

Entomological studies of time of death SEE Time of death, contemporary determination

Entomology

Entomology is the study of insects and their life cycles. Many insects live and feed on dead flesh, which is why entomology is relevant to **forensic science**. The forensic entomologist can help estimate **time of death** by looking at which insects are present on a corpse and where they are in their life cycle. Entomology can also shed light on the nature of injuries, whether a corpse has been moved, and whether drugs were involved in a death.

A newly deceased corpse attracts flies. Within minutes of a death, blowflies will start to lay their eggs in moist areas such as the nose, mouth, armpit, groin, or open wounds. The eggs hatch into larvae or maggots within 24 hours and these grow to around half an inch in length after about three days. Then, over the next six to ten days, they will develop into pupae with a hard outer case. Adult flies emerge about twelve days after this. If the corpse is not recovered by this time, the life cycle repeats itself so that flies at all different stages of development may be recovered from the corpse.

The forensic entomologist can use the life cycle of the flies found on a corpse as a kind of clock, giving the minimum time that elapsed since the time of death and the time of discovery. If eggs are found, it suggests death occurred less than 24 hours before discovery. The presence of maggots indicates the death occurred less than ten days ago. Pupae and mature flies will suggest a time of death one to three weeks before discovery of the corpse. However, the life cycle of flies is not an accurate clock. Flies are cold-blooded and their activities are dictated by the weather. Maggots may become dormant if it is cold and flies do not lay eggs at night. If someone is killed at midnight, flies will not appear till daylight, which means time must be added to the estimated time of death.

Because flies feed on human tissue, their own tissue can sometimes be used to measure levels of any drugs that may have played a role in the person's death. This is useful when the corpse itself does not yield tissue for analysis. Insect ecology varies from place to place and sometimes the species found on a corpse are not native to the place where the corpse is found. This may indicate that the corpse

A Thai health worker prepares to cremate hundreds of giant Madagascar hissing cockroaches seized as evidence in Bangkok in 2003. The cockroaches became the latest craze in pets in 2002, raising concern among health officials that the rapidly multiplying insects would spread diseases. © REUTERS/CORBIS

was moved after death. Furthermore, flies feed on open bleeding wounds and their presence may help distinguish between ante-mortem and post-mortem injuries.

SEE ALSO Time of death.

Environmental Measurements Laboratory

The Environmental Measurements Laboratory (EML) is a research laboratory located in New York City, first established in 1947, that is operated by the United States government. Research at the facility is coordinated by the Science and Technology (S&T) Directorate of the Department of Homeland Security. EML scientists are an integral part of the nation's radiological incident emergency response plans. As such, they contribute to forensic investigations.

As a federal laboratory, EML supports The United States Department of Energy (DOE) National Security objectives. EML responsibilities include monitoring international compliance with nonproliferation treaties. EML is a part of the Homeland Security Monitoring Network (HSMN) and is also an official U.S. Radionuclide Laboratory with facilities dedicated to support of the International Monitoring System.

EML programs are designed to develop and train personnel in instruments and technologies capable of detecting radioactive substances and identifying nuclear threats. EML has advanced programs in radiation survey planning, radiological monitoring and assessment, and radiation measurements (including **dosimetry** measurements). EML also hosts high resolution gamma sensors and equipment dedicated to measuring environmental radiation and radioactivity.

Unique EML research capabilities include the ability to generate atmospheric conditions that allow experimental evaluation of instrumentation. EML scientific programs include collaborative research with global meteorological groups dedicated to developing more accurate atmospheric modeling programs. Since the Cold War, EML has maintained the International Environmental Sample Archive (IESA), a collection of atmospheric and other environmental samples containing isotopes present in the atmosphere during periods when nations still engaged in atmospheric testing of nuclear weapons. These samples can be used to test current samples for signs of nuclear testing and are a part of nonproliferation monitoring. The samples can also allow quantitative and qualitative standardization of monitoring instrumentation.

As part of HSMN implementation, EML scientists constructed a prototype monitoring platform on top of the GSA building in New York city that is capable of detecting radiological anomalies. Radiation levels can be measured by instruments utilizing a pressurized ionization chambers (PIC), comprehensive radiation sensors (CRS), and direct analysis of trapping filters via high-resolution gamma-ray analysis. The instruments are capable of distinguishing between natural radioactive sources and artificial or man-made sources.

EML programs include surface, air, and high altitude sampling programs, soil and sediment sampling programs, and fallout measurement programs.

EML scientists have developed particulate collection systems that utilize sodium iodide gamma detectors, and RAMPSCAN, a highly portable battery-operated gamma radiation detector.

Other EML facilities include pulse ionization chambers capable of measuring radon levels, a gamma ray analysis laboratory, and a thermoluminescent dosimeter reader facility.

SEE ALSO Analytical instrumentation; Electromagnetic spectrum; Meteorology.

Epidemiology

Epidemiology is the study of the occurrence, frequency, and distribution of diseases in a given population. As part of this study, epidemiologists—scientists who investigate epidemics (widespread occurrence of a disease that occurs during a certain time)—attempt to determine how the disease is transmitted, and what are the host(s) and environmental factor(s) that start, maintain, and/or spread the epidemic.

Epidemiology can be an important facet of a forensic investigation. A recent infamous example occurred in the fall of 2001, when a number of letters containing **spores** of Bacillus anthracis, the agent that causes **anthrax**, were sent through the United States postal system. The illnesses and deaths that resulted prompted the near shut-down of the postal delivery system, and an investigation to find the sender(s) of the letters and the source of the bacterial spores. These investigations were rooted in epidemiology.

The primary focus of epidemiology is on groups of persons, rather than individuals. The primary effort of epidemiologists is in determining the etiology (cause) of the disease and identifying measures to stop or slow its spread. This information, in turn, can be used to create strategies by which the efforts of health care workers and facilities in communities can be most efficiently allocated for this purpose.

In tracking a disease outbreak, epidemiologists may use any or all of three types of investigation: descriptive epidemiology, analytical epidemiology, and experimental epidemiology.

Descriptive epidemiology is the collection of all data describing the occurrence of the disease, and usually includes information about individuals infected, and the place and period during which it occurred. Such a study is usually retrospective, i.e., it is a study of an outbreak after it has occurred. The 2001 anthrax investigation is one example.

Analytical epidemiology attempts to determine the cause of an outbreak. Using the case control method, the epidemiologist can look for factors that might have preceded the disease. Often, this entails comparing a group of people who have the disease with a group that is similar in age, sex, socioeconomic status, and other variables, but does not have the disease. In this way, other possible factors, e.g., genetic or environmental, might be identified as factors related to the outbreak.

Using the cohort method of analytical epidemiology, the investigator studies two populations, one who has had contact with the disease-causing agent and another that has not. For example, the comparison of a group that received blood transfusions with a group that has not might disclose an association between blood transfusions and the incidence of a blood borne disease, such as hepatitis B.

Experimental epidemiology tests a hypothesis about a disease or disease treatment in a group of people. This strategy might be used to test whether or not a particular antibiotic is effective against a particular disease-causing organism. One group of infected individuals is divided randomly so that some receive the antibiotic and others receive a placebo—a "false" drug that is not known to have any medical effect. In this case, the antibiotic is the variable, i.e., the experimental factor being tested to see if it makes a difference between the two otherwise similar groups. If people in the group receiving the antibiotic recover more rapidly than those in the other group, it may logically be concluded that the variable—antibiotic treatment—made the difference. Thus, the antibiotic is effective.

In the process of studying the cause of an infectious disease, epidemiologists often view it in terms of the agent of infection (e.g., particular bacterium or virus), the environment in which the disease occurs (e.g., crowded slums), and the host (e.g., hospital patient). Another way epidemiologists may view etiology of disease is as a "web of causation." This web represents all known predisposing factors and their relations with each other and with the disease. For example, a web of causation for myocardial infarction (heart attack) can include diet, hereditary factors, cigarette smoking, lack of exercise, susceptibility to myocardial infarction, and hypertension. Each factor influences and is influenced by a variety of other factors.

Epidemiologic investigations are largely mathematical descriptions of persons in groups, rather than individuals. The basic quantitative measurement in epidemiology is a count of the number of persons in the group being studied who have a particular disease; for example, epidemiologists may find 10 members of a village in the African village of Zaire suffer from infection with **Ebola virus** infection; or that 80 unrelated people living in an inner city area have tuberculosis.

A fundamental underpinning of infectious epidemiology is the confirmation that a disease outbreak has occurred. Once this is done, the disease is followed with time. The pattern of appearance of cases of the disease can be tracked by developing what is known as an epidemic curve. This information is vital in distinguishing a natural outbreak from a deliberate and hostile act, for example. The appearance of a few cases at first with the number of cases increasing over time to a peak is indicative of a natural outbreak. The number of cases usually begins to subside as the population develops immunity to the infection (e.g., influenza). However, if a large number of cases occur in the same area at the same time, the source of the infection might not be natural. Examples include a **food poisoning** or a bioterrorist action where the accidental or deliberate release of organisms will be evident as a sudden appearance of a large number of cases at the same time.

Any description of a group suffering from a particular disease must be put into the context of the larger population. This shows what proportion of the population has the disease. The significance of ten people out of a population of 1,000 suffering tuberculosis is vastly different, for example, than if those ten people were part of a population of one million.

Thus one of the most important tasks of the epidemiologist is to determine the prevalence rate—the number of persons out of a particular population who have the disease (prevalence rate). A prevalence rate can represent any time period, e.g., day or hour; and it can refer to an event that happens to different persons at different times, such as complications that occur after drug treatment (on day five for some people or on day two for others).

The incidence rate is the rate at which a disease develops in a group over a period of time. Rather than being a snapshot, the incidence rate describes a continuing process that occurs over a particular period of time.

Period prevalence measures the extent to which one or all diseases affects a group during the course of time, such as a year.

Epidemiologists also measure attributable risk, which is the difference between two incidence rates of groups being compared, when those groups differ in some attribute that appears to cause that difference. For example, the lung cancer mortality rate among a particular population of non-smoking women 50 to 70 years old might be 20/100,000, while the mortality rate among woman in that age range who smoke might be 150/100,000. The difference between the two rates ($150 - 20 = 130$) is the risk that is attributable to smoking, if smoking is the only important difference between the groups regarding the development of lung cancer.

Epidemiologists arrange their data in various ways, depending on what aspect of the information they want to emphasize. For example, a simple graph of the annual occurrence of viral meningitis might show by the "hills" and "valleys" of the line in which years the number of cases increased or decreased. This might provide evidence of the cause and offer ways to predict when the incidence might rise again.

Bar graphs showing differences in rates among months of the year for viral meningitis might pinpoint a specific time of the year when the rate goes up, for example, in summertime. That, in turn, might suggest that specific summertime activities, such as swimming, might be involved in the spread of the disease.

One of the most powerful tools an epidemiologist can use is case reporting: reporting specific diseases to local, state, and national health authorities who accumulate the data. Such information can provide valuable leads as to where, when, and how a disease outbreak is spread, and help health authorities to determine how to halt the progression of an epidemic—one of the most important goals of epidemiology.

Molecular epidemiology has been used to trace the cause of bacterial, viral, and parasitic diseases. This knowledge is valuable in developing a strategy to prevent further outbreaks of the microbial illness, since the probable source of a disease can be identified.

Molecular epidemiology arises from varied scientific disciplines, including genetics, epidemiology, and statistics. The strategies involved in genetic epidemiology encompass population studies and family studies. Sophisticated mathematical tools are now involved, and computer technology is playing a predominant role in the development of the discipline. Multidisciplinary collaboration is crucial to understanding the role of genetic and environmental factors in disease processes.

Much information can come from molecular epidemiology, even in the exact genetic cause of the malady is not known. For example, the identification of a malady in generations of related people can trace the genetic characteristic, and even help identify the original source of the trait. This approach is commonly referred to as genetic screening. The knowledge of why a particular malady appears in certain people, or why such people are more prone to a microbial infection than other members of the population, can reveal much about the nature of the disease in the absence of the actual **gene** whose defect causes the disease.

Various routes can spread infections (i.e., contact, air borne, insect borne, food and water intake, etc.). Likewise, the route of entry of an infectious microbe can also vary from microbe to microbe.

Laboratory analysis techniques can be combined with other techniques to provide information related to the spread of an outbreak. For example, microbiological data can be combined with geographic

A CDC scientist examines the structural proteins (DNA) of a previously unrecognized coronavirus in a patient with SARS.
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information systems (**GIS**). GIS information has helped pinpoint the source of outbreaks. In addition to geographic based information, epidemiologists will use information including the weather on the days preceding an outbreak, mass transit travel schedules, and schedules of mass-participation events that occurred around the time of an outbreak to try an establish a pattern of movement or behavior to those who have been affected by the outbreak. Use of credit cards and bank debit cards can also help piece together the movements of those who subsequently became infected.

Reconstructing the movements of people is especially important when the outbreak is of an infectious disease. The occurrence of the disease over time can yield information as to the source of an outbreak.

Epidemiologists were among the first scientists to effectively utilize the Internet and email capabilities to effectively communicate regarding disease outbreaks. The International Society for Infectious Diseases sponsors PROMED, a global e-mail based electronic reporting system for outbreaks of emerging infectious diseases and **toxins**, which is open to all sources.

SEE ALSO Anthrax, investigation of 2001 murders; Ebola virus; Pathogens; September 11, 2001, terrorist attacks (forensic investigations of).

Epilepsy

Epilepsy is a neurological disorder, usually characterized by either recurrent or sporadic seizures. Epilepsy presents a particular challenge for forensic scientists because sudden, unexplained death may occur in people with epilepsy, and up to 30% of individuals with epilepsy have no demonstrable **cause of death** at the time of **autopsy**.

Known as both sudden unexplained death syndrome (SUDS) and sudden unexpected death in epilepsy (SUDEP), the condition is often under-recognized. Deaths are sometimes attributed to other causes in people with epilepsy, such as drowning, when in fact, a seizure precipitated events leading to death. One study conducted in Australia in 2003 showed that SUDEP occurs in approximately one person per 200 people with epilepsy per year. Usually, a person with (SUDEP) dies in their sleep. With awareness of the condition growing and funding for research increasing, forensic scientists are assisting in collecting data and other research into unraveling the mystery of SUDEP.

Epileptic seizures are usually convulsive, affecting autonomic reflexes, as well as motor, sensory, and cognitive neuronal (nerve cell) functions. They are caused by the synchronous hyper-excitation of isolated groups of nerve cells in one of the brain cortical areas. Seizures can last from a few seconds up to minutes, depending on the intensity of neuronal excitability.

Epilepsy may be the result of inherited **gene** mutations, metabolic diseases, or brain malformation, or may constitute a major symptom of a neurological disease. When the epilepsy results from an identified cerebral condition, such as cerebral concussion or brain tumor, or is a clinical manifestation of a hereditary neurodegenerative syndrome, it is classified as symptomatic. Non-symptomatic epilepsies are those occurring in persons who do not present brain abnormalities or neurological disorders other than the seizures.

Other types of epilepsy may be induced through occupational damage, due to repeated exposure to acoustic or visual stimuli, or as a result of an isolated high-intensity auditory or visual stimulus. Whatever the case, the sensory stimulation induces chemical changes in the related brain areas, causing a kind of electrical short-circuit, with a group of neurons briefly firing in a synchronous rhythm. These stimuli-induced forms of seizures are known as acquired epilepsy. A dramatic example of seizures induced by repeated sensory stimuli happened in Japan on December 17, 1997, when hundreds of children suffered simultaneous epileptic seizures induced by the flashing red eyes of a Pokemon cartoon character. Epilepsies induced by sensory stimuli are also known as reflex epilepsies.

Absence epilepsy (e.g., non-convulsive epilepsy) occurs mostly in children between three and eight years of age, usually disappearing in adolescence. Non-convulsive epileptic episodes may happen one or more times a day, being characterized by a brief impairment of consciousness, absence of response to external stimuli, "stargazed" expression, and spatial disorientation. However, in contrast to reflex epilepsies, it cannot be induced by sensory stimulation. Convulsive forms of epilepsy are generally preceded by a brief state of dizziness, or external sensory shutdown, followed by convulsion. After convulsion, the person also experiences confusion, poor body equilibrium, and a few minutes of spatial disorientation.

Ignorance and prejudice in the past led to the popular and institutional belief that epilepsy was a kind of mental illness or disability that required institutionalization in psychiatric hospitals. It was also believed that some epileptic individuals entered in a state of somnambulism (unawareness) during the seizures and could commit crimes, which they could not recollect later. Thanks to the advances in neurosciences in the last fifty years, such assumptions have been disproved. However, popular prejudice and legal confusion still persist as to the degree of legal responsibility of epileptic offenders, both from the prosecution and the defense point of view. **Expert witnesses** in neurology and **psychiatry** are often requested to evaluate epileptic defendants and to inform the court about the nature of the disorder and the characteristics of seizures. In most developed countries, epileptic seizures are not considered a legal impediment for the full fruition of individual civil rights and liberties.

Epilepsy treatment usually requires the regular intake of controlled anti-convulsive medications. Law enforcement personnel are educated about the different intensities and types of epileptic seizures in order to prevent misinterpreting behavior, such as the appearance of intoxication, exhibited by persons experiencing a seizure or in the immediate recovery period.

SEE ALSO Brain wave scanners; Expert witnesses; Nervous system overview; Neurotransmitters.

Henry Erlich

6/4/1943–
AMERICAN
MOLECULAR BIOLOGIST

Since the early 1980s, Henry A. Erlich has been well-known in the forensic and medical communities for helping to pioneer the research and development of a **polymerase chain reaction** (**PCR**) technique that ultimately lead to a number of important forensic and clinical applications. As a result of the pioneering efforts of Erlich and his team of scientists, the first commercial PCR typing kit was developed specifically for forensic use. Currently, Erlich is the director of the Department of Human Genetics and vice-president of Discovery Research, both for Roche Molecular Systems, Inc.; and the co-director (and co-founder) of the HLA Laboratory at the Children's Hospital Oakland Research Institute—all three located in the San Francisco Bay Area of California.

Erlich grew up in Seattle, Washington. He began his bachelor's of art degree in 1961 at Harvard University in Cambridge, Massachusetts, where he completed his degree in 1965 with a major in biochemical sciences. That same year, Erlich was a research assistant at Yale University in New Haven, Connecticut. Erlich then began his advanced degree, completing his doctor's of philosophy (Ph.D.) degree in 1972 from the University of Washington (Seattle) with a genetics concentration. While working on his degree in 1967, Erlich also worked with street gangs as a Vista volunteer in New Mexico. Erlich did his postdoctoral work in microbial genetics (1972–1975) at Princeton University in New Jersey, where he was employed as a postdoctoral fellow at Princeton's Department of Biology. Erlich did further postdoctoral work in immunogenetics (1975–1979) at Stanford University (California), where he was employed as a postdoctoral fellow at Stanford's Department of Medicine, Division of Immunology.

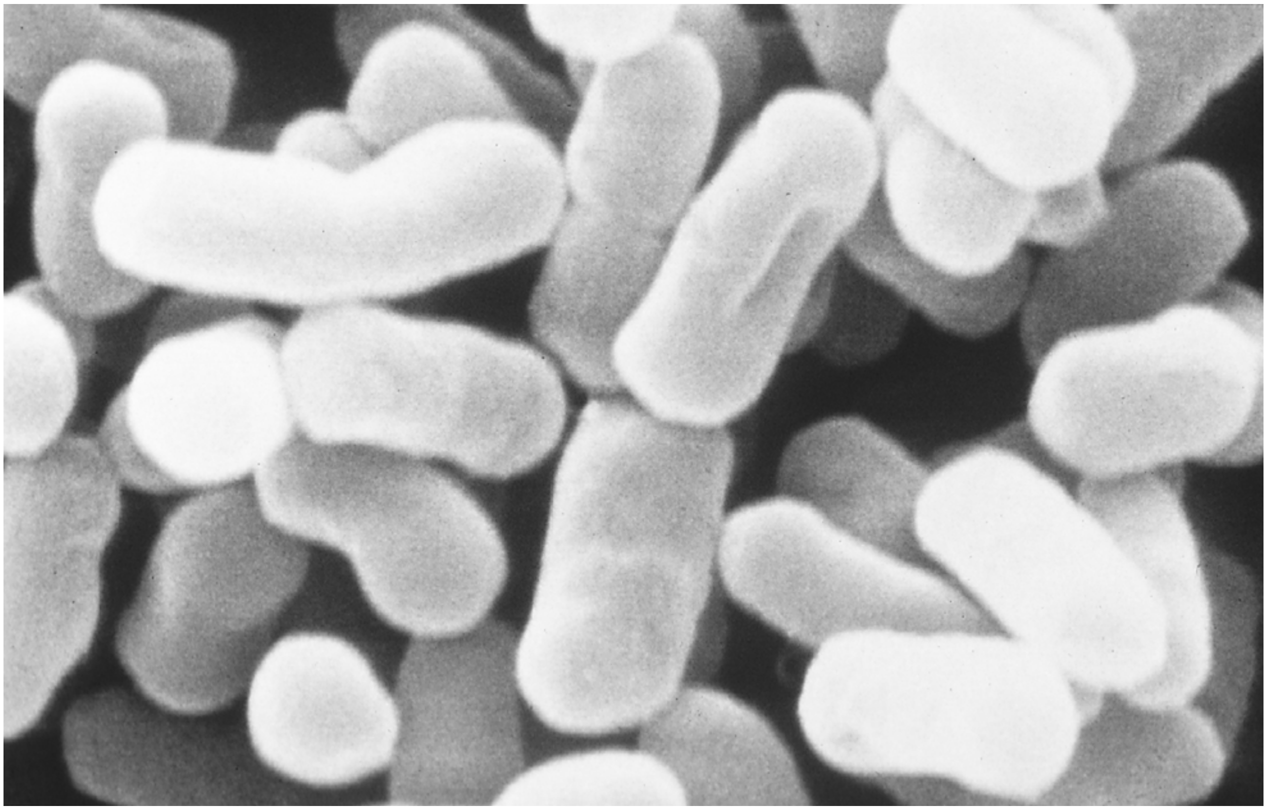
After completing his postdoctoral studies, Erlich became a scientist at Cetus Corporation, an Oakland-area biopharmaceutical/biotechnology company located in Emeryville, California, where he held various teaching positions and served on the editorial boards of such industry publications as *Human Immunology*, *PCR Methods and Applications*, and *Technique*. Erlich was later promoted to senior scientist and director of the Human Genetics Department, both positions that he held until 1991.

During his early-1980s work with Cetus, Erlich led the human genetics group in the research of PCR techniques. He was especially interested in developing technology for the study of human genetic variation, and with it the applications in forensics and clinical medicine. In 1986, Erlich's research resulted in development of a PCR technique that ultimately produced a number of clinical and forensic applications. Also in 1986, in what is generally considered the first use of PCR-based forensic **DNA** (deoxyribonucleic acid) analysis in a U.S. court case, Erlich carried out the confirmation that two **autopsy** samples came from the same person in the case *Pennsylvania v. Pestinikas*. About two years later, Erlich and his scientific team saw the development of a commercial PCR typing kit as the first forensic application within the United States of DNA typing of HLA-DQA (human leukocyte **antigen** with a DQ alpha PCR test) locus.

Erlich transferred to Roche Molecular Systems, Inc., located in Alameda, California, in 1991 when the company acquired the rights of PCR technology from Cetus. Today, Erlich holds three important positions with Roche: director of Roche's Human Genetics Department, since 1992; co-director of the HLA Laboratory at the Children's Hospital Oakland Research Institute (CHORI), in Oakland, California, since 1996; and vice president of Roche's Discovery Research, since 2000. Erich's work at CHORI puts into clinical practice the technologies that he had developed for PCR-based HLA typing.

The primary research performed by Erlich in concert with Roche involves the analysis of molecular evolution and population genetics of HLA genes along with human genetic variation and genetic susceptibility to diseases, especially on autoimmune diseases such as type 1 diabetes. He also researches the analysis of polymorphism in HLA genes and the development of HLA typing for class I and class II loci within tissue typing and transplantation, anthropological genetics, and individual **identification**.

Erlich maintains an academic affiliation with the Stanford School of Medicines, where he is an adjunct professor of medical microbiology and immunology. In addition, he also sits on several editorial boards (such as *Human Mutation* and *Tissue Antigens*); participates on numerous human genetics committees



Scanning electron micrograph of Escherichia Coli (E. coli), irregular short tubes in shades of gold/yellow, resemble irregular soft medicine capsules.

(such as the International Histocompatibility Council and the National Commission on the Future of DNA Evidence-Research and Development Working Group); and is a member of the American Society for Histocompatibility and Immunogenetics and the American Society for Human Genetics. Erlich has authored several books, with one of the latest titled *PCR Technology: Principles and Applications for DNA Amplification*.

Erlich has also been bestowed with many honors within genetic research and writing including such awards as the Gideon Goldstein Award (Walter and Eliza Institutes, 1989), the Biochemical Analysis Award (German Society of Clinical Chemistry, 1990), the Brown-Hazen Award (Wadsworth Center for Laboratories and Research, 1990), The Rose Payne Award (American Society of Histocompatibility Immunogenetics, 1990), the Advanced Technology in Biotechnology Milano Award (International Federation of Clinical Chemistry, 1991), the Award for Excellence (Association for Molecular Pathology, 2000), the Profiles in DNA Courage Award (**National Institute of Justice**, 2000), and the Colonel Harland Sanders Award (March of Dimes Clinical Genetics Conference, 2000).

SEE ALSO DNA; PCR (polymerase chain reaction).

Escherichia coli

Forensic investigations of a food- or water-related outbreak of disease will often focus on select bacteria. One bacterium often associated with contaminated food is *Escherichia coli*.

Escherichia coli (*E. coli*) is one of the most well-known and intensively studied bacteria. It normally inhabits the intestinal tract of humans and other warm-blooded mammals. *E. coli* constitutes approximately 0.1% of the total bacteria in the adult intestinal tract.

Despite its intestinal habitat, some types (strains) of *E. coli* cause diarrhea and gastroenteritis (an inflammation of the intestinal tract) in infants. If these more infectious types are present in water or food that is ingested, then an infection can result. The vast majority of the many types of *E. coli* are harmless to humans.

When *E. coli* is excreted from the intestinal tract, the bacteria are able to survive only a few hours. This characteristic of rapid death was recognized at the beginning of the twentieth century, when the bacterium began to be used as an indicator of fecal pollution of water. The presence of large numbers of *E. coli* in water is a strong indicator of recent fecal pollution, and so the possible presence of other intestinal bacteria that cause serious disease (i.e., Vibrio, Salmonella, Shigella). Even today, *E. coli* remains one of the important tests of water quality.

In 1975, the United States **Centers for Disease Control and Prevention** identified a new strain of *E. coli* that was designated O157:H7. Strain O157:H7 was first linked to human disease in 1983, when it was shown to have caused two outbreaks of a severe gastrointestinal illness in the Unites States. This strain is capable of causing severe, even lethal, infection. Those who recover sometimes have permanent kidney damage.

The origin of O157:H7 is not known for certain. The consensus among researchers, however, is that O157:H7 arose when a strain of *E. coli* living in the intestine and which was not disease causing became infected by a virus. The virus carried the **gene** coding for a powerful toxin called Shiga-like toxin. Thus, the *E. coli* acquired the ability to produce the toxin.

The toxin can destroy the cells that line the intestinal tract and can enter the bloodstream and migrate to the kidneys and liver. Severe damage to these organs can occur. The intestinal damage causes severe bleeding, which can be lethal in children and elderly people. During the summer of 2000, *E. coli* O157:H7 contaminated the drinking water of the town of Walkerton, Ontario, Canada. Over 2,000 people became ill and seven people died. The source of the strain was the intestinal tract of cattle, a known natural habitat of O157:H7.

SEE ALSO Air and water purity; Bacterial biology; Food supply; Water contamination.

Ethical issues

Professional **forensic science** organizations promulgate codes of ethics for their members. An example is the code of ethics of the American Society of Crime Lab Directors (ASCLD), developed in 2004, which states in part, "…as members of the American Society of Crime Laboratory Directors, we will strive to foster an atmosphere within our laboratories which will actively encourage our employees to understand and follow ethical practices. Further, we shall endeavor to discharge our responsibilities toward the public, our employers, our employees and the profession of forensic science in accordance with the ASCLD Guidelines for Forensic Laboratory Management Practices."

Any code of ethics articulates high ideals for its profession, but wide gaps can emerge between ideals and the reality of professional practice as it is carried out by fallible, and sometimes dishonest, human beings. Forensic science has not proven itself immune from these gaps.

For example, consider the performance of crime labs. The federal Clinical Laboratory Improvement Act established minimum standards for clinical laboratories in 1967, and the law was toughened in 1988. Both times, though, forensic laboratories remained exempt from the law, largely because it was assumed that such labs did not need such regulation. Under public pressure, though, the ASCLD in 1981 created an accreditation arm for the nation's some 400 crime labs. Fifteen years later, just 138 of those labs had earned accreditation, and the ASCLD refuses to release information about any labs that have applied for but failed to gain accreditation.

Meanwhile, studies have documented alarming levels of error in the nation's crime labs, leading molecular biologist Eric Lander to note: "Clinical laboratories must meet higher standards to be allowed to diagnose strep throat than forensic laboratories must meet to put a defendant on death row." While many of these errors result from simple human error, many represent a pattern of ethical lapses. In 1994, *USA Today* documented 85 cases over a 20–year period in which prosecutors had deliberately falsified **evidence**; during the same period at least 48 people were freed from death row when it was discovered that they were convicted on the basis of false evidence or that the prosecution had deliberately withheld potentially exculpatory forensic evidence.

Further, anecdotal cases of ethical lapses abound. A police forensic expert hired by the West Virginia State Police crime lab and later by the county medical examiner's office in San Antonio testified for 15 years, often in capital cases, about lab tests he had never run. A West Texas **medical examiner** faked over 100 autopsies and falsified **blood** and **toxicology** reports. An examiner in the **FBI** crime lab's

serology unit, who repeated lied under oath about his credentials, was found to have faked lab reports, including reports of blood analyses he never conducted, and to have issued reports confirming the guilt of suspects when he had ignored or distorted actual test results.

These ethical lapses could be dismissed as aberrations, but doing so does not erase the central ethical concern that confronts forensic science each day, the inherent conflict between science and advocacy. Scientists are dispassionate observers, not advocates for one side or the other. As scientists, forensic examiners are ethically obligated by the profession to follow the evidence wherever it leads, without bending to pressure from judges, prosecutors, the police, or the public to find results that serve their purposes. Scientists follow documented and widely accepted protocols in carrying out their work rather than working from an oral tradition that prevents outsiders from examining and questioning their methods. Scientists must follow the scientific method, which demands peer review so that other scientists can expose flaws in theories and procedures. At the heart of the scientific method is the criterion of "falsifiability." This criterion requires that for a theory to prove that *X* caused *Y* (e.g., that the defendant's gun fired the bullet), it has to state not only what is true (the markings on the bullet prove that it came from the defendant's gun), but also imply that other things could not be true (the markings could not have come from another gun). If those "other things" do in fact turn out to be true or could be true, the original theory has to be abandoned. All of this at the heart of the scientific method.

Forensic science is sometimes accused of being an arm of the prosecution—whose function is advocacy, not science—in large part because most forensic investigators are not independent experts. Estimates are that 80% of forensic examiners work in police laboratories, and most of the 80% and their superiors are law enforcement officers. As James Starrs, a law and forensic science professor at George Washington University, has noted, "They analyze material submitted, on all but rare occasions, solely by the prosecution. They testify almost exclusively on behalf of the prosecution... As a result, their impartiality is replaced by a viewpoint colored brightly with prosecutorial bias."

Rule 16 of the Federal Rules of Criminal Procedure states that all "results and reports" of forensic examiners are "discoverable" to the defense, meaning that the prosecution has to provide them to defense attorneys on demand so that they can examine the reports rather than having to accept the testimony of forensic examiners at face value. Some members of the forensic science and criminal justice communities consider Rule 16 problematic in two main areas. First, not all "results and reports" are written, or if they are, they are often brief and conclusory, sometimes deliberately so. Nothing requires forensic examiners to document their methods and procedures, so the defense sometimes has no meaningful way to examine "results and reports" that do not exist anywhere on paper. Some forensic labs have resisted inquiries into their methods and procedures; by committing as little as possible to paper they protect themselves from potentially damaging questions.

Another concern with Rule 16 is that it does not mention such items as notes, calculations, graphs, computer printouts, and other records made during testing. The courts have consistently ruled that these items are not discoverable because they do not represent the end product of forensic examination, "results and reports." During the 1983 trial of Wayne Williams, the Atlanta man accused of killing some 30 young African Americans, a hair and fiber expert testified for 11 days from bench notes, which the court ruled were not discoverable by the defense. Another expert testified about graphs produced during comparison of **fibers** from Williams's bedroom carpet and fibers found on the victims' clothing, but again the court ruled that those graphs were not discoverable. Further, defendants have no automatic legal right to test or retest evidence themselves, and labs have no legal duty to preserve records, including reports, bench notes, printouts, and the like, nor are they required to preserve **physical evidence** for later retesting.

In 1971, law professor James Starrs made proposals to solve these ethical problems at the institutional level. Among other things, he called for "full and complete disclosure of the entire case in a comprehensive and well-documented report," a requirement that forensic scientists "testify to the procedures undertaken and the results disclosed only when opinions can be stated in terms of reasonable scientific certainty," and a requirement that "a forensic scientist for the prosecution should permit the defense to interview him/her before the trial" without the need for the prosecutor's approval. In the years that followed, some of these proposals have been incorporated into forensic codes of ethics.

SEE ALSO American Academy of Forensic Sciences; Forensic science.

European Network of Forensic Science Institutes

Formed in 1992, The European Network of Forensic Science Institutes (ENFSI), aims to maintain a high level of forensic science throughout Europe. The initial meeting included eleven members of Western Europe's prominent governmental forensics institutes, who subsequently decided that membership into ENFSI should be open to forensic laboratories throughout Europe. To date, the organization has grown to include members of institutes from 32 European countries and the number continues to grow. Member organizations must fulfill stringent criteria to join and demonstrate high standards of forensic evaluation. Thus, ENFSI has become recognized as an expert group of forensic science institutes and thought leaders from the whole of Europe.

In order to fulfill its vision, "to ensure that the quality of development and delivery of forensic science throughout Europe is at the forefront of the world," ENFSI is structured into Standing Committees and Expert Working Groups. These groups meet on a regular basis and develop activities and guidelines to ensure that the goals of the group are achieved. ENFSI has several standing committees, The Expert Working Group Committee (EWGC), The Quality & Competence Committee (QCC) and The European Academy of Forensic Science (EAFS). The EWGC establishes and maintains the Expert Working Groups which may change in number and title but cover the spectrum of forensic science topics including **DNA**, forensic speech and audio assessment, and **firearms** and **explosives**, just to name a few. The QCC represents ENFSI on quality issues and supports the other committees and groups in terms of quality and international standards. They also develop and maintain laboratory proficiency testing programs for various forensic disciplines. Proficiency tests allow the laboratories to demonstrate the quality of their staff, assays, and organization. In addition, the EAFS establishes activities for the wide forensic community. These include seminars on forensic-related topics as well as annual meetings and other meetings for members of ENFSI. Through the EAFS, relationships are fostered with forensic colleagues worldwide to enable international networking and a true global forensic community.

ENFSI has several meetings a year, some of which are restricted to members only and others that are open to all forensic scientists. During these meetings, the latest forensic technologies are addressed, new standards are considered, and networking is a high priority. In addition to participating in such meetings, the Expert Working Groups meet to develop best practice manuals and guidelines to help to establish and maintain standards of expertise across European forensic laboratories. These documents also provide a framework so that laboratories can utilize common methods and means of considering forensic casework samples. The result is reduction in the complexity of comparing international crime data and samples and a means by which forensic laboratories can demonstrate their proficiency on internationally agreed comparable terms.

ENFSI members also strive to maintain close relationships with other forensic science bodies such as The American Society of Crime Laboratory directors (ASCLD), Senior Managers of Australian and New Zealand Forensic Laboratories (SMANZL), and Academia Iberoamericana de Criminalística y Estudios Forenses (AICEF). Thus, world-wide forensic laboratories have a means of communicating on a truly global and international level. Through these organizations, convergence of standard, common techniques is certain to continue.

One of the main goals of ENFSI is to maintain the highest standards of forensic work across Europe. Forensic laboratories are constantly under scrutiny to demonstrate the quality of their work. However, this is not always straightforward due to the confidentiality under which forensic casework samples must be evaluated. Furthermore, the lack of competition among many countries' government forensic laboratories, since they are commissioned, makes them susceptible to criticism and accusations of inadequate standards of evaluation. ENFSI gives these laboratories additional support by helping them maintain high standards. For example, the best practice manuals and ENFSI-approved guidelines detail the accepted methods and techniques. These materials are available to any laboratory, whether members of ENFSI or not. Utilization of these approved guidelines gives the laboratories additional confidence that they are performing to the standard accepted throughout Europe. ENFSI also helps labs with accreditation and best practices as well as the ongoing development of a system to assure competence for ENFSI laboratories.

As the forensic industry continues to grow and prosper, the ENFSI will continue to unite the forensic community across Europe. Their commitment to foster forensic standards and relationships with world-wide partners ensures that the industry as a whole is constantly assessing itself and improving.

SEE ALSO CODIS: Combined DNA Index System; DNA; DNA profiling; STR (short tandem repeat) analysis.

Evidence

Evidence is any item or information gathered at the scene of a crime, or at related locations, which is found to be relevant to an investigation. There are many different types of evidence, from **DNA** and tire marks, to bloodstains and fingerprints. Different kinds of evidence may require different types of expertise in interpretation. Analyzing DNA is a completely different discipline from understanding bite marks or bullet trajectories. However, there are some basic principles that apply to all forms of evidence. Perhaps the most important rule is that maintaining evidence is paramount; strict procedures must be observed by all involved in the investigation when it comes to collecting, labeling, and analyzing it. Above all, every effort must be made to ensure that evidence is not lost, damaged, or contaminated.

Evidence has many different roles in the investigation of a crime. It can link a suspect to a crime scene if, for instance, a footprint matching the shoe of the suspect is found. Evidence can also eliminate a suspect. If the shoe size of the suspect does not match that of footprint evidence, then those footprints cannot tie them to the crime scene. Evidence could also back up or contradict a witness statement, which may help guide the police in further investigations. Evidence such as DNA or fingerprints is also valuable in providing a firm **identification** of a perpetrator or suspect.

Forensic scientists place evidence into various categories. Direct evidence establishes fact without the need for further analysis. Perhaps the most important form of direct evidence is the eyewitness account. If someone saw a **murder**, then there may be nothing to add, although the witness could give false testimony and other evidence may be needed to prove this. **Circumstantial evidence** is more indirect and it is up to the forensic scientist to provide an explanation for it through his or her investigations. Most of the evidence handled in the forensic lab is circumstantial evidence. Although more objective than direct evidence, there is always the danger of losing or contaminating circumstantial evidence.

Forensic evidence is divided up into two basic classes, physical and biological. **Physical evidence** covers items of non-living origin, such as fingerprints, tire marks, footprints, **fibers**, paint, and **building materials**. Biological evidence comes from a living source, usually the victim or perpetrator. Biological evidence includes DNA extracted from **blood** or other bodily **fluids**, **semen**, hair, and **saliva**. Botanical items, such as pollen and plants, would also be considered as biological evidence. Fingerprints are probably the most valued type of physical evidence because of their ability to identify or eliminate a suspect. However, as DNA analysis technology becomes increasingly automated and rapid, it is likely that forensic investigators will place more emphasis on the collection of biological evidence.

In terms of the investigation as a whole, reconstructive evidence is relevant to understanding what actually happened at the crime scene and the sequence of events. Cast off blood, blood spatters and bullet holes can help determine exactly how the victim was attacked. Tool marks and broken **glass** can reveal how a perpetrator entered and left the scene. Associative evidence is used to create or eliminate a link between a suspect and a crime scene.

There are two kinds of associative evidence, class and individual. Class evidence relates to items that are, to some extent at least, mass-produced. In itself, class evidence cannot tie a crime to any one individual. For instance, a gun found at the crime scene will be of a particular make, but it will not be unique. Similarly, relatively new shoes all make similar footprints if they are the same brand and cannot be tied to any one person. However, if the shoe is worn, then the footprint may be particular to an individual, as people wear down their shoes in a unique way. Fingerprints and DNA are the most significant forms of individual evidence. In all investigations, it is individual evidence that provides the most information and is therefore, the most valued. Class evidence is also important but usually has to be taken in context with other evidence; the more, the better.

Trace evidence may fall into various categories and includes microscopic evidence such as hair, fibers, paint, and bloodstains. **Locard's exchange principle** explains that every contact between a suspect and people or objects at the scene of crime, including the victim, leaves traces. Evidence is transferred from suspect to scene and vice-versa. The suspect may leave their own hair behind and take seemingly invisible splashes of the victim's blood with them, for instance. Trace evidence can be a powerful form of associative evidence that can lead to identification of the perpetrator. Most often, trace evidence is found in the form of textile fibers and paint flakes.

When investigators arrive at the scene of a crime, they are faced with a wide range of evidence—from something as obvious as a body to the various kinds of trace evidence which may be present. All of it must be located, collected and packaged with the greatest care to avoid destroying or contaminated. The investigators will make a "fingertip" search to ensure that every part of the crime scene is searched for evidence. There are various ways of making this search. If a body is present, this will be searched first for trace evidence, like fibers, and swabs will be taken before it is removed. A further search will take place at the mortuary.

The investigators then might work outwards from a focal point, which could be where a body was found, or in towards it. Depending on the size and location of the scene, investigators will go over the ground in a systematic fashion in a specific pattern such as a grid or spiral. Usually two searches are carried out.

The first items to be collected are those which are fragile and could easily be damaged such as fingerprints, **shoeprints**, fibers, and hair. A systematic approach must be taken to ensure that the collection of one item of evidence will not destroy another. Taking casts of footprints is one example. The **casting** process will destroy any fingerprints present. Therefore, the location of the footprint must be dusted first for fingerprints. Some evidence may be invisible to the naked eye and may need special techniques for visualization. **Luminol** can reveal bloodstains and ultraviolet light shows semen stains. The investigators will also take **control samples** for use back in the laboratory to distinguish relevant from irrelevant evidence. For instance, if there are chemicals on a carpet, then samples of unaffected carpet must be taken for comparison. If a blanket was used to cover a corpse, then fibers must be taken to show that these do not have anything to do with the crime. The collection of individualizing evidence such as fingerprints and biological samples for DNA usually takes priority.

Each item of evidence is packaged separately to avoid contamination and damage. Every time an item is transferred from one person to another, it is signed and accounted for. The evidence is handled through a strict **chain of custody**, in other words. If it were not, then it could easily be challenged in court. Just one break in the chain of custody can invalidate the claim that the item of evidence was present at the scene or on the suspect and is relevant to the crime.

A U.S. customs agent shows x-ray evidence of a drug smuggler's stomach containing capsules of narcotics, along with the narcotics recovered from the smuggler.

Of course, the forensic service does not have the resources to investigate all crimes to the extent described above. Volume crime such as burglary is distinguished from serious crime such as rape or murder. In the former case, the search for evidence may be confined to fingerprints. In the latter case, all possible evidence will be collected. The investigators cannot usually go back a second time to collect evidence. Even if it were intact, they could not prove that it had not been placed there after the crime, so it would not be admissible in a court of law. For this reason, it is generally considered important to collect too much evidence rather than too little.

The forensic scientist is charged with answering various key questions about the evidence. First, and most obvious, is identification—what the evidence actually is. On its own, however, the identity of the evidence is insufficient to shed much light on the crime. The next stage is to carry out comparison studies, using the control samples that will be collected. For instance, if bloodstains are found in the suspect's car or on their clothes, samples of blood from the victim are needed so that comparison tests can be made. These can establish whether or not the blood associated with the suspect is that of the victim. Sometimes, however, the evidence will not be of sufficient quality to allow a clear result from the comparison test. The main thrust of the forensic investigators' work is to establish links through evidence—between a suspect and a victim, place, or object. Even if there is no link, then at least the suspect can be eliminated and the investigation narrowed down. Sometimes a link can be created between a suspect and one or more places. A footprint may be found at two or more scenes, for instance. Even if there is not a suspect at this stage, the very existence of this evidence may help police know more about the suspect they are searching for, or the crime they are attempting to solve.

SEE ALSO Analytical instrumentation; Animal evidence; Anthropology; Anthropometry; Artificial fibers; Autopsy; Ballistic fingerprints; Bloodstain evidence; Bite analysis; Crime scene investigation; Crime scene reconstruction; CODIS: Combined DNA Index System; Death, cause of; Decomposition; DNA fingerprint; Entomology; Exhumation; Fingerprint; Hair analysis; Impression evidence; Pathology; Trace evidence.

Evidence, chain of custody

Evidence found at the scene of a crime must eventually be presented and questioned in the courtroom. For the evidence to be of use in a trial, it must make the journey from crime scene to court in a validated and secure manner so that all involved can be assured that it has not been contaminated and that the evidence is relevant to the crime investigation. In order to insure validity, investigators must follow a routine commonly known as the chain of custody when it comes to collecting and handling evidence.

The first person to collect an item of evidence, be it a bloodstain or a bullet, will sign their initials and date either on the item itself or on its packaging. Clearly, marking an item ensures there is no ambiguity, as packaging could be separated from the evidence itself. However, some types of evidence, such as bullets, may be altered if marked and, of course, it is not possible to mark evidence like bloodstains or fingerprints directly.

Evidence usually goes from the crime scene to the forensic laboratory for examination where the receiving officer signs the evidence package and dates it. Everyone who handles the evidence does likewise until the analysis is complete. At this stage, the evidence will be given to the police for storage until its presentation in court. The receiving police officer will sign for the evidence and it will be stored in a secure area to minimize the risk of interference or loss.

When the case is presented in court, the prosecuting lawyer takes over custody of the evidence and signs to that effect. If the chain of custody procedure is handled correctly, the case can proceed with all involved being aware of the precise journey the evidence took from crime scene to the court. This allows evidence to be admitted in court, and witnesses to have the assurance that the item of evidence was indeed present at the scene of the crime and testify accordingly. The judge and jury are then able to use the evidence, along with witness statements and other information, to guide their decision-making process.

SEE ALSO Crime scene investigation; Cross contamination.

Evidence, circumstantial SEE Circumstantial evidence

Exhumation

Exhumation is the removal of a body from a grave. It is a relatively rare occurrence and can be distressing for relatives. The most common reason for exhumation is need or desire to move the body to a different location. This may happen if a cemetery closing or if the family buys a new burial plot or wishes to re-inter the deceased elsewhere with other family members. However, some cases of exhumation occur because there is a request from a court to carry out or repeat an **autopsy** to gain new forensic **evidence**. This is more likely in countries where the autopsy rate is low. With cremation becoming increasingly common, exhumation is less important than in previous years.

Requirements vary from place to place, but it is usually necessary to obtain a license from the local or higher authorities to perform an exhumation. It is also usual to get the permission of the family of the deceased. The procedure is not without risk to public health, so an environmental health officer is usually present. If the body is buried in consecrated ground, it will be also necessary to obtain permission from

A forensic anthropologist excavates the grave of J. Frank Dalton in Texas. Dalton claimed until his death in 1951 that he was really the outlaw Jesse James and had faked his death 69 years earlier. DNA testing on the exhumed body proved inconclusive.

the church. Obtaining the necessary licenses may sometimes be time-consuming, and it is also very unusual to perform exhumations on people only recently buried.

The environmental health officer, or equivalent, will ensure that the correct grave is opened. If the grave cannot be identified, the exhumation is not carried out and nor is it if the body lies underneath another body which is not to be exhumed. In other words, anything that interferes with the respect due to the body to be exhumed or others buried on the site will be a reason to refuse permission for the exhumation. Proceedings must be carried out in daylight and are planned for a time of day to ensure maximum privacy; the area involved is usually screened. Protective and disposable masks, gowns, and gloves are worn by all involved to protect from any possibility of transmission of disease. Those concerned will take every care to show respect to the corpse. A medical officer should be present and will examine the body before it is moved and take photographs. This is important because bones may become brittle after they have been buried for some time and may break when moved. The body is usually transferred into a new casket made of timber lined with zinc for security. Pieces of the old casket are transferred, along with the body, to the new casket. The area of exhumation is then thoroughly disinfected. The body is then transferred to its destination as quickly as possible.

There may have been some **decomposition** so any autopsy will need to be performed promptly. The results will rarely be as good as those from an autopsy on a fresh body. However, an autopsy on an exhumed body can still yield some useful information. Although the procedure of performing an autopsy on an exhumed body is basically the same as that for a fresh body, decomposition may mean some modification is necessary. There may be worms or insects present in the corpse, but they should not be sprayed with insecticide or other chemicals as this interferes with tests on the body. There may also be a strong odor when the body is opened, and the investigators might wear gauze masks dipped in potassium permanganate to minimize exposure to particulate matter in the air. Sometimes only bones are left in the grave if the body has been buried for some time. It is the usual practice to boil the bones before autopsy. They can still yield useful information about **cause of death**. However, autopsy on an exhumed body is generally a task for a skilled and experienced pathologist.

Should poisoning be thought to be a factor in the death of the person involved, samples of soil from above, below, and to the sides of the coffin should be taken and sent for **toxicological analysis**. A control sample would also be taken from another part of the cemetery. Many exhumation cases have involved investigation of possible arsenic poisoning, a less common cause of **murder** these days. Arsenic remains in the body for a long time, so it can be detected after burial. For example, it was long held by some historians that the twelfth President of the United States, Zachary Taylor, died from arsenic poisoning rather than by natural causes. Exhumation took place 141 years after his death. Extremely sensitive tests showed that levels of arsenic in his body were normal; poisoning was not involved in his death. Other exhumation cases have, however, proved the opposite. It is particularly important to take soil samples in the case of arsenic poisoning for comparison. Otherwise it is not possible to know if arsenic entered the body from the soil or by poisoning.

SEE ALSO Anthropology; Autopsy; Decomposition; Skeletal analysis; Toxicology; War forensics.

Exothermic reactions

An exothermic reaction is a chemical reaction that produces heat. The term exothermic is composed of the root *exo*, which is Greek for outside, and *thermic*, which means heat. Therefore, exothermic defines heat going outside. Exothermic reactions are important to forensic sciences and particularly to fire and explosion investigation. When a chemical reaction requires heat (rather than producing it) and results in cooling down the surroundings, it is conversely called endothermic.

Exothermic reactions occur in many phenomena and applications of every-day life. The speed at which they occur can range from extremely slow to extremely fast. For example, an exothermic reaction occurs when a piece of steel rusts. Rust is iron oxide (Fe_2O_3), which is produced by the reaction of iron (Fe) with oxygen (O_2). This reaction releases heat and is therefore, exothermic. However, it takes place at such a slow pace that it is impossible to observe a difference of temperature on the piece of steel. Fire is an exothermic reaction that occurs much faster. When a fuel is burning, it releases heat, which can easily be felt. An explosion is also an exothermic reaction. Even if the end result of an explosion is the high pressure generated that pushes everything away from its seat, heat is first produced in great magnitude.

All combustion reactions are exothermic. In a **fire investigation**, it is important to know what kind of chemical reaction occurred and caused a fire. In order to do that, it is necessary to know the substances involved and how they react with one another. Some reactions also require a threshold amount of energy given to them before they can release (more) energy. This is called the energy of activation. For example, it is necessary to light wood on fire with a lighter or matches before it will burn and liberate heat.

Finally, it is possible to measure the amount of heat or energy liberated by a given chemical reaction. In order to do this, an instrument called a calorimeter is used. The calorimeter is a container placed in a well-insulated water bath. A known amount of the substance or substances that will react is placed in the container and the reaction takes place. Ideally, all the heat generated by the reaction is transferred to the water, whose temperature increases. By monitoring the temperature of the water, it is possible to accurately measure the amount of heat liberated.

SEE ALSO Chemical equations; Explosives.

Expert witnesses

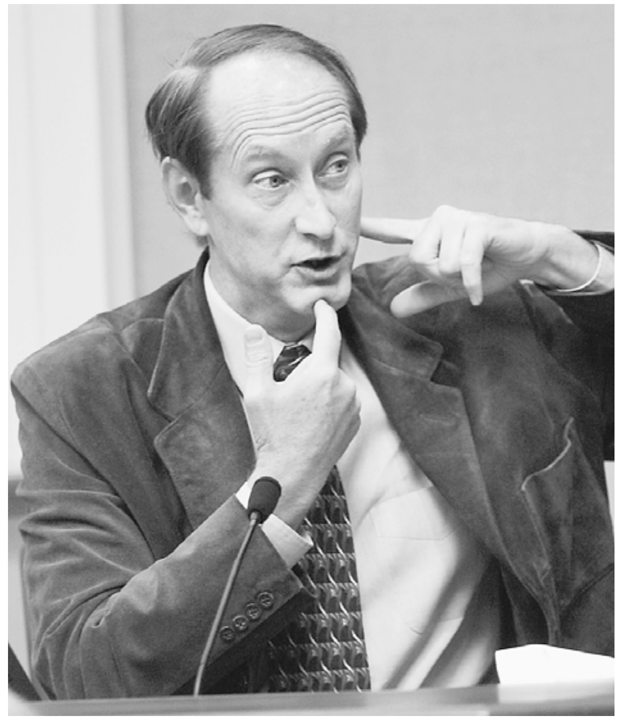
Many criminal and civil investigations turn to expert witnesses in court to help resolve cases where the facts are unclear or in need of some explanation. An expert witness is a person who can provide information and opinion drawn from the body of knowledge that makes up their own area of expertise. An expert witness does not need to be legally qualified. Commonly the witness will be a forensic scientist or forensic pathologist providing information outside the realm of common knowledge about the circumstances of a crime. For instance, a scientist with knowledge of **paint analysis** or soil can help interpret **trace evidence**. A pathologist can help with the difficult questions such as the **cause of death** when a body is recovered from water or what **bloodstain evidence** might really mean in terms of how someone was killed.

Being an expert witness is not a profession in its own right. The expert witness is created and recognized as such by the judge and the court. There are many databases of people willing to act as expert witnesses in various specialties, and they also have their own professional organizations to represent their interests. The expert witness will have been vetted for suitability; they will also have undergone **training** in court procedures so that **evidence** may be given to the best of their ability to help the judge and jury come to a decision. Although many expert witnesses come from a **forensic science** or medical discipline, they can be drawn from any area of expertise, depending on the circumstances and background of the case. Document examiners and structural engineers may be called in to advise and give evidence, as may those from non-scientific disciplines as diverse as art history, mountaineering, or martial arts.

Either prosecution or the defense may call in an expert witness. He or she is expected to look at the evidence relevant to their discipline and put it in the context of the whole case. They will produce a report that can be taken up into the witness stand. First of all, the party who engaged the expert witness will ask questions that prove identity, experience, and background to the court. Then they will ask questions that generally take the court through the expert witness' report.

The expert witness can expect to be cross-examined by the opposing counsel. That is, an expert witness for the prosecution will be questioned by lawyers for the defense, and vice-versa. The other side may also engage their own expert witness. The purpose of cross-examination is to find flaws in the evidence and conclusions presented by the expert witness. Many people are experts in their own subjects, but it takes special skill and training to defend one's findings in public while still remaining objective and impartial.

The expert witness has a large responsibility, as the manner of giving evidence can influence the judge and jury—the decision makers in the case. Expert testimony is especially important when other evidence is insufficient to help come to a clear verdict. At the same time, in a stalemate situation, the expert witness must remain completely unbiased. Expert witnesses have a duty to give concise, detailed, and clear answers to all the questions put to them. After all, the jury often consists of lay people who may have had little or no experience in **medicine**, building construction, or the many other subjects that are often relevant in a crime. The judge is, naturally, more knowledgeable about crime and its circumstances, from his or her experience. However, there will be cases in which the judge also needs more information about what may have occurred and how. The expert witness performs a vital role in helping judge and jury come to the right conclusions about what really happened at a crime scene.



A forensic pathologist serves as an expert witness during the trial of convicted sniper John Allen Muhammad in 2003. © DAVIS TURNER/CORBIS

The expert witness is the only one in court who is allowed to give opinion as well as facts. This is because the court has confidence in the facts and knowledge on which the opinion is based. Thus, the forensic psychiatrist is allowed to say, "I believe this man to be capable of this **murder**, with this degree of violence, based upon my assessment of his mental state." With other evidence, that opinion may be what is required for judge and jury to make up their minds in the case.

SEE ALSO Evidence.

Explosives

An explosive is defined as a substance or mixture of substances that is capable of producing an explosion by itself, without the need for an outside source of oxygen. An explosion is a rapid oxidation reaction that liberates a large quantity of energy and is accompanied by the evolution of a large volume of hot gases and a loud noise. Explosives are often used in criminal and, more particularly, terrorist activities. Crime scene investigators and forensic scientists are called to the scene of an explosion to determine if an explosive was used, and thus, what kind of explosive was used and how it was used. Therefore, knowledge of explosives and their characteristics is paramount for a forensic scientist involved in such criminal investigations.

In general, explosives are classified into two categories: low explosives and high explosives. Low explosives are characterized by a slow rate of reaction, also said to be rapid combustion, resulting in a deflagration. Deflagration is defined as an explosion whose resulting pressure wave travels at subsonic speed (less than 340 meters, or 1,115 feet, per second). These explosives are usually designed to produce a push or to heave a mass. These explosives are also referred to as propellants. Examples of such explosives are black powder, and single-, double-, and triple-base gun powder.

High explosives are characterized by a high rate of reaction resulting in a detonation. Detonation is defined as an explosion whose resulting pressure wave travels at supersonic speed (more than 340 meters, or 1,115 feet, per second). High explosives create a powerful blasting or shattering effect.

High explosives are further classified into primary and secondary explosives depending on their susceptibility to be initiated. Primary explosives are very sensitive to heat or shock and undergo a rapid transition to detonation. They are used to provide the minimum necessary energy to initiate the secondary explosives. Examples of primary explosives include lead azide, lead styphnate, mercury fulminate, and diazodinitrophenol (DDNP). Secondary explosives are much more stable and require a higher initiation energy to be detonated. They will only be detonated by an explosion, such as the one created by a primary explosive. Nevertheless, they are generally more powerful than primary explosives and are thus, mostly used as main charges. Examples of secondary high explosives are 2,4,6-trinitrotoluene (TNT), ammonium nitrate fuel oil (ANFO), cyclotrimethylenetrinitramine (RDX), cyclotetramethylenetetranitramine (HMX), ethyleneglycoldinitrate (EGDN), and pentaerythritoltetranitrate (PETN). Secondary high explosives are designed to destruct by a shattering effect.

Most explosives are used in a combination of two or more explosives, adding the effects of the different types of explosives to the mixture. Dynamite was originally nitroglycerine absorbed into dry silica. Modern formulations of dynamite present some variations, but usually include a mixture of nitroglycerine, nitrocellulose, a fuel/oxidizer mixture, and sometimes EGDN. Semtex is a mixture of RDX and PETN. Amatol is composed of TNT and ammonium nitrate. C-4 is a plasticized composition of RDX. Pentolite is a mixture of TNT and PETN.

Detonating cords are plastic tubes filled with a powder form of explosive. These tubes are often wrapped with fibers to make them more solid. They are mostly used to link different charges by transmitting the shock wave of the detonation. They may also be used as an explosive charge by themselves. In such instances, they are typically used to perform small and accurate destruction. Detonating cords typically use PETN as their explosive content. In some instances, when the cord needs to be used in a medium with a high temperature where PETN would not be suitable, other explosives such as RDX or HMX may be used.

Boosters are defined as the components in the explosion train that propagate and amplify the shockwave from the detonator to the main charge. They are necessary with some secondary explosives that are insensitive and the shockwave created by the detonator would not be enough to initiate the main charge. Thus, the booster is placed after the detonator and amplifies this detonation, initiating the main charge. Examples of boosters are pentolite or tetryl (2,4,6-trinitrophenyl-methylnitramine).

The forensic analysis of explosives has two interests. On intact material, it is to determine if the material is an explosive. On explosive residues, it is to determine the nature of the explosive and to profile its origin. Identifying the nature of the explosive involved may lead to the author of the crime. Explosives are usually regulated and controlled by the government. Thus, they are not easily obtained by regular citizens. Explosives are often stolen or smuggled from one country to another. Once the nature of the explosives used is identified, it is possible to relate it to recorded thefts or smuggled activities. Some terrorist groups have been known to use one particular explosive consistently, thus allowing the investigation to head one direction or another.

Italian forensic officers carry out a search after a small package of explosives blew up at a language school in Rome on June 17, 2003. The package contained around 500 grams (1.1 lbs) of high explosive powder stuffed into a small metal cylinder.

Also, when several explosions occur over a certain time span, it is possible to establish links between them if the same explosives have been used.

SEE ALSO Air plume and chemical analysis; Analytical instrumentation; Biodetectors; Bomb damage, forensic assessment; Bomb (explosion) investigations; Gas chromatograph-mass spectrometer; Oklahoma bombing (1995 bombing of Alfred P. Murrah building); September 11, 2001, terrorist attacks (forensic investigations of); Unabomber case and trial; World Trade Center, 1993 terrorist attack.

Explosives (historical cases)

Some of the most significant and tragic events in the history of the last few hundred years have involved **explosives** in the form of bombs—devices used in a deliberate attempt to harm others. The forensic investigation of these incidents has often been a multi-disciplinary affair. Explosives experts and fire investigators are needed to analyze the event itself and discover what kind of device was used and where it may have originated. Bombs typically cause multiple injuries that can be challenging for the forensic pathologist to assess. There has also increasingly been a role for the forensic psychiatrist, as some of those responsible for a bombing are clearly mentally disturbed.

Bombs are often planted by those with political motivations or grudges, working as a group or alone. Their actions, or even the threat of them, cause a great deal of public anxiety and are remembered for a long time. In Britain, one of the first major explosion attempts, the 1605 Gunpowder Plot, is now remembered in the annual celebration of Guy Fawkes, or Bonfire, Night on the fifth of November. Guy Fawkes and his co-conspirators were extremists who wanted to return England to the Catholic faith by blowing up the Houses of Parliament, killing King James I and his government. This bold plan involved rolling 36 barrels into the cellars of the Houses of Parliament. However, one of the group sent a warning letter to a friend in Parliament and this was intercepted and handed to the King. The group was arrested before they could ignite the gunpowder and put to death after trial.

On Bonfire Night, people in Britain burn effigies of Guy Fawkes on bonfires and set off fireworks to commemorate the would-be explosions. It is all harmless fun, many firework displays are now organized by local authorities in the interests of public safety.

In the twentieth century, Britain has suffered terrible losses of life through the bombings of the Irish Republican Army (IRA), a group wanting the re-unification of Northern Ireland and the Irish Republic. On November 21, 1974, bombs exploded in two pubs in central Birmingham, The Mulberry Bush and the Tavern in the Town, killing 21 people and injuring another 182. This was one of the worst IRA atrocities and of special interest because of some forensic issues it raises. The IRA at first claimed responsibility for the bombings, then withdrew their statement. It is widely assumed the group was behind the attack. Police arrested six men known to have associations with IRA personnel in connection with the bombings and they were convicted in 1975. However, the "Birmingham Six" were freed on appeal in 1991. Police and prison officers were found to have extracted false confessions and there was, in fact, no hard **evidence** of any kind linking the men to the bombing scene. Forensic evidence at the trial had included a positive Griess test for traces of explosives on the hands of two of the suspects. In fact, the results of these tests proved inconclusive and were the subject of some dispute between the forensic experts engaged on the case. No-one else has ever been convicted of the Birmingham pub bombings.

Letter bombs are often the work of one individual who wishes to terrorize others, for whatever reason. Perhaps the most famous case of letter bomb crime involved Theodore Kaczynski, also known as the Unabomber. In the first Unabomber incident, a package found in a University of Illinois parking lot in Chicago on May 25, 1978, exploded, injuring one person. Several similar incidents followed. The first fatality occurred on December 11, 1985, when the owner of a computer company picked up a bomb left outside his business.

A sighting of the Unabomber in 1987 led to a cessation of attacks until 1993 when Kaczynski revealed his anarchist views in a letter to the *New York Times*. After more bombings and fatalities, the Unabomber was finally caught on April 3, 1996. Forensic psychiatrist Sally Johnson declared Kaczynski fit to stand trial even though he was diagnosed as a paranoid schizophrenic. He was convicted and sentenced to life imprisonment without parole.

Britain's worst ever terrorist incident involved the placing of a bomb on Pam Am Flight 103 over Lockerbie, Scotland, on December 21, 1988. None of the 259 crewmembers and passengers on board survived. Forensic investigation revealed that the U.S.-based plane was brought down by a bomb placed in one of the overhead lockers. The plane disintegrated in mid-air, creating 1,200 significant items of debris needing to be investigated. Larger items, such as the engines and the aircraft wings, fell on the town of Lockerbie, producing a fireball and killing 11 people on the ground. Lighter debris was scattered for many miles.

Forensic scientists discovered traces of explosive material in the debris and were able to reconstruct the explosion and the impact it had on the plane. Post-mortem examination of the victims revealed they died of multiple injuries consistent with a mid-air explosion followed by impact on the ground. A former Libyan intelligence officer called Abdel Bassett al-Megrahi was convicted of the bombing and is serving a life sentence in Scotland.

The terror attacks of September 11, 2001, were not the first suffered at New York's World Trade Center. On February 26, 1993, a car bomb was planted in the underground garage below Tower One, killing six people when it went off and injuring over 1,000 others. Analysis revealed the 1300-pound bomb was composed of urea, nitroglycerin, sulfuric acid, aluminium azide, and bottled hydrogen gas. The device was placed in a van and attached to four fuses which the perpetrator, a Kuwaiti man called Ramzi Yousef, ignited with a cigarette lighter. He escaped to Pakistan after the explosion and was involved in many other terrorist attacks before his capture in 1995. He is now held in the same prison as the Unabomber, the ADX Florence maximum security facility in Colorado.

ADX Florence is also the prison where the Oklahoma bomber Timothy McVeigh was held prior to his execution in 2001. Until the attacks of September 11, the **Oklahoma bombing**, in the nine-story Alfred P. Murrah local government building, was the worst terror incident on U.S. soil. It killed 168 people and injured more than 500 others. The homemade bomb was found to have 2,200 kilograms of ammonium nitrate and fuel oil packed into a hired van. McVeigh, a former soldier, was said to be obsessed with guns and mistrustful of authority. His motive was, apparently, to retaliate against the U.S. government for its part in a siege by the Bureau of Alcohol, Tobacco, and Firearms (**ATF**) in Waco, Texas, where 82 members of the Davidian sect were killed.

After September 11, there were two major terror attacks involving bomb explosions, one in Bali and one in Madrid, Spain. The Bali bombing occurred on October 12, 2002, in Paddy's Bar, in the town of Kuta, killing 202 people and injuring another 209, most of them foreign tourists. An electronically-triggered bomb ripped through the bar, driving the injured into the street. A few seconds later, a second, and much more powerful, car bomb went off in front of the Sari Club. This main bomb proved to be made of ammonium nitrate. In 2003, four men were sentenced to death for their part on the bombing, although the sentences have not yet been carried out as of March 2005.

On March 11, 2004, in Madrid, Spain, 191 people died when a string of ten bombs placed in backpacks and carried on four separate commuter trains went off. Later, three more backpack bombs were safely detonated; they had been timed to go off when rescuers and investigators would have been on the scene. More than 1,500 people were injured and many call the event "Spain's 9/11." It is certainly proving a challenge for forensic investigators and reveals how complex a business global terrorism has become.

Twenty-two suspects are being held in Spain and there is debate as to whether an Islamic fundamentalist group like Al Qaeda or the Basque separatist group ETA was responsible for the blasts. The explosive used in the train bombs was a type of dynamite sold in Spain and used in mining. The material resembles that previously used by ETA, although it is a more modern version. Analysis of the backpack bombs showed the explosive was reinforced with shrapnel, and investigators also found a detonator with a cell phone and a timer. The phones have proved a particularly useful source of evidence. Later, a similar unexploded bomb was found on a railway line at Mocejon, 40 miles south of Madrid. The devices had detonators of the type used in the mining industry, although they were made of copper, which is regarded as more sophisticated than the aluminum versions normally used by the ETA group.

The investigation of the Madrid bombings has covered other possibly related incidents, including the discovery in the previous month of a van with 500 kilograms of explosives, and the prevention of a similar attack where multiple bombs would have gone off simultaneously on the commuter trains system. Both of these incidents involved ETA. On the other hand, the near simultaneous attacks of the Madrid bombings were more typical of Al Qaeda. The attack was larger in scale than anything ETA has ever carried out before. Like the IRA, the group generally accompanies its attacks with warnings and claims responsibility for them. In the case of the Madrid bombings, ETA has denied involvement. It is up to the court, backed by expert evidence, to decide who is responsible and, it is to be hoped, convict the perpetrators. **Forensic science** can do much to help in the "war against terror" as experience is gained through the investigation of the dreadful events of recent years.

SEE ALSO Bomb damage, forensic assessment; Bomb detection devices; Bomb (explosion) investigations.

F

Facial recognition

Facial recognition is a biometric method of identifying a person based on a photograph of their face. Biometric methods use biological traits to identify people. The human eye is naturally able to recognize people by looking at them. However, it recognizes known people much more easily than perfect strangers. Moreover, concentration span for a human eye is limited. As a result, it is not useful in longer surveillance tasks or comparing hundreds of images to find a match to a photograph. Therefore, computerized methods have been developed to perform the facial recognition. **Identification** of faces is important for security, surveillance, and in forensics.

Biometric methods have been under development since the late 1980s. In the 1990s the first commercial systems appeared on the market. The first large trial of the technology was in 2000, during Super Bowl XXXV in Tampa Bay, Florida. Spectators were photographed, without their knowledge, as they entered the stadium. The images were then compared to a police database.

Currently, the technology is used by police, forensic scientists, governments, private companies, the military, and casinos. The police use facial recognition for identification of criminals. Companies use it for securing access to restricted areas. Casinos use facial recognition to eliminate cheaters and dishonest money counters. Finally, in the United States, nearly half of the states use computerized identity verification, while the National Center for Missing and Exploited Children uses the technique to find **missing children** on the Internet. In Mexico, a voter database was compiled to prevent vote fraud. Facial recognition technology can be used in a number of other places, such as airports, government buildings, and ATMs (automatic teller machines), and to secure computers and mobile phones.

Computerized facial recognition is based on capturing an image of a face, extracting features, comparing it to images in a database, and identifying matches. As the computer cannot see the same way as a human eye can, it needs to convert images into numbers representing the various features of a face. The sets of numbers representing one face are compared with numbers representing another face.

The quality of the computer recognition system is dependent on the quality of the image and mathematical algorithms used to convert a picture into numbers. Important factors for the image quality are light, background, and position of the head. Pictures can be taken of a still or moving subjects. Still subjects are photographed, for example by the police (mug shots) or by specially placed security **cameras** (access control). However, the most challenging application is the ability to use images captured by surveillance cameras (shopping malls, train stations, ATMs), or closed-circuit television (**CCTV**). In many cases the subject in those images is moving fast, and the light and the position of the head is not optimal.

The techniques used for facial recognition can be feature-based (geometrical) or template-based (photometric). The geometric method relies on the shape and position of the facial features. It analyzes each of the facial features, also known as nodal points, independently; it then generates a full picture of a face. The most commonly used nodal points are: distance between the eyes, width of the nose, cheekbones, jaw line, chin, and depth of the eye sockets. Although there are about 80 nodal points on the face, most software measures have only around a quarter of them. The points picked by the software to measure have to be able to uniquely differentiate between people. In contrast, the image or photometric-based methods create a template of the features and use that template to identify faces.

Algorithms used by the software tools are proprietary and are secret. The most common methods used are eigenfaces, which are based on principal component analysis (PCA) to extract face features. The analysis can be very accurate, as many features can be extracted and all of the image data is analyzed together; no information is discarded. Another common method of creating templates is using neural networks. Despite continuous improvements, none of the current algorithms is 100% correct. The best verification rates are about 90% correct. At the same time, the majority of systems claim 1% false accept rates. The most common reasons for the failures are: sensitivity of some methods to lighting, facial expressions, hairstyles, hair color, and facial hair.

Despite the differences in mathematical methods used, the face recognition analysis follows the same set of steps. The first step is image acquisition; once the image is captured, a head is identified. In some cases, before the feature extraction, it might be necessary to normalize the image. This is accomplished by scaling and rotating the image so that the size of the face and its positioning is optimal for the next step. After the image is presented to the computer, it begins feature extraction using one of the algorithms. Feature extraction includes localization of the face, detection of the facial features, and actual extraction. Eyes, nose, and mouth are the first features identified by most of the techniques. Other features are identified later. The extracted features are then used to generate a numerical map of each face analyzed.

The generated templates are then compared to images stored in the database. The database used may consist of mug shots, composites of suspects, or video surveillance images. This process creates a list of hits with scores, which is very similar to search results on the Internet. It is often up to the user to determine if the similarity produced is adequate to warrant declaration of a match. Even if the user does not have to make a decision, he or she is most likely determining the settings used later by the computer to declare a match.

Depending on the software used, it is possible to compare one-to-one or one-to-many. In the first instance, it would be a confirmation of someone's identity. In the second, it would be identification of a person. Another application of facial recognition is taking advantage of live, video-based surveillance. This can be used to identify people in retrospect, after their images were captured on the recording. It can also be used to identify a particular person during surveillance, while they are moving around. It can be useful for catching criminals in the act, cheaters in casinos, or in identifying terrorists.

Most of the earliest and current methods of face recognition are 2-dimensional (2-D). They use a flat image of a face. However, 3-D methods are also being developed and some are already available commercially. The main difference in 3-D analysis is the use of the shape of the face, thus adding information to a final template. The first step in a 3-D analysis is generation of a virtual mesh reflecting a person's facial shape. It can be done by using a near-infrared light to scan a person's face and repeating the process a couple of times. The nodal points are located on the mesh, generating thousands of reference points rather than 20–30 used by 2-D methods. It makes the 3-D methods more accurate, but also more invasive and more expensive. As a result, 2-D methods are the most commonly used.

An extension of facial recognition and 3-D methods is using computer graphics to reconstruct faces from skulls. This allows identification of people from skulls if all other methods of identification fail. In the past facial reconstruction was done manually by a forensic artist. Clay was applied to the **skull** following the contours of the skull until a face was generated. Currently the reconstruction can be computerized by taking advantage of head template creation by using landmarks on the skull and the ability to overlay it with computer-generated muscles. Once the face is generated, it is photographed and can be compared to various databases for identification in the same way as a live person's image.

The use of facial recognition is important in law enforcement, as the facial verification performed by a forensic scientist can help to convict criminals. For example, in 2003, a group of men was convicted in the United Kingdom for a credit card fraud based on facial verification. Their images were captured on a surveillance tape near an ATM and their identities

A British Passport Office volunteer has his face scanned for a biometrics enrollment card in London, 2004. © PETER MACDIARMID/ REUTERS/CORBIS

were confirmed later by a forensic specialist using facial recognition tools.

Despite recent advances in the area, facial recognition in a surveillance system is often technically difficult. The main reasons are difficulties in finding the face by the system. These difficulties arise from people moving, wearing hats or sunglasses, and not facing the camera. However, even if the face is found, identification might be difficult because of the lighting (too bright or too dark), making features difficult to recognize. An important variable is also resolution of the image taken and camera angle. Normalization performed by the computer might not be effective if the incoming image is of poor quality.

One of the ways to improve image quality is to use fixed cameras, especially in places like airports, government buildings, or sporting venues. In such cases all the people coming through are captured by the camera in a similar pose, making it easier for the computer to generate a template and compare to a database.

While most people do not object to the use of this technology to identify criminals, there are fears that images of people can be taken at any time, anywhere, without their permission. However, it is clear that the ability of identifying people with 100% certainty using face recognition is still some time away. However, facial recognition is an increasingly important identity verification method.

SEE ALSO Biometrics; Composite drawing.

False memories

False memory syndrome (FMS), as defined by John F. Kihlstrom (**psychology** professor at the University of California, San Francisco) and utilized by the False Memory Foundation, is a condition in which a person's identity and interpersonal relationships are centered on a memory of a traumatic experience that is objectively false, but one that the person strongly believes. Note that the syndrome is not characterized by false memories as such. Almost everyone has memories that are inaccurate. Rather, the syndrome may be diagnosed when the memory is so deeply ingrained that it orients the individual's entire personality and lifestyle, in turn disrupting all sorts of other adaptive behavior. The analogy to personality disorder is intentional. False memory syndrome is especially destructive because the person diligently avoids confrontation with any evidence that might challenge the memory. Thus, it takes on a life of its own, encapsulated and resistant to correction. The person may become so focused on that memory that he or she may be effectively distracted from coping with the real problems in his or her life.

False memories are often of childhood sexual abuse (CSA) or satanic ritual abuse (SRA). The syndrome has been reported since the late 1980s; at that time, psychotherapeutic use of hypnosis and the concept of recovered memories were also becoming widely publicized. Persons with FMS typically report that they have suddenly remembered events of past abuse and, thus, feel compelled to confront their alleged perpetrators. The memories of the alleged abuse are typically reported to have been awakened during the course of some form of therapy. The response of the accused perpetrator is generally one of shock and disbelief, followed by adamant denial of its occurrence, and of the accusation. Adult children with FMS who accuse parents or other relatives (or other persons formerly close to them) often become estranged from their families. The accusers sometimes seek lawyers and the involvement of the legal system.

There is a cluster of characteristics associated with the development of FMS. Clients are typically adult females who seek psychotherapy because of significant negative life stressors, including relationship difficulties or dissolution, job dissatisfaction or loss, birth or death in the immediate family, addiction, or eating disorders. The nature of the presenting symptoms often prompts the therapist to search for memory of a childhood, or early life, trauma that could have acted as a catalyst for the current symptoms, generally at the expense of dealing with "real-time" problems while focusing on (real or imagined) past events. Patients experiencing FMS generally blame all current difficulties on the remembered past abuse, and adapt their identities to those of abuse survivors. They typically become increasingly dependent on the therapist, who professes belief in their abuse allegations, and they estrange themselves from those who either disagree with their new self-identification or attempt to prove them wrong.

One reported abuse survivor confronted her family with memories of repeated instances of incest occurring between the ages of three and eight with her father as the alleged perpetrator. She further asserted that the sexual abuse occurred in the attic of their home. She claimed she was taken to the attic via a back stairway. Her parents responded to the accusations by insisting that the home they lived in during that time had only one floor, no attic, and no staircase. They offered to bring the client (and the therapist) to the former home, to show her that the memory was incorrect. The daughter refused and cut off all further contact with her parents.

From a forensic **psychiatry** perspective, the issue of FMS is a challenging one. It is virtually impossible to distinguish between real and recovered or false or imagined memories, and it is difficult to validate early childhood memories via the use of objective data. Plus, it is difficult to base a legal or criminal case on recovered memory data as a result. The cost (both emotional and financial), when the memory is actually false, can be enormous, to the individual with FMS, to the accused family member (or other former close associate), and to the legal system.

SEE ALSO Crime scene reconstruction; Ethical issues; *Frye* standard; Physical evidence.

Fatherhood, determination SEE Paternity evidence

Henry Faulds

6/1/1843–3/1930
SCOTTISH
PHYSICIAN

Henry Faulds was a Scottish physician who laid the groundwork for the scientific study of fingerprints in **criminology**.

Faulds was born in Beith, Scotland. His parents were initially quite prosperous but lost most of their money in the famous City of Glasgow bank collapse in 1855. Henry was withdrawn from school, employed as a clerk, and in 1858 he became apprenticed to a shawl manufacturer where one of his duties was to classify varied Paisley shawl patterns.

At the age of 21, Henry became conscious of his deficient education and took classes at Glasgow University in mathematics, logic, and classics. Then, at age 25, he decided that his true vocation was **medicine**, so he enrolled at Anderson's College, Glasgow, and became a licentiate with commendation in 1871. By this time, Henry had developed a strong religious faith.

In September 1873 he married Isabella Wilson. Following hospital posts at St. Thomas London and Glasgow Royal Infirmary, he took up a post with the Church of Scotland as medical missionary at

Darjeeling, India. He resigned a year later and then joined the United Presbyterian Church. In 1874, as their first medical missionary, Faulds went to Tokyo, Japan, where, in 1875, he established the Tsukiji hospital.

His reputation grew rapidly and he was offered a post as personal physician to the Imperial House. Faulds ran his hospital, lectured Japanese medical students, taught **physiology**, Darwinism, and Professor Joseph Lister's principles of antisepsis to Japanese surgeons, and trekked into the mountains to heal the bedridden. He became the first foreign doctor to be allowed to carry out post mortems, and was consulted by the authorities on the control of rabies, typhoid, and cholera epidemics. Provision for the blind was limited and Henry Faulds devised a bible for them to read using raised letters—a forerunner of Braille. By 1882 his hospital treated 15,000 patients annually.

While in Japan, Faulds and an American archeologist, Edward S. Morse, struck up a friendship. Morse's Japanese excavations were distinguished by cooking pots and other vessels made from clay. One day, Faulds noticed minute patterns of parallel lines impressed in the clay. Some months earlier, Faulds had lectured his medical students on touch and he had noticed the swirling ridges on his own fingertips. In a flash, he realized that the 2,000-year-old impressions he now examined in clay came from the ridges on the fingers of ancient potters.

Finding fingerprints on the ancient clay fragments of Japanese pottery led Faulds to study fingerprints with a scientific approach. Faulds and his medical students shaved off their finger ridges with razors until no pattern could be traced. They repeated the experiment, removing the ridges by any number of methods and each time the ridges grew back in exactly the same patterns.

Over a period of two years, he also examined the hands of large numbers of infants and children to see if growth affected their fingertip patterns. When an epidemic of scarlet fever swept through Japan, causing severe peeling of the skin, Faulds again studied the fingerprints and found no before-and-after change. He amassed a significant collection of prints and eventually found each person had a unique **fingerprint**. In an attempt to promote the idea of fingerprint **identification**, Faulds sought the help of the noted naturalist Charles Darwin in 1850. Darwin declined to work on the idea, but passed it on to his relative **Francis Galton**.

On October 28, 1880, while still in Japan, Faulds' first paper on the subject, entitled "On the Skin-Furrows of the Hand," was published in the scientific journal *Nature*. This included a remarkable forecast that fingerprints from mutilated or dismembered corpses might be of forensic importance in identification. Furthermore, Faulds anticipated the transmission of fingerprints by photo-telegraphy. He also suggested that criminal registers be kept of "the for-ever-unchangeable finger-furrows of important criminals."

Faulds' letter was the first in the scientific literature to suggest the basic concepts of the fingerprint system of identification as we know it today. Twenty years earlier, however, Sir William Herschel had begun collecting fingerprints, too. In the month following publication of Faulds' paper, Herschel published a letter, also in *Nature*, in which he explained that he had been using fingerprints as a means to identify criminals in jail since 1857. However, he had been using fingerprints merely as a means of signature and failed to mention the potential for forensic use. Later, Herschel published another letter in *Nature*, giving full credit to Faulds for his original discovery. This disclaimer was largely unnoticed and others had by this time usurped Faulds' place in history.

Due to his wife's illness, Faulds returned to Britain in 1885. He dispatched letters offering his fingerprinting system to the chiefs of the major police forces around the world, though he had little response. To make matters worse, a second system of scientific criminal identification, **anthropometry**, had been developed by the young Frenchman **Alphonse Bertillon**. In 1892 Francis Galton published a book on the use of fingerprints, with no mention made of Faulds' contribution. In 1901 Edward Henry, a former colleague of Galton and the Commissioner of Police at Scotland Yard, set up a fingerprint bureau.

It is to these three men—Galton, Herschel, and Henry—that credit is frequently given for the discovery of the use of fingerprints in criminology. Faulds became embittered and returned to the life of a police surgeon in the town of Fenton, Staffordshire. In 1922, he sold his practice and moved to Wolstanton where he died in obscurity in 1930.

SEE ALSO Criminology; Fingerprint; Medicine; Physiology.

FBI crime laboratory

The central premise of the Federal Bureau of Investigation's (FBI's) Crime Laboratory is that the successful solution of crimes, from investigation of an alleged crime scene through conviction of perpetrator(s), relies upon several factors: careful gathering of physical and **trace evidence**; preservation, delivery, and forensic scientific analysis of this **evidence**; presentation of forensic scientific analysis results; and demonstration of guilt or innocence of alleged perpetrator(s).

The FBI's Crime Lab, as one of the premier forensic research and analysis facilities, offers its expertise to law enforcement agencies across the nation and, at times, across the world, at no cost to the requesting entity. Teams of special agents and administrative staff offer on-site forensic and technical support, nationally and globally, in the event of disasters involving mass casualties or wide-ranging investigations.

Among the services currently provided by the Lab, both within its facilities and off-site, are: analysis of **blood**, tissue, and other biological evidence; analysis of **firearms**, weapons, and **explosives**; analysis of legal and illegal drugs; and courtroom expert witness testimony for cases involving **FBI** Crime Laboratory forensic investigations.

Under Director **J. Edgar Hoover**, the science of **criminalistics** in the United States became centrally located with the dedication of the United States Bureau of Investigation's Technical Laboratory in Washington, D.C., on November 24, 1932. The Technical Laboratory was located in room 802 of the Old Southern Railway Building, which had been outfitted with a newly purchased Bausch and Lomb microscope, an ultraviolet light machine, a machine designed to examine gun barrel interiors, moulage kits, wiretapping kits, photographic supplies, and various chemicals.

At its inception, the Technical Crime Laboratory was staffed by just one forensic scientist, Special Agent Charles Appel, whose area of special interest was in the area of questioned document examination (at the time, this consisted primarily of handwriting, typewriting, and printed document examination and authentication). The research capabilities and the assigned staff of the Lab grew over time, and the addition of subject matter experts broadened its range of expertise. Samuel Pickering, a specialist in chemical analysis, was the first such resident expert. Additional agents, specially trained in the areas of cipher analysis, research on infrared rays, use of dyes for **identification** of extortion packages, blood grouping, creating systems for the marking of ransom money, and the chemical development of latent fingerprints, were added to the cadre of scientists at the Lab.

In 1934, the Technical Laboratory moved to the Justice Department building. In 1935, the United States Bureau of Investigation was given the title of Federal Bureau of Investigation by Congress. In 1942, the Technical Laboratory became the Crime Laboratory, and was officially named a division within the FBI.

Both the Lab and FBI headquarters moved to the newly constructed J. Edgar Hoover Building in 1974. In 1981, the Lab's Forensic Science Research and Training Center (FSRTC) was created at the FBI Training Academy in Quantico, Virginia. This site gained worldwide acclaim as a training and research facility dedicated to sharing cutting-edge forensic and criminalistics knowledge and technology with the worldwide law enforcement communities. In April 2003, the FBI's Crime Lab moved to its fourth, and current, location at the Quantico Marine Corps Base. The new facility was seven years and $130 million in the making; it is comprised of three adjoining five-story towers, and contains 463,000 square feet of laboratory and office space. The glass-enclosed laboratory workspaces, spanning two-thirds of every floor of the towers, are sterile environments that contain 100% clean air. They are separated from the office areas by a walkway called the bio-vestibule.

At present, the FBI Crime Laboratory has two primary operating branches: Forensic Analysis and Operational Support. The Forensic Analysis Branch includes the Forensic Analysis and Scientific Analysis Sections. The Operations Support Branch is comprised of the Forensic Science Support, Operational Response, and Operational Support Sections.

The Forensic Analysis Section contains several units, including the Cryptanalysis and Racketeering Records Unit, tasked with examination of written communication and records related to terrorist and criminal organizations. This Unit has four program areas. The first is Cryptanalysis, which involves examination, analysis, and **decryption** of **ciphers** and **codes** embedded in all manner of written and electronic communications. Second, the Drugs program area analyzes and examines records related to illegal drug-trafficking operations. The third area, Racketeering, examines and analyzes records pertaining to all forms of gambling, loan-sharking, and prostitution. Fourth, the Money-laundering area analyzes a broad-range of criminally suspect financial records pertaining to the illegal movement of money both within and outside U.S. borders.

Also within the Forensic Analysis Section is the Firearms and Toolmarks Unit, which is charged with examining all aspects of the mechanical condition of various firearms and ballistic materials, as well as the examination of evidence toolmarks for identification of recovered or suspected tools.

The Latent Print Unit examines and analyzes latent prints on submitted evidence. Latent prints occur when the friction ridge skin of human palms, fingers, or the soles of the feet make contact with a surface and leave physical impressions thereon. Located within the Latent Prints Unit are the FBI Disaster Squad, which is composed largely of latent print and **fingerprint** analysis experts who are called to mass casualty scenes in order to assist in the identification of remains, and IAFIS (**Integrated Automated Fingerprint Identification System**), which was created and implemented by the FBI in 1999. IAFIS is a large database system designed to store and compare fingerprints (primarily in 10-fingerprint units) in order to facilitate identification or exclusion of suspects.

The Questioned Documents Unit is staffed with experts in the examination of printing, handwriting, typewriting, printing by hand, obliterated impressions, erasures, and alterations of written communications. Examiners in this unit are also proficient in the identification of edges, imprints, stamping, watermarks, **fibers**, and other components of writing surfaces, as well as analysis and identification of the media used to mark on them, such as photocopying and facsimile machines, and the media used therein (ribbons, cartridges, etc.). Databases within the Questioned Documents Unit include the National Fraudulent Check database, Bank Robbery Note database, Shoeprint database, Anonymous Letter database, and Watermark Files database.

The Scientific Analysis Section contains six functional units, the first of which is the Chem-Bio Sciences Unit, involved in extremely high-quality, standardized forensic examination of hazardous chemical, biological, and nuclear evidence, along with related materials.

Another functional unit is the Chemistry Unit, which contains six program areas.

- The first program area, General Chemistry, is used to analyze and characterize unknown materials in solid or liquid form. Chemists identify chemicals and dyes used in bank or other security devices and examine suspect cloth, clothing or currency for their presence; they compare stains, markings, and lubricants with possible sources; they also identify source inks by assessing and comparing the compositions of various types and forms of questioned and known ink types. Program area chemists may also utilize various scientific means to determine the elemental composition, quantify and identity of suspected, but unknown controlled substances.
- Second, the Toxicology area is where toxicological analyses are conducted on food products or biological samples in order to ascertain the presence of poisons, drugs, or drug metabolites. This unit is also responsible for assessing claims of commercial **product tampering**.
- The third program area, Paints and Polymers, examines and analyzes paint specimens in order to make comparisons with suspected sources. These subject matter experts use obtained samples to identify automotive make, model and year; they also oversee the National Automotive Paint File and the National Forensic Tape File. Other forensic scientists in this unit examine plastics for comparison with suspected sources. Additional scientists examine caulks, sealants, and other adhesives and engage in chemical and material analyses of various types of tape in order to determine composition, construction, color, type and manufacturer, as well as to identify tape from torn or cut ends of suspected rolls.
- Fourth, Metallurgy experts examine and analyze evidence recovered from air, rail, and nautical calamities, along with product tampering, material strength assessments, structural damage and failure analyses, suspected fabrication and specification fraud, and appliance and device malfunction. Metallurgy experts also study material corrosion.
- Elemental section staff in the fifth program area perform examinations and chemical analyses of **glass** and light bulb shards, bullet contents, substrates and components isolated from biological or biochemical samples, and make materials comparisons in the investigation of **arson**, homicides, suicides, and accidents.
- The sixth program area, Instrumentation Operation and Support, provides oversight for maintenance of all unit instrumentation, databases, and reference libraries.

The third Unit, in the Scientific Analysis Section is **CODIS** (Combined DNA Index System), which utilizes advanced electronic computer technologies in tandem with cutting edge forensic science as a means of solving distant violent crimes. A computerized database and analysis system enables forensic labs across the country to share real-time data of

DNA profiles. Investigators use this information to evaluate and link crimes committed in differing geographical areas, serial crimes, and the comparison of known perpetrator DNA with DNA recovered from crime scenes.

The fourth Scientific Analysis Unit is dedicated to DNA Analysis. At crime scenes, DNA is extracted from questioned blood, tissue, and body fluid specimens. These specimens are compared with DNA analysis of known samples. By so doing, it is often possible to link victims, alleged perpetrators, and crime scenes.

Explosives, the fifth Unit, is staffed by scientists who analyze and compare samples from suspected explosions and evidence obtained from recovered explosives (or fragments thereof), in an effort to link the two. They also conduct on-site bomb scene investigations, search suspected bomb-making locations, and oversee the Terrorist Explosive Device Analytical Center (TEDAC).

The sixth Unit, Trace Evidence, provides expert identification and analysis of physical materials that may be transferred between victim, alleged perpetrator, and crime scene. Some common trace materials are fibers from cloth, ropes, ligatures, bindings, coverings or textiles, human and animal hair, wood or soil particles, glass fragments, and building or construction materials. This Unit archives samples of textiles, fibers, animal and human hair, different types of soil, wood, and feathers.

Housed with the Forensic Science and Support Section is the Counterterrorism and Forensic Science Research Unit, the mission of which is to continually research and broaden the security community's knowledge base in order to more effectively combat terrorism. This Unit has three subsections: (1) Biology, tasked with the automation of forensic DNA analysis; (2) a Chemistry Subunit which houses subject matter experts in the areas of chemical separations and mass spectrometry, who are equipped for field chemical research, evidence collection and analysis; and (3) the Physical Sciences Unit, which focuses on document analysis, imaging and **latent fingerprint** studies, and materials analysis.

The Evidence Control Unit is tasked with ongoing analysis of recovered evidence, as well as the oversight and management of the evidence control system, which tracks the movement of all forms of evidence throughout the investigational and judicial processes.

The Quality Assurance and Training Unit is responsible for the management and maintenance of all aspects of quality assurance and best practice standards within the FBI Crime Laboratory. It also coordinates and manages quality oversight training programs throughout the Bureau. In addition, this Unit maintains the FBI Crime Laboratory Library, which is responsible for the production and publication of the juried journal *Forensic Science Communications*, publication of the *Handbook of Forensic Services*, production of field and laboratory manuals and training materials, and has oversight and management responsibility for all forensic science training programs within the Bureau and among the field laboratories.

The Special Photographic Unit houses the FBI's entire forensic imaging and photographic continuum, from camera and equipment maintenance and repair, to technical assistance on concealment operations, to aerial and surveillance filming. There are three subunits: the Forensic Studio which is responsible for all FBI forensic photographic operations; the Field Support subunit, which processes film and produces hard copy and digital photographic images and trains Bureau and field personnel in photographic equipment use and image production; and the Training subunit, which is responsible for teaching new Special Agents and field support staff basic and advanced crime scene **photography**.

The Operational Response Section is comprised of the Bomb Data Center, in which specially trained forensic scientists create and implement advanced technologies designed to increase safety for those involved in bomb disarmament and disposal. The Hazardous Devices School is housed within this unit and its mission is to provide certification-level training to personnel involved with explosive device render-safe technology. Bomb Data Center staff are tasked with interface between the FBI and the law enforcement communities. It is the Center's responsibility to provide field technical support to the public sector on an as-needed basis. The Bomb Center Data Unit produces the *Special Technician's Bulletin*, the *Investigator's Bulletin* and the *General Information Bulletin*, as well as any other requested technical manuals, bulletins, and reports.

The Evidence Response Team Unit coordinates and supervises Evidence response Teams (ERTs) throughout the FBI. ERTs are comprised of specially equipped and trained Special Agents, support and administrative staff who are expert at planning, preparation, organization, and conduction of major evidence-recovery missions at disaster, crisis, and mass casualty sites. ERT staff are trained and experienced in leading techniques and have access to the most advanced scientific methodologies and forensic technologies available.

Lab workers perform the early stages of mitochondrial DNA extraction at the FBI's new crime laboratory in Quantico, Virginia, in April 2003. Forensic and evidence lab cost $155 million. Investigators from around the world use the academy, whose facilities are among the best in the world, for research. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

The FBI Crime Laboratory's Hazardous Materials Response Unit is dedicated to countering terrorism in the nuclear, radiological, and biological realms, as well as to the investigation of environmental crimes. This Unit also provides training, equipment, and certification-level coursework for FBI central and field staff involved in hazardous materials operations.

Within the Operational Support Section, the Administrative Unit provides oversight, coordination, and adherence to published FBI and Crime Laboratory Policy and Procedural guidelines; the Facility Services Unit is responsible for assuring the safety and integrity of both the Crime Laboratory staff and the physical plant itself; the Investigative and Prosecutive Graphics Unit is responsible for the sub-areas of crime scene survey, documentation and reconstruction; forensic facial imaging; demonstrative evidence; and provision of the full range of FBI Director's Office Support, including the President and Presidential staff, the Attorney General of the United States, Congress, the Department of Defense, and various national and international officials and dignitaries.

The Planning and Budget Unit is charged with tracking, management, and financial oversight of the FBI Crime Laboratory budget as well as its federal funding and appropriations.

Finally, the Structural Design Unit plans, designs, develops, and implements actual physical models and evidentiary mock-ups for courtroom **crime scene reconstruction** and evidentiary clarification in support of expert witness testimony.

Vast in complexity and ever-broadening in scope, the modern-day FBI Crime Laboratory far surpasses the early vision of J. Edgar Hoover and his G-men; it continues to stand as one of the best known and most inclusive forensics research facilities in the world.

SEE ALSO Accident investigations at sea; Artificial fibers; Bacterial biology; Bioterrorism; Building materials; Crime scene staging; Cryptology and number theory; Fracture matching; Luminol; Mitochondrial DNA analysis; Mitochondrial DNA typing.

FBI (United States Federal Bureau of Investigation)

The United States Federal Bureau of Investigation (FBI) is the nation's primary federal investigative service. The mission of the FBI is to uphold and enforce federal criminal laws; aid international, state, and local police and investigative services when appropriate; and to protect the United States against terrorism and threats to national interests.

An important part of the FBI's mandate includes **forensic science**, both directly in the form of field investigations of accidents or deaths deemed of national interest, and in the maintenance of databases that can be accessed by local, state and federal law enforcement, and forensic investigators. An example of the latter function is the **Integrated Automated Fingerprint Identification System** (IAFID), which maintains millions of fingerprints for perusal.

The FBI employs nearly 30,000 men and women, including 12,000 special agents. The organization, headquartered in Washington, D.C., is field-oriented, maintaining a network of over 50 domestic field offices, 45 foreign posts, and 400 satellite offices (resident agencies). The agency relies on both foreign and domestic intelligence information, since the agency only has jurisdiction in interstate or federal crimes.

Origins and Formation of the FBI

In the nineteenth century, municipal and state governments shouldered the responsibility of law enforcement. State legislatures defined crimes, and criminals were prosecuted in local courts. The development of railroads and automobiles, coupled with advancements in communication technology, introduced a new type of crime that the contemporary legal and law enforcement system was unequipped to handle. Criminals were able to evade the law by fleeing over state lines. To combat the growing trend of interstate crime, President Theodore Roosevelt proposed the creation of a federal investigative and law enforcement agency.

In 1908 Roosevelt and his Attorney General, Charles Bonaparte, created a force of Special Agents within the Department of Justice. They sought the expertise of accountants, lawyers, Secret Service agents, and detectives to staff the ranks of the new investigative service. The new recruits reported for examination and **training** on July 26, 1908. This first corps of federal agents was the forerunner of the modern FBI.

When the federal bureau began operations, there were few federal crimes in the legal statutes. Federal agents investigated railroad scams, banking crimes, labor violations, and antitrust cases. The findings of their investigations, however, were usually disclosed to local or state law enforcement officials and courts for prosecution. In 1910, the federal government passed the Mann Act, expanding the jurisdiction of the investigation bureau by outlawing the transport of women over state lines for the purpose of prostitution. Granting federal agents the right to investigate, arrest, and prosecute persons in violation of the Mann Act solidified the interstate authority of federal investigative services.

The intervening decades, including the first World War, saw the FBI's mandate evolve. This evolution was particularly dramatic during the 1920s and 1930s, during the early tenure of director **J. Edgar Hoover**. Under Hoover's direction, the field office network grew from nine offices to over 30 offices within ten years. Agency personnel policy changed, requiring new agents to complete a rigorous, centralized training course. Promotions within the organization were secured through merit and consistency of service, not seniority. The agency still sought agent-recruits with training in accountancy and law, but expanded their search to include linguists, mathematicians, physicists, chemists, medical practitioners, and forensic specialists.

Technical advancements also changed agency operations. Basic forensic investigation began to be employed in FBI crime scene investigations. The Bureau established a **fingerprint identification** and index system in 1924. The national index assumed fingerprint records from state and local law enforcement agencies, as well as an older Department of Justice fingerprint registry dating back to 1905. The agency opened its first Technical Laboratory in 1932. The facility quickly expanded to cover a variety of forensic research, aiding investigators by comparing bullets, guns, **tire tracks**, watermarks, counterfeiting techniques, handwriting samples, and **pathology** reports.

In the 1960s, for example, the agency's forensic efforts helped prosecute criminals in several high profile civil rights cases. Field agents in Louisiana and Mississippi investigated the **murder** of three voter registration workers in Philadelphia, Mississippi, before turning the case over to FBI headquarters in Washington, D.C. FBI agents conducted crime scene, forensics, and extended investigations of the assassinations of civil rights leaders Martin Luther King, Jr. and Medgar Evers. They eventually arrested, aided in the prosecution of, and gained convictions for the assassins, although Byron De La Beckwith, who shot Medger Evers, was not found guilty until 1994.

Forensic accounting became an important part of the FBI's operations. Combating the rise of white-collar financial crimes and the drug trade were other priorities of the FBI during the 1980s. FBI investigations implicated high-ranking government officials in financial fraud and abuse of power scandals, including members of the Congress (ABSCAM), the defense industry (ILL WIND), and the judiciary (GREYLORD). Federal agents also investigated fraud cases during the savings and loan crisis.

To aid its current operations, the FBI embraced the use of several new technologies in its operations. Aid came with the advent of personal computers and Internet research, speeding up the **processing** of investigation information. Searchable databases now store information on suspects, crime statistics, fingerprints, and **DNA** samples. However, their use also created security risks that necessitated the creation of specialized information systems protection task forces. The agency created Computer Analysis and Response Teams (CART) to aid field investigators with the recovery of data from damaged or sabotaged electronic sources. In 1998, the establishment of the National Infrastructure Protection Center (NIPC) permitted the FBI to monitor the dissemination of computer viruses and worms.

Forensic use of DNA radically altered both the legal process and forensic research of FBI investigations. DNA analysis allows specialists to positively identify victims and perpetrators of crimes by comparing particular patterns in individual DNA. FBI forensic specialists created a national DNA databank in 1998 to aid ongoing investigations.

After the September 11, 2001, terrorist attacks on the United States, and subsequent **anthrax** attacks on national post offices and media outlets, the FBI expanded its counterintelligence and counter-terrorism operations to include anti-bioterrorism task forces. Various forensic techniques germane to the detection of biological agents are used in this effort, which continues to the present day.

SEE ALSO Anthrax; Bioterrorism; FBI crime laboratory; Integrated automated fingerprint identification system.

FDA (United States Food and Drug Administration)

Forensic science can involve the examination of foodstuffs and other items used by consumers. If contaminated or faulty, these items can cause illness or death.

Various federal government agencies participate in the regulation of consumer goods, which can involve the forensic determination of the circumstances surrounding accidents, illness outbreaks, or deaths. Principal among these is the Food and Drug Administration (FDA).

The FDA is an agency of the Department of Health and Human Services. Its mandate is the regulation of the development, sale, and distribution of food products, prescription and over-the-counter drugs, cosmetics, and medical equipment. The FDA's reach is extensive; one-fifth of all consumer dollars spent in the U.S. purchase a product regulated by the FDA. The goal of the FDA is to protect consumers by ensuring the safety of food and drug products sold in the U.S.

The FDA traces its history to 1862, when President Abraham Lincoln created a chemistry division under the Department of Agriculture. Congress created the modern FDA in 1906 with the passage of the Food and Drugs Act. The 1906 law gave limited power to the FDA to monitor the safety of food and drug products. In 1938, Congress expanded the power of the FDA by passing the Food, Drug, and Cosmetic Act. This act granted the FDA the power to test drugs and determine their safety and efficacy before allowing companies to sell the new drugs. The act also granted the FDA authority to regulate cosmetics.

While the FDA's primary task is to ensure food and drug safety, in recent years the agency has taken on an increased role in addressing the deliberate contamination of foods. The FDA is leading efforts to develop and produce **vaccines** and, in conjunction with agencies such as the **Centers for Disease Control and Prevention**, takes a role in the forensic investigation of food-borne outbreaks, especially if the outbreak can be traced to a breach in the food chain from the field to the consumer.

SEE ALSO *Escherichia coli*; Food poisoning; Pathogens; Toxins.

After the FDA received evidence of 31 U.S. deaths due to severe rhabdomyolisis, a condition resulting in muscle-cell breakdown in patients taking the cholesterol-fighting drugs Staltor and Cholstat, the drugs were withdrawn worldwide. © REUTERS/CORBIS

Federal court (forensic evidence)

The Federal court system creates the standards, rules, and procedures for use by all of the lower courts in the nation. Four **Federal Rules of Evidence** are of particular significance in the world of **forensic science**.

Rule 702 involves testimony by experts. The pertinent text of the Rule states "If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the **evidence** or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, **training**, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is sufficiently based upon reliable facts or data. (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case."

In 1993, a Supreme Court case entitled *Daubert v. Merrell Dow Pharmaceuticals* resulted in a ruling that when expert evidence based upon scientific knowledge is part of the evidentiary proceedings in a trial, and the testimony is questioned or challenged by the litigant, the judge is responsible for acting as a "gatekeeper" who must decide whether the expert testimony should be considered scientifically reliable or valid. The gatekeeping function extends to technical and other potential specialized knowledge as well as to scientific knowledge.

As a result of the *Daubert* decision, many of the lower courts had to examine whether the *Daubert* factors applied to decisions about the reliability of expert evidence need also be applied to **expert witnesses** who were not offering opinions based strictly on scientific principles, but on specialized or technical knowledge. The general consensus was that the *Daubert* rules should be applied to all expert opinion testimony.

The *Daubert* rules were extended and clarified in 1999 by another Supreme Court decision, *Kumho Tire v. Carmichael*, in which it was mandated that trial judges act as gatekeepers who must make certain that only reliable expert opinion evidence and testimony be admitted, and that this rule apply to all possible forms of expert testimony. The text of the Committee Note following that decision is as follows: "The specific factors explicated by the *Daubert* Court are: (1) whether the expert's technique or theory can be or has been tested—that is, whether the expert's theory can be challenged in some objective sense, or whether it is instead simply a subjective, conclusory approach that cannot reasonably be assessed for reliability; (2) whether the technique or theory has been subject to peer review and publication; (3) the known or potential rate of error of the technique or theory when applied; (4) the existence and maintenance of standards and controls; and (5) whether the technique or theory has been generally accepted in the scientific community."

As a result of the *Kumho Tire* decision, the Court publicly stressed that these factors might not necessarily be fully applicable to all forms of expert opinion testimony, that the factors were more on the order of guidelines than rigid requirements, and that there might be specific situations or circumstances in which lower courts might give equal consideration to other factors that might best permit assessment of reliability or validity of nonscientific expert opinion testimony offered during a trial.

Among the procedural conclusions of *Daubert* was an assertion that the judicial decision regarding reliability for admissibility of evidence lay in the principles and methodology of techniques rather than on the conclusions reached by applying them. In the 1997 case *General Electric v. Joiner*, the Court partially reversed that language, by stating that it is not always possible to separate conclusions from the methods by which they were reached.

In its current wording, Rule 702 directs trial courts to determine not only whether an expert's analytic methods are based upon sound and scientifically accepted principles, but whether the expert used those methods in a reliable and scientifically appropriate manner, in order to reach the conclusions stated in testimony regarding the disputed facts of the case.

The relevant portion of Rule 703, regarding bases of expert opinion testimony, states: "The facts or data in the particular case upon which an expert bases an opinion or inference may be those perceived by or made known to the expert at or before the hearing. If of a type reasonably relied upon by experts in the particular field in forming opinions or inferences upon the subject, the facts or data need not be admissible in evidence in order for the opinion or inference to be admitted. Facts or data that are otherwise inadmissible shall not be disclosed to the jury by the proponent of the opinion or inference unless the court determines that their probative value in assisting the jury to evaluate the expert's opinion substantially outweighs their prejudicial impact."

In the original version of the Federal Rules of Evidence (1975), experts could base their opinions not only on facts brought into evidence, but also on facts not in evidence, and even on facts which would not under any circumstances be admissible as evidence, as long as the non-admitted or non-admissible facts were part of the aggregate body of knowledge that other experts in the same field of study would utilize in making professional judgments in situations not involving litigation. To clarify, the Federal Rules of Evidence sought to allow a subject area expert the latitude to use relevant and appropriate professional tools in order to render the most accurate and informed opinion possible, and to be able to communicate that decision to the participants of a particular proceeding in a court of law.

Rule 701 concerns opinion testimony given by lay witnesses. The significant portion states, "If the witness is not testifying as an expert, the witness' testimony in the form of opinions or inferences is limited to those opinions or inferences which are (a) rationally based on the perception of the witness, (b) helpful to a clear understanding of the witness' testimony or the determination of a fact in issue, and (c) not based on scientific, technical, or other specialized knowledge within the scope of Rule 702."

Members of the general public, as non-expert witnesses, may offer their personal opinions as evidence in situations where they have very strong recollection of specific events. They may testify as to what they observed or perceived: "he appeared to be drunk and his clothing smelled of beer," or "she was driving a great deal faster than the 15 mile per hour speed limit in the school zone." This rule does not permit expert witnesses to offer their perceptions, thoughts, or opinions in the guise of lay testimony.

Finally, Federal Rule 706, in relevant part, states, "(a) Appointment. The court may on its own motion or on the motion of any party enter an order to show cause why expert witnesses should not be appointed, and may request the parties to submit nominations. The court may appoint any expert witnesses agreed upon by the parties, and may appoint expert witnesses of its own selection. An expert witness shall not be appointed by the court unless the witness consents to act. A witness so appointed shall be informed of the witness' duties by the court in writing, a copy of which shall be filed with clerk, or at a conference in which the parties shall have the opportunity to participate. A witness so appointed shall advise the parties of the witness' findings, if any; the witness' deposition may be taken by any party; and the witness may be called to testify by the court or any party. The witness shall be subject to cross-examination by each party, including a party calling the witness...(c) Disclosure of Appointment. In the exercise of its discretion, the court may authorize disclosure to the jury of the fact that the court appointed the expert witness."

Federal Rule 706 essentially states that the court has the discretion to appoint or to deny appointment to any expert witness agreed upon by both parties; it also has the right to select its own expert witnesses, as well as the right to inform the jury that it has done so. In theory, a court-appointed expert is truly objective, as he or she is not employed by either party, the court-appointed expert has no potential loyalty to anything other than an unbiased assessment of the facts at hand.

These Federal Rules of Evidence are of particular importance for the forensic scientist: they inform the way in which expert witnesses may be used, the means with which the term "expert" must be defined, the role of the general public as trial witnesses, and the impeachability of expert witness testimony based on who is the employer of the expert.

SEE ALSO Ethical issues; Evidence; Expert witnesses; *Frye* standard; Pseudoscience and forensics.

Federal Rules of Evidence

The Federal Rules of Evidence are broad principles promulgated by the United States Supreme Court governing the admissibility of any evidence in a criminal or civil trial. As such, they are applicable in trials in federal courts, although most state courts have adopted them as well. From the standpoint of forensic evidence, which is gathered, examined, and interpreted by specialists who are often called on to testify as **expert witnesses**, the key rule is Rule 702, Testimony by Experts: "If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, **training**, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case." A considerable body of case law applies this general principle to the facts of particular cases and defines standards for the admissibility of forensics evidence as interpreted by expert witnesses.

Historically, the courts relied on the *Frye* test, formulated by the Court in *Frye v. United States* in 1923. The case involved the admissibility of lie detector tests, at that time called "systolic blood pressure deception tests." This form of scientific evidence was then in its infancy and, at least according to the defendant, lacked what the Supreme Court would later call "sufficient facts or data" and "reliable principles and methods." The judge based his decision to admit the evidence on its "general acceptance in the particular field" (Frye, 293 F. at 1014). This was a key development, for it shifted the focus from the conclusions, even hunches, of a particular expert to an expertise recognized by other practitioners and gained from shared specialized training and experience. The Frye standard, however, had two principal problems: It failed to distinguish science from a pseudoscience such as astrology or, in the view of some legal experts, **forensic science**, and it rendered the court a passive observer, bound to accept expert testimony if it reflected "general acceptance in the particular field."

Accordingly, a new, more rigorous standard for the application of Rule 702 evolved from a 1993 case, *Daubert v. Merrell Dow Pharmaceuticals, Inc.* Under the *Daubert* standard, a trial judge can no longer defer to "general acceptance in the particular field" but must serve as a kind of gatekeeper by holding what are commonly called Daubert hearings, or pretrial hearings on the validity of the science in question using a five-pronged test: (1) whether the theory or technique can be and has been tested, (2) whether the theory or technique has been subjected to peer review and publication, (3) the known or potential rate of error, (4) the existence and maintenance of standards controlling the technique's operation, and (5) whether the theory or technique enjoys general acceptance within a relevant scientific community.

The relatively recent *Daubert* standard raised complex legal issues. Technically, it requires the courts to reexamine the validity and reliability of such forensics tools as polygraph testing, **DNA** testing, fingerprinting, **handwriting analysis**, fiber comparison, and the **identification** of **firearms**, bite marks, tire marks, and **blood spatter** patterns. Many of these are staples of forensic testimony, and some, such as **fingerprint** comparison, have a venerable century-old history, so the courts are reluctant to exclude them. Yet many observers, especially defense attorneys, contend that the research base that supports them is often inadequate, and they are increasingly launching attacks. In *United States v. Havvard* (2000), for example, the defense filed a motion to exclude the government's expert fingerprint witness, arguing that "there is no reliable statistical foundation for fingerprint comparisons and no reliable measure of error rates in latent print identification, especially in the absence of a specific standard about the number of points of identity needed to support an opinion as to identification" (Havvard, 117 F. Supp. 2d at 850–51).

While the Court denied the defendant's motion, this type of challenge became more frequent after 1993 as defense attorneys become more sophisticated in their ability to assess and challenge scientific evidence. In the case of fingerprinting, for example, they are challenging the belief that a print match proves that the prints came from the same person. Defense attorneys note that fingerprint experts do not compare latent prints directly to known prints, but rather take points of comparison and then estimate the likelihood that the two came from the same person. More practically, defense attorneys challenge the reliability of forensics evidence (error rates), noting the many opportunities for error as evidence is found, bagged, labeled, transported, removed from storage, handled, examined, and re-stored.

SEE ALSO Evidence; Expert witnesses; Federal rules of evidence; *Frye* standard; U.S. Supreme Court (rulings on forensic evidence).

Felony

A felony, as applied to common law, is any crime generally punishable by more than one year in prison or by death. It is the second in seriousness of the three classifications of crimes: it is punished more severely than a **misdemeanor** (the least serious classification that covers minor offenses) but usually not as seriously as treason (the most serious classification). Examples of felonies are: assaults that cause serious bodily injury; **murder**; rape or sexual abuse in the first degree; grand theft; kidnapping; serious drug crimes; and racketeering.

The distinction between felonies and misdemeanors is not always clear, but generally any crime that has a sentence of only a fine or confinement in a local jail is not a felony. However, the offense may not be labeled a felony, but the punishment may make the offense a felony. For example, a state code could label a crime as an aggravated misdemeanor but provide for a sentence of more than one year in a state penitentiary, thereby treating the so-called misdemeanor as a felony.

Forensic science uses sophisticated laboratory techniques to solve felonies by detecting the presence of substances in the victim or suspected criminal, or at the crime scene. For instance, while investigating a murderous felony that involves a firearm, a scanning electron microscope can magnify objects 100,000 times in order to detect the minute gunpowder particles present on the hand of any suspect who has recently fired a gun. These particles can also be chemically analyzed to identify their ballistic origin from a particular bullet in order to match it with the bullet found within a victim.

In 1987, as an important example of using forensic **evidence** to decide a felony case, Tommy Lee Andrews became the first American ever convicted of a felony that utilized forensic **DNA** evidence. During the night of February 21, 1987, a break-in, burglary, and rape at knifepoint occurred at a Florida woman's home. During the next six months, law enforcement officials felt that the same man continued to commit over twenty felonious acts. In one case, Andrews' fingerprints were found on a window of a prowled house. Further, DNA samples of **semen** taken from several rape victims matched **blood** drawn from Andrews, while one rape victim made a positive **identification** of him. With overwhelming amounts of traditional and forensic evidence, Andrews was arrested and tried in court.

Since a DNA sample during the Andrews case was considered new scientific technology, it had to pass tests of acceptability in order to be used as testimony in the felony trial. That is, DNA analysis had to prove to be scientifically reliable in interpretation, method, and theory, and it had to be positively reviewed by peers. Passing all of these strict criteria, Andrews was initially sentenced to a twenty-two year prison sentence for the felonies of burglary, aggravated burglary, and rape. He was eventually tried for serial rape and convicted to a 115-year sentence.

In the 1980s no state had DNA databases, but after forensic evidence was shown to help convict felony lawbreakers, state courts and legislatures began to see how effective DNA was as evidence. They soon began to establish state DNA databases in order to assist law enforcement officials. Today, all fifty states require the collection of DNA samples into DNA databases for certain types of felons. Furthermore, in the first ten years of using forensic DNA evidence, the **FBI** reported DNA evidence being used in deciding over 6,800 felony cases.

SEE ALSO Misdemeanor.

Fiber evidence SEE Artificial fibers

Fibers

Fibers are one of the several pieces of forensic **evidence** known as **trace evidence**. Even though fibers are small and can be difficult to detect, their importance can be considerable. For example, textile fibers from an article of clothing can be influential in linking a suspect to the scene of a crime.

A fiber is the smallest portion of a textile material. Whether synthetic (i.e., rayon) or natural in origin (i.e., cotton), all fibers share the trait of being very much longer than their diameter. A short length of sewing thread is a good visual analogy of a fiber. The different origins of the materials that make up a fiber, and the differing ways that a fiber can be formed together to create the finished fabric, are all important in identifying the fiber.

Analysis of fibers that are found on a victim will involve determining the types of fibers present at the scene. For example, a fiber can be transferred from a carpet to a body. This fiber will not be as significant as a fiber found on a victim that is not present anywhere else at the scene. If a similar fiber is found on a suspect, this can be a powerful piece of evidence linking the suspect to the scene.

Fibers tend not to cling to other fabric tenaciously. Thus, forensic examiners must handle a victim with care, to minimize fiber loss. Retrieving the victim's clothing as soon as possible is a prudent step to preserving as many fibers as possible.

Fibers are typically collected using adhesive tape. The strips of tape are examined for fibers that match the fibers that are thought to be a normal part of the crime scene. This collection and analysis of fibers are tedious tasks.

Among the natural fibers, cotton and wool are the most popular. Other examples include flax, jute,

FBI lab technician cuts a sample of fabric from the clothing of a hit-and-run victim for comparison with fibers taken from the bumper of a suspect's car. © BETTMANN/CORBIS

hemp, and kapok. Each type can present a different appearance under an examination technique such as **polarized light microscopy**. Different fibers will refract light differently. Depending on a fiber's shape, the fiber can appear brighter along the edges or in the middle. Natural fibers tend to be circular when viewed in cross-section. In contrast, synthetic fibers can have a variety of shapes.

The number and location of fibers on a victim and a suspect are important in connecting the individuals together, especially if the fibers match. Matching fibers involves comparing the fiber type, color and type of dye used. The latter can be especially significant, given the nearly unlimited number of dye combinations that are possible.

Color is determined using a visible light microspectrophotometer or by thin-layer **chromatography**, which separates the various dye components. Synthetic fibers can also be examined by infra-red **spectroscopy**, which can also yield information on the chemical makeup of the fiber.

SEE ALSO Bindle paper; Crime scene investigation; Filaments; Trace evidence.

Filaments

A filament is a thin wire made of tungsten that glows brightly when an electric current passes through. Filaments are found in light bulbs. A filament glows because the electrical current raises the temperature of the filament to about 4,000°F (2204°C). The study of lamp filaments can be important in accident reconstruction. In some instances, when a road accident occurs, it is not clear if the lights of a vehicle were on or off. One witness might contradict another one, and this question might be very pertinent to the outcome of the case. The forensic scientist can examine the remnants of the light bulbs and determine if they were on or off by looking at the filament.

Filaments are manufactured by extruding molten tungsten through a die, in a very similar process to the one used to manufacture spaghetti. The filament is then folded in a spiral and takes the general shape of a spring. The filament is supported by small steel arms placed inside the bulb. The filament is also connected at each end to electrical contacts, which will allow the current to pass through. The bulb is usually filled with an inert gas such as argon. If oxygen is present, the filament will burn as soon as it is switched on.

The determination of whether a light was on or off is based on the study of the breakage of the filament. Several situations can occur, each of them leading to a different phenomenon. If the filament was off, it is cold. If a shock is strong enough to break the filament, it will bear a neat break and a clean fracture surface will be present. If the filament was on and broke with the **glass** of the light bulb still intact, the fracture surface will show evidence of melting and the filament will be completely distorted. The reason is that the shock is fairly violent and when the filament is hot, it is easily deformed due to its spring shape. If the filament was on (hot) and the glass broke, it will burn in the air. Tungsten will react with oxygen to form tungsten oxide. If tungsten oxide is present on the filament or on the glass around the filament, it means that electricity was running through the filament while it was exposed to the air. If the filament was on at the time the glass broke, small particles of glass will be attracted toward the center of the light bulb, due to the slightly negative pressure inside the bulb, and would be deposited on the incandescent filament. At this point, the glass would melt and stick on the filament in the form of spherical glass beads. This could be the only evidence that a filament was on when the glass of the light bulb broke.

Examination of lamp filaments is performed under a microscope, so magnifications of 5–20 times can be achieved. If a light microscope does not allow the forensic scientist to conduct the examination properly, a scanning electron microscope (SEM) can also be used. The SEM provides the examiner with a much clearer picture of the filament and particularly of the glass beads, if present.

SEE ALSO Accident reconstruction; Crime scene investigation; Physical evidence.

Film (forensic science in cinema)

Crime investigation has long been a favorite theme in film. **Evidence**, such as **blood**, weapons, and fingerprints, can provide fascinating plot twists and many films feature a detective as the protagonist. Crime labs, crime scene investigations, and autopsies often appear in such films. Some are based on true stories, such as the 1971 classic *10 Rillington Place* which is about the serial killer John Christie. Others are based on the work of famous crime authors, such as Agatha Christie or Raymond Chandler. If the filmmakers have consulted with police and forensic experts to get the details correct, then watching **forensic science** in film can be both educational and entertaining.

Film critics classify the detective-mystery film, the type that is most likely to feature forensic science, as a sub-genre of the crime-gangster or suspense-thriller movie. These are two of the major film genres, alongside horror, war, romantic comedy, and other genres. When talking about the history and development of film, genre is a term referring to a type of film with a specific theme, structure, content, subject matter, or filmic technique. Like other genres, the detective-mystery movie has undergone many developments and changes during the last century. Some are dark and haunting; others are action-packed, fast-paced, clinical, or even funny. What they all have in common is a narrative that follows an investigation—which is where the forensic science comes in to a greater or lesser extent, depending on the period—and a protagonist acting as a detective figure, be it a private investigator, a police officer, or a forensic expert. The plot of a detective-mystery film is often focused on the deductive ability and diligence of the central protagonist as he or she unravels the crime by gathering evidence, seeking clues, interrogating witnesses, and tracking down suspects.

The first significant detective-mystery films concerned the exploits of Sherlock Holmes, the private investigator created by the Scottish author

Sir **Arthur Conan Doyle** (1859–1930). There have been more than 160 Holmes movies, ranging from a 30 second silent film featuring the detective that was produced sometime between 1900 and 1905, and the 2002 made-for-TV version of *The Hound of the Baskervilles*. Perhaps the most famous portrayal of Holmes, with his Inverness cape, deerstalker hat, curved stem pipe, and magnifying glass, was by the British actor Basil Rathbone who appeared in 14 of the films between 1939 to 1946, including the classic *Hound of the Baskervilles*. The magnifying glass symbolizes the Holmes approach to detection: careful, painstaking, and, above all, scientific. The character was modeled on one of Conan Doyle's teachers at medical school, Joseph Bell, who always emphasized the importance of observation in making a diagnosis, advice that is equally applicable to criminal investigation.

Another classic series of detective-mystery films, appearing from the 1930s, featured the brilliant amateur detective Ellery Queen, based on the novels of cousins Frederic Dannay (1905–1982) and Manfred B. Lee (1905–1971), who used the character's name as a joint pseudonym. Ellery Queen was to become one of the most popular authors of the golden age of American mystery fiction between the 1920s and 1940s, although the radio plays and films did not, perhaps, have the same impact as the short stories and novels. Other detective heroes of this era include Charlie Chan, Bulldog Drummond, teenager Nancy Drew, and husband-and-wife team Nick and Nora Charles.

Several of the stories of the world's most famous detective writer, Agatha Christie (1890–1976), have been made into films. Her fussy eccentric Belgian sleuth Hercule Poirot appears in perhaps the best known of the Christie films, *Murder on the Orient Express* (1974). Directed by Sidney Lumet, the all-star cast including Albert Finney as Poirot. In the tale, a man is found murdered on the Orient Express and all the other passengers are suspects. It turns out they are all involved directly or indirectly in the case, and each one had a motive. Other Christie films feature a female investigator, the gray-haired Jane Marple, played by Margaret Rutherford, who was the protagonist in four films from the 1960s: *Murder She Said*, *Murder at the Gallop*, *Murder Most Foul*, and *Murder Ahoy*. Miss Marple has spent all her life in a sleepy English village where nothing much ever happens, but she has a remarkable eye for detail that serves well for crime investigation in any setting.

The history of the detective-mystery film can be traced through the evolution of the type of protagonist that, in turn, reflects changes in the pattern of crime and other societal factors. The gentlemanly approach of Sherlock Holmes, with his emphasis on logic and deduction seemed inappropriate for dealing with organized crime and gangs. Private investigator heroes became more physical, more likely to use violence in their pursuit of the criminal in films from the 1920s to 1940s. A significant development was the emergence of film noir, a film style characterized by moral and visual darkness, developed in the 1940s. Classics of the film noir era include *The Maltese Falcon* (1941), based on a story by Dashiell Hammett (1894–1961) and starring Humphrey Bogart as Sam Spade. The story has Spade investigating the death of his partner and being hounded by the police himself, while getting involved in the pursuit of a valuable statuette called the Maltese Falcon. *The Big Sleep* (1946) also stars Bogart, this time as as Philip Marlowe, the creation of Raymond Chandler (1888–1959). The complex plot involves seven killings, gambling, pornography, vice, and corruption. Both Spade and Marlowe are typical of the hard-boiled detective hero, preferring action, even violence, to analysis and careful investigation of evidence. These somewhat troubled heroes perhaps reflected the post-war mood in America, where men returning home often faced unemployment, disability, and a sense of alienation.

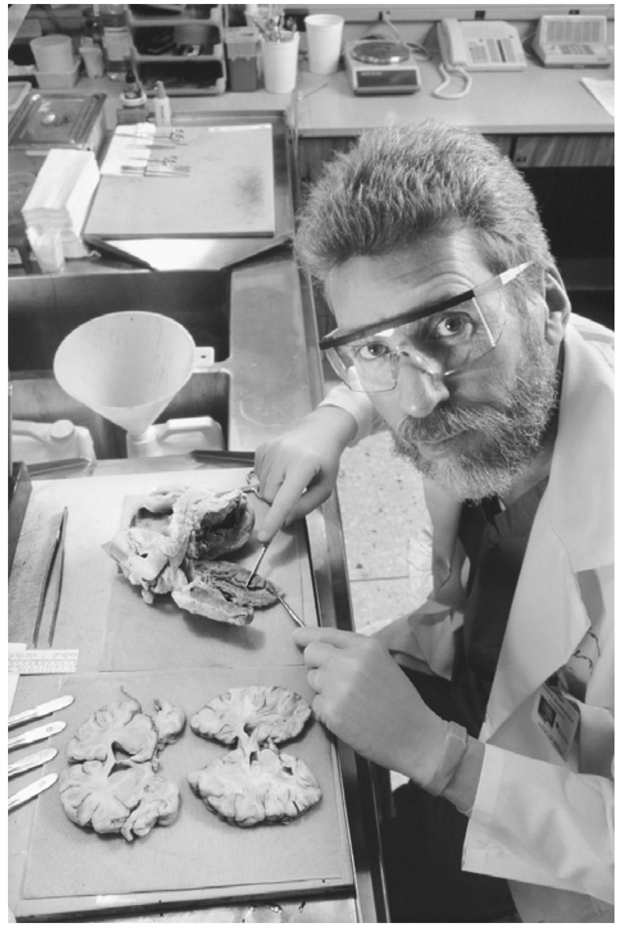
It was not until the late 1940s that the police and police procedure began to be a major focus in detective-mystery film. A major influence on the police procedural in film was the TV series *Dragnet*, which ran from 1951 to 1970. Dragnet emphasized the technical side of crime investigation, presenting it as rather less than glamorous. Details such as **ballistics**, surveillance, and forensic lab work soon began to find their way into film. The policeman hero was organized and methodical in his pursuit of the criminal. However, a new kind of protagonist began to emerge from the 1960s, as exemplified by *Dirty Harry* (1971), where a San Francisco cop, played by Clint Eastwood, tracks down a serial killer. Another classic from this era, *The French Connection* (1971), has Gene Hackman playing a New York City police officer pursuing drug smugglers. These heroes were tough and often angry and prepared to use controversial means of solving a crime. The action hero trend continued through the 1980s with films like *Lethal Weapon* (1987), starring Mel Gibson as a suicidal cop partnered with a more experienced officer as they investigate a drug smuggling racket in a blend of action and comedy.

However, from the 1990s to the present, there has been a return to the more intellectual, well-educated hero prepared to use observation and deduction rather than violence to solve a crime. One example is Clint Eastwood's *Bloodwork* (2002). Clint Eastwood plays a retired psychological **profiling** specialist, Terry McCaleb, who is recovering from a heart transplant. The plot twist comes when his new heart turns out to have come from a murder victim. Her death has been staged to look like a robbery gone wrong but is actually the work of a serial killer. McCaleb sets off in pursuit, an unlikely protagonist in comparison with the all-action hero.

Several aspects of forensic science also provide a background for *The Silence of the Lambs* (1991), directed by Jonathan Demme, in which the female protagonist, Clarice Starling (Jodie Foster), is a trainee **FBI** agent-investigator. The film concerns two **serial killers**, one of them, Hannibal Lecter (Anthony Hopkins), is behind bars while the other, known as Buffalo Bill, has just claimed a fifth victim whose **autopsy** is narrated in detail by Starling. The killer has kidnapped a sixth victim and the search is on to free her. To this end, Starling attempts to build a **psychological profile** of Bill, with Lecter's help. Lecter is a psychopathic psychiatrist who cannibalizes his victims and who has always been clever enough to avoid revealing his motives and inner fantasies to forensic investigators. Bill skins his victims post-mortem and also leaves an unusual signature. A forensic entomologist is brought in to identify the cocoon of the Death's-head moth, which is lodged in the throat of each victim. The film contains many other forensic and police procedural references.

Finally a forensic scientist himself becomes the victim in *Death of an Expert Witness* (1983), directed by Herbert Wise, which was the first film adaptation of the work of the English detective author P. D. James. It features Adam Dalgleish, a detective who writes poetry, and is set in a forensic laboratory in the East of England. The victim, as the title suggests, was also an expert witness. One of his colleagues may have killed him, a nice irony, given that forensic scientists are usually on the side of the law and are rarely under investigation themselves.

SEE ALSO Literature, forensic science in; Television shows.

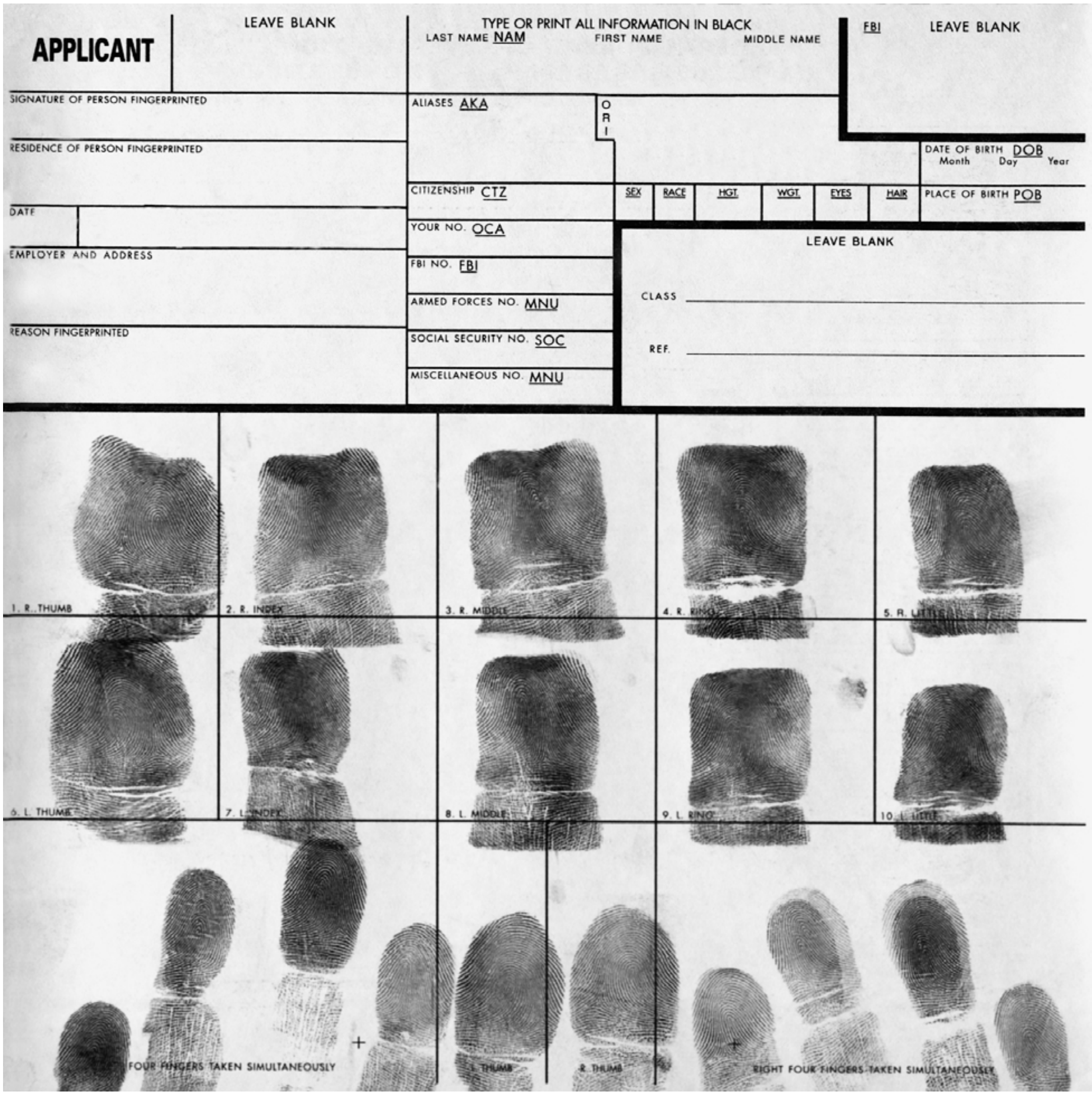


Dr. John E. Glassco, a pathologist in Los Angeles, examines a human organ in the hospital lab. Dr. Glassco also works to match up people in the medical industry for work in Hollywood feature films that require expertise in medicine. © JIM SUGAR/CORBIS

Fingerprint

Fingerprints are the impressions that are left behind by tiny ridges in the skin on the tips of the fingers and on the palms of the hand. The patterns left by these ridges, which are called friction ridges, are unique to every person. They are determined by the time a fetus is about six months old and they remain constant throughout a person's life. Even identical twins with identical **DNA** have different patterns of friction ridges on their fingers. Although many features of a person can be changed, fingerprints cannot. As a result, fingerprints are an extremely important tool for **identification** of individuals.

The outer layer of skin contains many microscopic pores that secrete sweat and oils. Sweat is mostly water, but it contains a very small fraction (1.5%) of salt, amino acids, and proteins. These



Fingerprints on a criminal record. © RANDY FARIS/CORBIS

chemicals remain on the skin after the water evaporates. The skin also contains sebaceous glands, which produce oils. Although the fingertips contain few sebaceous glands, the face and head contain many and people touch their faces and hair often, transferring oil to the fingertips. The oil and the residual chemicals from sweat cling to the surface of the fingers and attract dirt and other substances such as cosmetics and grease from foods and oils. Whenever a person touches something, these residues are transferred to that surface. Since people rarely commit crimes without using their hands, the prints from their fingers are often left on surfaces at the crime scene.

Detectives look for fingerprints at crime scenes in locations where things have been broken or disturbed. They also usually check the doorknobs and doorways, where a criminal may have entered or exited. Fingerprints can be found on a variety of surfaces including paper, human skin, smooth surfaces, painted surfaces, **glass**, the insides of gloves and **firearms**. They can last for a just a few hours in cold, dry weather or they may be visible indefinitely in warm, moist environments.

Fingerprints are classified into three groups. Plastic prints are prints that make an impression on a pliant surface like putty or tacky paint. Visible prints occur when someone has a material on their fingers that leaves a visible mark, such as **blood**, ink, or make-up. The most common fingerprints are called latent prints and they are formed from the oils and residues on the hands. Latent prints must be developed using one of many different chemical techniques.

Dusting for fingerprints is the most common technique for visualizing a latent print. This process begins by dipping a very soft brush into very fine powder. Most fingerprint kits contain black, gray, white, and red powders and the detective will choose a color of powder that contrasts best with the surface on which the print has been left. The detective carefully brushes the powder over the print and then blows the excess powder away. After the print becomes visible, it is photographed and then transferred onto special tape in a process called lifting.

Several other chemicals and techniques are commonly used to develop latent prints, and they are chosen depending on the surface and other environmental conditions. A chemical called ninhydrin, which is attracted to the amino acids that remain on the skin after the water in sweat evaporates, is used to develop fingerprints on paper. Iodine fumes can also be used to develop fingerprints on paper. The iodine vapors react with oils, turning them a brownish-violet color. Surfaces containing fingerprints can be dipped into or sprayed with silver nitrate, which turns black in the presence of salt. Superglue™ fumes, which produce white crystals in the presence of moisture in the fingerprints, are also commonly used to develop latent prints. In addition, specialized light sources, such as lasers and ultraviolet lights, can be used to make latent prints appear in situations where chemical techniques are impractical.

There are three basic classifications of fingerprints: arches, loops, and whorls. Of these, loops are by far the most common, next are whorls and a small fraction are arches. Arches are classified into plain arches, which are generally symmetric arched friction ridges, and tented arches, which become so narrow that their core is a single friction ridge. Loops look somewhat like a cursive letter "e," but can be slanted either to the right or to the left. Loops are subdivided into radial loops, which flow towards the thumb, and ulnar loops, which flow toward the little finger. Whorls are circular or spiral shapes. They are subdivided into plain whorls, double loop whorls, central pocket whorls, and accidentals. As a result there are eight major categories of fingerprint patterns.

Forensic officials scan a fingerprint of a tsunami victim in Khabi province south of Bangkok on December 31, 2004. © CHAIWHAT SUBPRASOM/REUTERS/CORBIS

Fingerprint experts start with the basic patterns of friction ridges when they study fingerprints, but they depend heavily on the details called minutiae within fingerprints. These minutiae include ridge endings, dots, short ridges, bifurcations, and trifurcations. In addition, the location of sweat pores and the pores for oil glands serve as markers that can be used for identification.

SEE ALSO Bloodstain evidence; Crime scene investigation; Fingerprint; Superglue® fuming.

Fingerprint analysis (famous cases)

Forensic investigators have been using **fingerprint evidence** as a source of **identification** of suspects for over a hundred years. Early work was by visual analysis of very obvious prints left at the scene of a crime. Modern forensic scientists now have a range of techniques for finding prints, cleaning up and enhancing print images, and rapidly finding a match from a database using computer technology. Fingerprint evidence is seen as one of the best types of **physical evidence** linking a suspect to an object or location or for establishing identity. Therefore, the forensic investigator will always search for fingerprint evidence at the scene of a crime and at related locations, such as a suspect's home or car.

A fingerprint is the pattern of ridges and related characteristics found on the fingerpads, the fleshy parts of the fingers used for touching and gripping. Each person's fingerprints are unique and stay unchanged throughout life. According to Sir **Francis Galton**, the nineteenth-century English anthropologist, the chances of two fingerprints being identical are as small as 64 billion to one. In over a century of forensic fingerprinting, no two prints have ever been found to be the same, even those of identical twins.

Skin is never completely dry or clean; grime, oil, and sweat on the fingerpads create fingerprints whenever a person touches something. That is why criminals, unless they are wearing gloves, leave fingerprints behind. If their hands are bloodstained, then they will leave bloody fingerprints behind, an example of a patent (visible) print. Plastic prints are fingerprint impressions made in a soft material like soap or dust. Latent fingerprints are invisible, but the forensic scientist can visualize them though special lighting or with the application of chemicals. Fingerprints have been recovered from all kinds of surfaces, even plastic bags. It would be very useful to be able to reliably detect fingerprints on human skin. So far, this been very difficult to do if more than two hours have elapsed from the time the fingerprints were made. Potential methods are being developed to recover fingerprints after longer time periods have elapsed.

A fingerprint found at the scene of a crime can be dusted with chemicals to make it easier to see and then lifted or photographed. It is then compared with the fingerprints of known offenders stored in a computer database. In the past fingerprints were classified according to the specific features that make up the unique pattern of each print. With computerized storage and retrieval systems, however, classification is not really necessary as the computer can readily scan and match the whole pattern of thousands of prints. The image of fingerprints found at the scene of a crime can readily be enhanced and clarified with scanning and digitizing technology. This means that even partial prints can be of value in identifying someone at the scene of a crime.

In 1892 Francesca Rojas, an Argentine woman, became the first person ever to be convicted on fingerprint evidence. When her two young children were found beaten to death, she tried to blame a man called Velasquez who vigorously denied the charge and, in any case, had a firm alibi. Investigator **Juan Vucetich**, who was intrigued by the relatively new technique of fingerprint analysis, found a bloody fingerprint on a bedroom door in Rojas' house. He sawed the portion away and then had the woman give an ink-print of her thumb. Even with only a basic understanding of fingerprint analysis, it was obvious to the investigators that the bloody print belonged to Rojas. She confessed to the crime when confronted, and admitted that she committed the murders to improve her chances of marrying her boyfriend, who was known to dislike children. Rojas was sentenced to life imprisonment.

The brutal **murder** in 1905 of Thomas Farrow, manager of a shop in Deptford, near London, and his wife Ann was to become a milestone case in the use of fingerprint analysis in Britain. Money had been taken and a thumbprint was found on the cash box. The Criminal Investigation Department (CID) had already built up a file of fingerprints of known criminals, but this print did not match any of them. A witness led the investigators to two brothers called Albert and Alfred Stratton. A match was found between one of the men and the print found at the scene. The court battle over the evidence was, however, lengthy. Much hung in the balance as it was the first time fingerprint evidence had been used in a murder case in Britain. After two hours of deliberation, however, the jury found the two men guilty and they were later hanged.

In 1910, Thomas Jennings was arrested on suspicion of the murder of Clarence Hiller in Chicago. The main evidence against him was fingerprints, and four experts testified at his trial. However, fingerprint evidence was still relatively new and Jennings brought an appeal questioning its admissibility. In a landmark judgment, the Illinois Supreme Court upheld the conviction, saying that fingerprints were indeed a reliable form of identification. Jennings was sentenced to death and executed on February 16,

1912. He was the first person in the United States to be convicted of murder on fingerprint evidence.

Fingerprint analysis also played a role in convicting the man responsible for an audacious theft. On August 21, 1911, Leonardo da Vinci's *Mona Lisa* was stolen from the Louvre Museum in Paris. There was a clear fingerprint on the **glass** that had protected the painting. Fingerprint pioneer **Alphonse Bertillon** spent many months trying to match the print to samples in his collection but to no avail. Two years after the theft, police arrested Vicenzo Perugia in connection with the crime. His prints matched those from the crime scene. Ironically, Perugia's thumbprint had been in Bertillon's collection all the time, but it was of his right thumb. The one left on the glass in the Louvre was from his left thumb.

Criminals soon realized that fingerprints could be used to convict them and took evasive measures. Some used gloves but others, like John Dillinger, a gangster who terrorized the Chicago area in the 1930s, went further. While on the run from authorities, he had a plastic surgeon burn off the outer layer of his fingertips with acid, in the belief that this would erase his fingerprints for good. A tip off put the **FBI** on Dillinger's trail, they confronted him and shot him dead. In the morgue, they discovered Dillinger's attempts to burn away his this fingerprints. He had not succeeded. Fingerprints usually grow back and, in any case, go down through several layers of skin.

Early fingerprint investigators had a tough job sorting manually through print records. Today, matching is accomplished with the aid of high-speed computers. The FBI began to automate print analysis in the 1960s with **AFIS**, the **Automated Fingerprint Identification System**. The AFIS computer scans and digitally encodes fingerprint records into a database. It can match a sample, either a ten-print set or a single or partial print, by searching the database. Early versions of AFIS searched hundreds to thousands of prints a second; now the speed is up to 500,000 prints per second.

One notable success for AFIS was catching Richard Ramirez, a notorious killer known as the Night Stalker. He had committed a number of brutal rapes and murders throughout Southern California between 1984 and 1985, entering victims' homes at night and cutting the phone line. He would shoot any men present before raping their spouse, often in the same bed where the corpse laid. His final crime involved a couple in Mission Viejo, where he shot the man and raped the wife. Fortunately, both survived and the woman saw Ramirez' car, while another witness got the number of the vehicle. The stolen car was found abandoned and a partial fingerprint was recovered from the vehicle. The Los Angeles Police Department had just begun to use an AFIS system that could compare more than 60,000 prints per second and they found a match for the print in the car within minutes. A photo of Ramirez, a 25-year-old drifter from El Paso, went out in the papers and he was recognized within a day by residents in east Los Angeles, who overpowered him when he tried to steal another car. He was convicted by a jury and, on November 7, 1989, was given 19 death sentences.

Palm prints contain even more detail on them than fingerprints, and helped solve the kidnap and murder of 12-year-old Polly Klaas in 1993. The girl was enjoying a pajama party with friends at her home in Petaluma, California, when a man appeared through an open window with a knife and carried her off. The FBI used special light sources and fluorescent powder to locate an otherwise invisible palm print on a bunk bed. They also had a description of the intruder from the other girls. Torn children's clothing was found a few weeks later near a site where a man's car had rolled into a ditch. That man was Richard Allen Davis, who had two previous convictions for kidnapping. A fingerprint expert was able to match the FBI's palm print found at the scene of the crime to Davis, who then confessed and showed police where Klaas' body was. He was sentenced to death in 1996 for kidnapping and murder.

SEE ALSO Anthropometry; Fingerprint; Latent fingerprint; Ridge characteristics.

Fingerprints, ballistic SEE Ballistic fingerprints

Fire accelerants SEE Accelerant

Fire debris

Fire debris is a general term used to define the debris from a fire that is collected as **evidence** for laboratory examination. When a fire investigator suspects that a fire might have been deliberately set using accelerants such as ignitable liquids, it is possible to collect and analyze fire debris to see if such products are present.

When a person pours an ignitable liquid onto a substrate such as carpet, furniture, or clothing, that liquid gets adsorbed inside the substrate. When the liquid is set on fire, only the surface of the liquid burns and part of it is protected deep inside the substrate. If the fire department puts out the fire early enough, there are traces of this liquid left where the liquid was poured inside the burned debris. The fire investigator who collects the debris then sends it to the laboratory for analysis. The debris needs to be packaged in special containers that are sealed to prevent vapors of flammable or combustible liquids from escaping.

The forensic laboratory analyzes the debris using chemical techniques. First, the residues of the liquid are extracted from the debris, so they can be analyzed without the debris. For this step, different procedures can be used, but usually the sample is heated and the vapors are trapped onto a charcoal strip. This charcoal strip would then contain the residues of ignitable liquid. These residues are separated from the charcoal using a solvent. Once in the solvent, it is possible to analyze the residues with a gas chromatograph or **gas chromatograph–mass spectrometer**.

Once the analysis is done, it is important to interpret the results carefully. Modern furniture and clothing are composed of polymers that are based from petroleum products, the same petroleum products that are used to manufacture most of the flammable and combustible liquids such as gasoline, diesel fuel, charcoal starter fluid, and paint thinner. Thus, it is very important for the forensic scientist to be able to distinguish the presence of ignitable liquid from the chemicals that are produced by modern substrates. Only the proper collection, examination, analysis, and interpretation of the fire debris sample allow the forensic scientist to reach the proper conclusion.

SEE ALSO Arson; Canine substance detection; Chromatography; Fire investigation.

Fire investigation

Fire investigation is a field of forensic sciences dedicated to the determination of the origin and the cause of a fire. Determining the origin of the fire answers the question, "Where did the fire start?" Determining the cause of the fire answers the question, "Why did the fire start?"

In order for a fire to occur, three conditions must be met. There must be a combustible (fuel), an oxidizer (oxygen), and a sufficient heat energy source (source of ignition). The key elements that determine the cause of the fire rely on the determination of the first material ignited and of the source of ignition. Heat energy can be produced by mechanical, electrical, chemical, or radioactive means. The role of fire investigation is to identify the event that brought together the combustible, the oxidizer, and the source of ignition that started the fire.

Causes of fire can be natural, accidental, deliberate, or undetermined. Natural causes of fire include all the actions of nature that can cause a fire, such as lightning from the sky or lava from a volcano. Accidental fires include both fires that are caused by a negligent human intervention or by accidental occurrence without the necessary presence of a human being. Deliberate fires are caused by the intentional intervention of a human being. However, not all deliberate fires are arsons. For example, if one sets fire to backyard debris, it is deliberate but may not constitute **arson**. Arson is a legal term that can greatly vary from one country to another or from one state to another. In many instances, fire investigators will not be able to determine where and/or why the fire started, and the cause is classified as undetermined.

The determination of the origin of a fire is made based on observations of smoke, heat, and burn patterns at the fire scene. Fire evolves following the laws of physics and chemistry. While combustion is a complicated phenomenon that can be random in some instances, it is most often possible to determine the direction of fires. By tracing the direction backward, it is possible to find the origin of the fire. Once the origin of a fire is found, it is necessary to determine its cause.

One of the most important objectives in fire investigation is determining if a crime occurred in connection with the fire. If the fire is due to arson, it is extremely important to quickly determine that a crime occurred and gather **evidence**, so that an arrest may be made. If an accidental or natural fire occurred, it is important to determine how it started, so that the proper measures can be taken to prevent similar fires and to protect lives and property from future damage. In addition, in the case of accidental fire, it is important to determine the exact cause of the fire, because people or companies might bear a responsibility in the loss. The responsibility might be civil or criminal and carry an important financial burden. Many criminal laws also allow charges to be brought against people who accidentally created a fire.

Fires are investigated by fire investigators or criminalists. Fire investigators come from many

An arson inspector (foreground) in Los Angeles follows firefighters into a smoking fire scene to search for evidence of arson. © LAYNE KENNEDY/CORBIS

different backgrounds. In some European countries, fire investigators are commonly part of the police department, usually the crime scene unit. In English-speaking countries and in the United States in particular, it is often the fire department that employs fire investigators. Also, almost every state in the United States has a state fire marshal's office, which specializes in fire investigation. Furthermore, the Bureau of Alcohol, Tobacco, Firearms, and Explosives has a strong fire investigation practice and can dispatch the National Response Team within 24 hours almost anywhere in the United States to support state or local investigators.

In many instances, fire investigators need to rely on the knowledge of special experts such as electrical or mechanical engineers, forensic scientists, or chemists. For example, if the fire investigator suspects that liquid accelerants were used, he/she can collect **fire debris** to be sent to the forensic laboratory in order to search for such liquids. If an electrical apparatus is suspected to have caused a fire, an electrical engineer might help in the evaluation of the circuit or apparatus. If the failure of a shaft in a factory is suspected to have created the blaze by overheating, a failure analyst or mechanical engineer might be needed to determine the exact cause of the failure of the shaft.

Fire investigation is a harsh job, as it consists of working in dangerous conditions around burned structures or vehicles and in atmospheres containing many contaminants that are detrimental to the lungs and health. Fire investigators must often dig through debris from fire scene in order to see burn patterns. Often, it is necessary to reconstruct the fire scene in order to determine the pre-fire conditions.

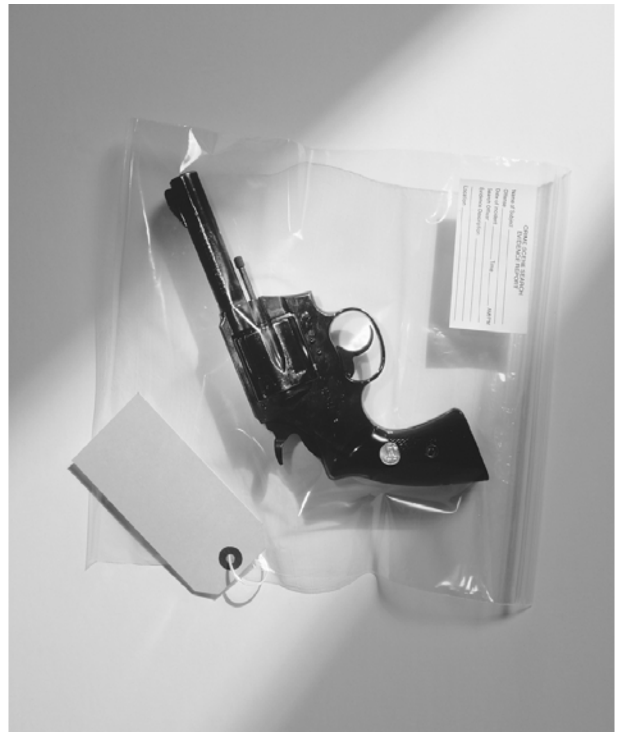
SEE ALSO Accelerant; Exothermic reactions; Explosives; Gas chromatograph–mass spectrometer.

Firearms

A firearm is a weapon of attack or defense that expels a projectile via the action of the force exerted by the gases resulting from the rapid combustion of an explosive mixture. A firearm is often associated with the commission of a violent crime and is commonly found at crime scenes or on suspects. Also, many people who commit suicide use a firearm. An interest in firearms in forensic sciences is therefore, paramount. In **criminalistics**, the study of firearms consists first in the knowledge and **identification** of firearms and their ammunition, second in the internal, external, and terminal **ballistics**, and finally in the analysis of powders, primers, and their residues.

The birth and evolution of firearms is directly linked to the discovery of black powder. It is believed that the discovery of black powder dates from 1242, when the French monk Roger Bacon (1214–1294) wrote a letter describing the recipe for black powder. At that time, it was composed of about 40% saltpeter (potassium nitrate), 30% charcoal, and 30% sulfur. The first barrels, ancestors of the modern firearms, were developed at the beginning of the fourteenth century. At that time, the barrel was loaded from its end (muzzle), first with powder, and then with the projectile. The powder was ignited with a match, which was connected to the powder through the base of the barrel. Around 1800, mercury fulminate started to be used and the first primers were developed. In 1835, French arms manufacturer Casimir Lefaucheux (1802–1852) invented the first metallic cartridge. One year later, in 1836, American arms manufacturer Samuel Colt (1814–1862) invented the revolver. The pistol was invented prior to that time, however, it was loaded by the end of the barrel. The modern semi-automatic pistol (using a magazine) was invented after the revolver in 1893.

A firearm expels a projectile at high velocity. The projectile is part of the cartridge. The cartridge consists of a shell holding the primer at one end and the projectile on the other with powder in the middle. The cartridge is inserted either manually or automatically in the barrel of the firearm. The trigger of the firearm is then pulled, which arms the hammer. At some point, the hammer is released and hits the firing pin, which hits the primer. The shock to the primer starts its combustion, which, in turns, ignites the powder in the cartridge. The powder combusts very rapidly and produces gases, which increase the pressure inside the cartridge (and therefore the barrel) tremendously. This pressure is in the order of 2,000–4,000 atmospheres. This pressure is exerted on the base of the projectile, which is pushed into the barrel. The projectile then exits the barrel at high velocity, usually ranging from 250–1,000 meters per second (273–1094 yards per second).



Handgun confiscated as evidence. © RON SLENZAK/CORBIS

Firearms are classified in two main categories: light and heavy firearms. Light firearms include handguns and shoulder guns. Handguns are then further classified into revolvers, pistols (semi-automatic, automatic, and machine), and Derringers (single-shot and double-barreled pistols). Shoulder weapons are divided into two subcategories: weapons with a rifled barrel, such as rifles and carbines, and weapons with a smoothbore barrel, such as shotguns. It is important to understand that some shoulder weapons may have more than one barrel. They can have two or more one-over-the-other barrels or side-by-side barrels. There are some shoulder weapons that have a combination of rifled and non-rifled barrels. Among the rifled shoulder weapons are the semi-automatic and automatic assault rifles and machine guns. Usually, heavy weaponry includes weapons that shoot calibers above 12.7 millimeter and are found on vehicles or armored tanks. These are specialized, usually military, weapons and are not encountered in the daily routine of a crime scene unit. Finally, there is the category of improvised or homemade weapons, which includes an enormous variety of different weapons of all calibers and functions.

Firearms are characterized by many variables, such as brand, model, size, length of barrel, shape, color, and functionality. Some of the most important variables of the firearm are the general rifling characteristics (when dealing with a rifled barrel), which include the **caliber**, the direction and degree of twist, and the number and width of grooves and lands. The caliber is correlated to the barrel's diameter and the power of the cartridges for which the firearm is designed. With few exceptions, a firearm is designed to use one given caliber. Upon shooting a projectile, the firearm leaves impressions on the projectile and the cartridge's casing. The observation of these impressions allows the forensic scientist to establish a link between the firearm and the elements of ammunition.

When dealing with a firearm found at a crime scene or on a suspect, the first security measure is to consider it as loaded and ready to shoot. Security with firearms is paramount and must be prioritized over everything else. If the firearm has just been found at a crime scene, it is possible to sketch, photograph, and take notes about it before touching it. Then, it is either placed in a container specifically designed to transport firearms and resist accidental discharges, or it needs to be secured. The firearm is then transported to the forensic laboratory where the firearms and **toolmarks** examiner can examine it.

SEE ALSO Ballistics; Crime scene reconstruction; Drugfire; Integrated Ballistics Identification System (IBIS); Microscope, comparison; Trajectory.

Michael First

AMERICAN PSYCHIATRIST

Michael First is known as one of the world's foremost experts in the areas of psychiatric assessment and diagnosis. He is an associate professor of clinical psychiatry at Columbia University College of Physicians and Surgeons, and an associate attending psychiatrist at Presbyterian Hospital in New York City. His undergraduate degree, earned summa cum laude from Princeton University, was in computer science; his expertise in information technology has resulted in First's creation of a variety of quite popular computer-administered programs utilized for psychiatric interviewing.

First is well known as the text and criteria editor of the psychiatric diagnostic guide for the DSM-IV (Fourth Edition of the *Diagnostic and Statistical Manual of Mental Disorders*); he was the editor for the DSM-IV-TR (*Diagnostic and Statistical Manual of Mental Disorders*, Fourth Edition, Text Revision), as well as the DSM-IV-TR version developed especially for primary care physicians. The DSM is the universally accepted (as a valid and reliable research and diagnostic tool) diagnostic manual for psychiatry, **psychology**, and the behavioral health (mental health and substance abuse) professions.

First is the primary author of the Structured Clinical Interview for the DSM-IV (SCID). This is a longitudinally studied, highly reliable and valid diagnostic instrument employed by psychiatric, psychological, and behavioral health researchers, by the pharmaceutical industry, by clinicians and educators in many different settings, and by forensic clinicians and researchers as part of their psychodiagnostic and culpability assessments, as well as by those forensic psychologists and psychiatrists who make competency (to stand trial) assessments. The SCID is the most widely used diagnostic assessment tool in psychiatry.

First's **forensic science** expertise includes diagnostic assessment, differential diagnosis, and psychiatric interviewing. He is particularly noted for observing the subtle diagnostic underpinnings of the various personality disorders. First has published well in excess of thirty peer-reviewed articles on substance dependence, mood disorders, personality disorders, assessment, and psychiatric diagnosis. As a result of First's worldwide reputation as an expert in the fields of psychiatric and psychodiagnostic interviewing and assessment, he has been asked to act as a consultant to the Federal Bureau of Investigation (**FBI**) on the classification of violent crime. He serves also as a distinguished member of the professional organization the Forensic Panel, and he provides expert commentary to the journal *Forensic Echo*.

SEE ALSO Careers in forensic science; Computer modeling; Criminal responsibility, historical concepts; *Mens rea*.

First responders

It is usually a call to the emergency services that triggers the investigation of a potential crime. That is why the first person on the scene, known as the first responder, is usually a police, fire, or medical officer. His or her priority is always the safety of those who are at the scene, but the responder also has to be aware of the importance of preserving **evidence** that may be relevant to any crime that has been committed. After all, he or she is the only person to see the location in its original state. The actions and observations of first responders can therefore be crucial in terms of gathering and preservation of evidence that may eventually be presented in court.

On arrival at the scene, the first responder will carry out an initial assessment of whether a crime has actually been committed. If there is an obvious victim, the first priority has to be to offer first aid and any other assistance. In the case of a serious crime, the first responder will call for help so that the tasks of dealing with those present and preserving evidence can be delegated.

Although the first responder's first priority is assistance rather than looking for evidence, he or she will still keep the latter in mind in all their actions. However, the destruction of evidence is acceptable if it is needed to help a victim or even save their life. Whatever first responders do has the potential to affect evidence, and they need to be aware of this. Their first task is to assist any victims present at the scene of crime. They will also look for any suspects and arrest them if possible. Witnesses must be detained and kept separately. This is to stop them sharing from their stories and contaminating evidence. Should the first responder see suspects, victims, or witnesses trying to clean up or dispose of evidence, then they have a duty to stop them in the interest of preserving the scene.

The first responder will then secure the scene of crime by taping it off and taking careful note of who comes in and out. Entry is restricted to those who

Emergency workers attend to an 80-year-old woman involved in a single-car accident which caused her car to flip onto its roof in Berlin, Vermont, on August 14, 1998. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

have a need to be there. Evidence outside this barrier may be easily contaminated, so the first responder should make the sealed-off area as wide as is practicably possible. The cordon should be policed and arrangements made to deal with the public and press, giving them information without allowing access that could otherwise disturb evidence.

When the first responder attends to a victim, he or she may need to move the person or any evidence. When this happens, a record should be taken of any actions that are performed. The original position and posture of the body and anything that is moved should be carefully recorded. The victim could need to go to the hospital and, ideally, someone would go with him or her. However, should the first responder be alone, the duty is to remain at the scene.

In the case of a serious crime, forensic investigators will be called to the scene. It is important for the first responder to mark out a common approach path for those coming to the scene later. This reduces the possibility of disturbing or contaminating the evidence at the scene, which can easily happen if people are moving at random through the site. Often the common approach path is from the cordon to the focal point of a crime, such as a body. Possible entry and exit points of perpetrators will also be avoided so that valuable evidence is not disturbed.

First responders must always minimize the impact they themselves have on the scene. They should attempt to minimize their own fingerprints or other trace left evidence behind and take special care to avoid areas and items that may contain suspects' fingerprints, such as doorknobs and light switches. Everything they do should be carefully recorded in case it alters the original crime scene. Sooner or later the first responder will be joined or replaced by others. It is particularly important that a record of what has been observed and carried out by the first responder is handed over by those who are next on the scene of crime. The **chain of custody** of evidence begins with first responders, even though they are not forensic experts. Their actions at the scene can be vital in the preservation of important evidence.

SEE ALSO Crime scene investigation.

Raymond M. Fish

AMERICAN
ELECTRICAL INJURY EXPERT

Raymond M. Fish has practiced emergency **medicine** for over two decades, and has become an expert in the study of electrical injury. As an instructor, researcher, lecturer, and author, Fish has spread his knowledge of treating electrical injuries and explaining the biological effects of electrical currents on the human body. He also has served as an expert witness and consultant in cases concerning electrical injury and related topics.

Fish earned his Ph.D. in biomedical engineering from Worcester Polytechnic Institute and Clark University. He is board certified in emergency medicine and has practiced this specialty since the 1980s. Fish also works as a professor, teaching bioengineering, surgery, advanced cardiac life support, advanced trauma life support, and electrical and computer engineering at the University of Illinois at Urbana-Champaign. At the university's Beckman Institute, Fish has conducted studies that combine engineering and medicine, such as the possibilities of using ultrasound to diagnose medical conditions. He is a fellow of the American College of Emergency Physicians, and a member of the Institute of Electrical and Electronics Engineers.

Fish is well known for his literary contributions to the treatment and investigation of electrical injury. He is a contributing author of *Forensic Aspects of Chemical and Biological Terrorism.* Written for public health and safety workers, the book addresses the roles and responsibilities of these officials in the event of a terrorist attack. Fish also co-wrote *Medical and Bioengineering Aspects of Electrical Injuries*, which serves as a reference manual for treating electrical injuries. He also has written many articles for trade journals and other periodicals, on topics including the effects of tasers and stun guns and physician and hospital responsibility.

Fish's interest in the interaction of law with medicine led him to work as a witness and consultant in legal cases involving electrical injuries and medical negligence. Through this involvement with attorneys and lawsuits, Fish has written books and articles related to medical/legal topics. He co-wrote *Electrical Injuries: Engineering, Medical and Legal Aspects*, which analyses electrical injury issues dealt with by litigators and investigators. He also wrote *Preparing for Your Deposition*, a book that outlines the deposition process and gives advice for dealing with deposition tactics.

SEE ALSO Death, cause of; Technology and forensic science.

Flame analysis

Some forensic analytical determinations rely on the separation of the various components in a mixture of compounds. One means of accomplishing this separation is to heat the sample using a flame.

The separated compounds can then be analyzed and identified. For example, when metals are burned, they can produce a characteristic color. The colors produced by the flame test are compared to known standards and the presence of certain elements in the sample can be confirmed. The color of the flame and its spectrum (component colors) is unique for each element.

Flame analysis or atomic emission **spectroscopy** (AES) is based on the physical and chemical principle that atoms—after being heated by flame—return to their normal energy state by giving off the excess energy in the form of light. The frequencies of the light given off are characteristic for each element.

Flame analysis is a qualitative test and not a quantitative test. A qualitative chemical analysis is designed to identify the components of a substance or mixture. Quantitative tests measure the amounts or proportions of the components in a reaction or substance.

The unknown to be subjected to flame analysis is either sprayed into the flame or placed on a thin wire that is then put into the flame. Volatile elements (chlorides) produce intense colors. The yellow color of sodium, for example, can be so intense that it overwhelms other colors. To prevent this, the wire to be coated with the unknown sample is usually dipped in hydrochloric acid and subjected to flame to remove the volatile impurities and sodium.

As useful as it is to forensic analysis, the flame test does not work on all elements. Those that produce a measurable spectrum when subjected to flame include, but are not limited to, lithium, sodium, potassium, rubidium, cesium, magnesium, calcium, strontium, barium, zinc, and cadmium. Other elements may need hotter flames to produce measurable spectra.

Other forensic analytical techniques are required to identify such substances. Typically, if there is enough of a sample, the sample can be divided into portions for testing by various techniques. This increases the likelihood of properly identifying the components of the sample.

Special techniques are required to properly interpret the results of flame analysis. The colors produced by a potassium flame (pale violet) can usually be observed only with the assistance of **glass** that can filter out interfering colors. Some colors are similar enough that line spectrum must be examined to make a complete and accurate **identification** of the unknown substance, or the presence of an identifiable substance in the unknown.

Flame analysis can also be used to determine the presence of metal elements in water by measuring the spectrum produced by the metals exposed to flame. The water is vaporized and then the emissions of the vaporized metals can be analyzed.

SEE ALSO Analytical instrumentation; Chromatography.

Flight data recorders

In the aftermath of an air crash, an extremely important task is to determine the cause of the disaster. This can be a daunting task, requiring patience and great attention to detail, since very little may be left of the aircraft. Eyewitness information, burn patterns, and the pattern of wreckage can all yield information as to the cause of the crash. The forensic work is greatly aided by the recovery of what is termed the "black box," or flight data recorder.

The flight data recorder is a repository of information about the operation of the aircraft. Sensors positioned throughout the aircraft relay information about the plane for storage in the data recorder.

In the earliest days of air transportation, plane crashes yielded few clues for safety investigators. Investigators would struggle to determine what happened immediately preceding the accident but often failed to come to any definite conclusions regarding the cause of the crash.

In June 1960, a Fokker F27 plane crashed while landing in Queensland, Australia, killing 29 people. Despite intensive investigations, the underlying cause for the accident was never determined. The mystery prompted the Australia board of inquiry to recommend that all airplanes be fitted with a flight data recorder (FDR) that would detail the flight crew's conversation.

Efforts to make the FDR a mandatory part of civil aircraft date back to the early 1940s. The idea, however, had one enormous technological challenge. Design specifications required that the unit survive the forces of an aircraft crash, as well as any resulting fire exposure.

In 1953, at a time when flight engineers were attempting to understand why a number of airliners had inexplicably crashed, Australian aviation scientist David Warren of the Aeronautical Research Laboratories in Melbourne invented a fully automatic "Flight Memory Unit." His prototype could record cockpit noise and instrument readings and remain intact following a crash or fire. Much to Warren's surprise, Australian aviation experts and pilots originally rejected the idea on the premise of privacy issues. Warren took the concept to the United Kingdom, where it was well received by aviation officials. By 1957, the FDR was in production. Australia then became among the first countries to require the device on commercial aircraft.

The common nomenclature for the FDR, the "black box," is actually a misnomer, since the unit is typically bright red or orange to facilitate visual location after a crash. The FDR is encased in heavy steel and surrounded by multiple layers of insulation to provide protection against a crash, fire, and extreme climatic conditions.

The device records actual flight conditions, including altitude, airspeed, heading, vertical acceleration, and aircraft pitch. A second device, the cockpit voice recorder (CVR), keeps tabs on cockpit conversations and engine noise. Both are installed in the rear of the aircraft.

In the 1970s, FDR technology was combined with a flight-data acquisition unit (FDAU), located at the front of the aircraft. The unit acts as the relay for the entire data-recording process. Sensors run from various areas on the plane to the FDAU, which in turn sends the information to the FDR.

In the early days, data were embossed onto a type of magnetic foil known as Incanol Steel. The foil proved to be destructible and FDR manufacturers began using a more reliable form of magnetic tape. Electromagnetic technology remained the data-recording medium of choice until the late 1990s, when solid-state electronics began to show promise. Solid-state recorders rely on stacked arrays of non-moveable memory chips. The technology is considered more reliable than magnetic tape, as the lack of moving parts provides a reduced chance of breakage during a crash.

Solid-state recorders also track a much greater number of parameters; 700 are tracked compared to the magnetic tape parameter recording potential of 100. Faster data flow allows the

A cockpit voice recorder, from crashed ValuJet Flight 592, drips mud after crash site searcher recovered it from the Florida Everglades. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

solid-state devices to record up to 25 hours of flight data. In 1997, the United States Federal Aviation Administration (FAA) issued a requirement that all aircraft manufactured after August 19, 2002, record at least 88 parameters. The action came in the wake of two B-737 airplane crashes in which insufficient data was available to determine the cause of the accidents.

Modern day devices also track time, control-column position, rudder-pedal position, control-wheel position, horizontal stabilizer, and fuel flow.

Since its inception, the FDR has played a vital role in establishing the probable cause of a crash or other unusual occurrences and has allowed safety regulators to implement corrective actions. The value of flight data recorders was clearly evident in the investigation of the ATR-72 accident in Roselawn, Indiana, in October 1994. The FDR captured information on 115 parameters. Analysis of the data revealed a telltale, rapid wing movement that prompted the National Transportation and Safety Board to immediately issue urgent safety recommendations to improve flying in icy conditions.

SEE ALSO Aircraft accident investigations.

Fluids

Forensic analytical chemistry plays a crucial role in the **identification** of **physical evidence**, such as body fluids, tissues, and inorganic specimens (e.g., **artificial fibers**, accelerants, gun powder) found at crime scenes. Substance-specific metabolites, derived from the physiologic transformation of medications, **illicit drugs**, poisons, or alcohol, can be identified in **blood**, **saliva**, and urine. Blood and **semen** are also the preferred sources for **DNA** extraction from both victims and suspects, although saliva may also contain epithelial cells from the oral tract, from which DNA can be extracted. Therefore, body fluids may be used to detect drugs or other harmful chemicals present in the body or for DNA analysis.

Toxicological tests provide both qualitative results (the identification of substances present in the body) and quantitative results (amounts of substances present the body). Legal **medicine** also uses these tests for several other purposes related to public health, such as the determination of acceptable levels of **toxins** in the food and water supply, and determining the toxic potentials of prescription drugs and their interactions with other drugs.

Blood alcohol levels can be detected even after three or more hours after drinking. Metabolites of cannabis, LSD, and other hallucinogenic drugs persist in the system much longer, up to 72 hours, and are detected in cerebrospinal fluid, urine, blood, and other tissues. Blood levels of morphine derived from heroin injection and methamphetamine metabolites may be identified in several fluids and tissues, such as blood, urine, liver, muscles, and cerebrospinal fluids. The same is true for a variety of other chemicals and toxic gases as well as animal toxins, such as poison metabolites from venomous animals or insect bites.

Forensic investigators **processing** a crime scene must collect, condition, store, and transport body fluids, following strict technical and legal protocols to avoid contamination in order to guarantee credibility in courts. **Evidence** should be handled by the minimum possible number of personnel, preferably only two: the crime scene technician who collects it and the crime laboratory expert in charge of forensic testing. This is important because by law, all those who handled the evidence between the time of its collection and its analysis must be prepared to testify in court. This procedure is termed the “chain of custody.” A **chain of custody** usually consists of the officer who seized the evidence and the forensic toxicologist, forensic chemist, or other officer who entered in direct contact with the substance before or after it was packaged (but not those who touched the outer sealed container). The validity and acceptability of the evidence may be questioned in court if this procedure is not properly followed and reported.

Biological fluids from victims and suspects are analyzed and compared for matches in cases of **murder**, rape, or in paternity tests. The first blood test involves usually ABO and other blood typing. Because this procedure only narrows the population of probable suspects, DNA analysis from blood, or semen, or other tissue may be necessary to establish a more precise match. Sometimes blood at a crime scene, especially near a victim, contains DNA from both the victim and the aggressor. DNA analysis is known as DNA typing or **DNA profiling**, and consists of several molecular techniques that screen specific segments of human DNA where certain characteristics are almost 100% unique in each individual.

DNA profiling is useful either to exclude a suspect or to identify one, through the comparison of the suspect's DNA with samples taken from the crime scene. In the absence of a suspect, the sample may be compared against DNA data banks such as **CODIS**, where thousands of DNA profiles of known criminals and suspects are recorded. DNA analyses do not always offer a 100% certainty in all cases, because DNA content in samples could have suffered degradation, or because the quantity of a sample is not large enough. However, the combination of several DNA tests, each one specific to a different segment or locus of the DNA molecule, may provide a unique pattern of matches that allows a high degree of scientific certainty as to whom it belongs. The probability that a person other than the suspect would display that same genomic pattern is about one in every five trillion individuals chosen from the population, with the exception of identical twins. Because the world population is around six billion, DNA profiling is a powerful identification tool.

SEE ALSO Assassination weapons, biochemical; Blood spatter; Bloodstain evidence; Breathalyzer®; Chemical and biological detection technologies; CODIS: Combined DNA Index System; Cross contamination; DNA evidence, cases of exoneration; DNA profiling; DNA sequences, unique; DNA typing systems; Luminol; Medical Examiner; Narcotic; Paternity evidence; Rape kit; Saliva; Serology; Toxicological analysis; Toxicology; Toxins.

Fluorescence

Fluorescence is an optical phenomenon wherein a material emits light in response to some external stimulus. Normally, the fluorescent light that is emitted is of a specific color or group of colors that is released when the material is bombarded with light in some other part of the color spectrum.

Certain **minerals** have a characteristic fluorescence pattern when hit with white light or ultraviolet light. Fluorite and calcite are two examples of fluorescent minerals. There are also many organic dye molecules with useful fluorescent properties. These molecules absorb light energy from external sources, and this energy causes some excitation of the electron orbitals in a process called pi-bonding. When the excited pi-bonds relax back to a lower energy state, photons of a specific wavelength are emitted in the process, giving rise to the fluorescent light. These organic dyes can be characterized by the wavelengths of light that they absorb (excitation wavelengths), and the wavelengths of light that they emit (emission wavelengths). The excitation and emission wavelengths are properties of each dye that are highly specific and reliable. Organic dyes tend to degrade over time as they are bombarded with light in a process called photodegradation. During photodegradation, the excited pi-bonds can break, rather than relaxing into their lower energy state. Organic fluorescent dyes have been in use for many years.

More recently, it has been discovered that very small particles of certain semiconductor materials also fluoresce, and the color of the fluorescence is dependent only on the size of the particles. These materials are referred to as quantum dots. Quantum dots absorb energy from a range of wavelengths, but the energy is not taken into pi-bonds. Rather, the fluorescence results from quantum mechanical interactions within the material. Smaller particles emit light on the blue end of the spectrum, whereas larger particles emit light on the red end of the spectrum. Because light energy is not absorbed into fragile pi-bonds, the rate of photodegradation is much lower for quantum dots compared with organic dyes, and thus the fluorescent signals are brighter and more durable.

There are a number ways in which fluorescence plays into forensic investigations. Biological materials sometimes have a characteristic fluorescent property that facilitates quick **identification** under UV examination. **Semen** stains, for example, may be identified by their characteristic fluorescence under ultraviolet light examination. Fluorescence of other biological samples can be brought about by chemical treatment to make their detection easier. Fingerprints can be treated with fluorescent powders to permit identification and detection even of relatively faint (latent) or degraded prints. Likewise, application of highly fluorescent materials, such as spy dust, permits tagging and tracking of suspects or agents across fairly wide areas by following the path of dispersal of the fluorescent agent as they drag and redistribute an unseen powder with their shoes or clothing. Certain chemicals, such as **explosives** and nerve agents, can sometimes be traced in the environment from their characteristic fluorescent spectral patterns. Examination of microscopic **fibers** for fluorescence can produce **evidence** linking suspects to crime scenes or other physical locations.

Fluorescence is a tool that allows evidence that would normally be invisible to come to light. It is a source of evidence only found with careful examination by those who are aware of its latent powers.

SEE ALSO Chemical and biological detection technologies; Confocal microscopy; Microscopes; Semen and sperm.

Food poisoning

Forensic investigations can involve determining if an illness or death was related to the contamination of food, along with the origin of the contamination.

Food poisoning refers to an illness that is caused by the presence of bacteria, poisonous chemicals, or another kind of harmful compound in a food. Bacterial growth in the food is usually required. Food poisoning is different from food intoxication, which is the presence of pre-formed bacterial toxin in food.

There are over 250 different foodborne diseases. The majority of these are infections, and the majority of the infections are due to contaminating bacteria, viruses, and parasites. Bacteria cause the most food poisonings. The United States **Centers for Disease Control and Prevention** estimates that 76 million Americans become ill each year from food poisoning. The cost to the economy in medical expenses and lost productivity is estimated at $5–6 billion per year. Infections with the common foodborne bacteria called salmonella alone exact about a $1 billion economic toll per year.

Aside from the economic costs, food poisoning hospitalizes approximately 325,000 Americans each year, and kills more than 5,000 Americans.

Staphylococcus is the most common cause of food poisoning. The bacteria grow readily in foods such as custards, milk, cream-filled pastries, mayonnaise-laden salads, and prepared meat.

Two to eight hours after eating, the sudden appearance of nausea, stomach cramps, vomiting, sweating, and diarrhea signal the presence of food poisoning. Usually only minor efforts need be made to ease the symptoms, which will last only a short time even if untreated. Over-the-counter preparations to counter the nausea and diarrhea may help to cut short the course of the condition. Recovery is usually uneventful.

This syndrome is especially prevalent in summer months when families picnic out-of-doors and food can remain in the warmth for hours. Bacterial growth is rapid under these conditions in lunchmeat, milk, potato salad, and other picnic staples. The first course of eating may be without consequences, but after the food remains at ambient temperature for two hours or more, the probability of an infectious bacterial presence is increased dramatically. The second course or mid-afternoon snacks can lead to an uncomfortable sequel.

A far more serious form of illness is produced by a toxin secreted by the bacterium *Clostridium botulinum*. Botulism, which is frequently fatal, is a hazard of home canning of food and can develop from commercially canned products in which the can does not maintain the sterile environment within it. Affected food has no tainted taste. Normal heating of canned products in the course of food preparation will neutralize the toxin but will not kill the bacterial **spores**. These will open inside the body, the bacterium will multiply, and sufficient toxin can be produced to bring about illness.

Ingestion of botulism-contaminated food does not lead to the gastric symptoms usually associated with food poisoning. Botulism toxin affects the nervous system, so the symptoms of botulism may involve first the eyes, with difficulty in focusing, double vision, or other conditions, then subsequent difficulty in swallowing and weakness of the muscles in the extremities and trunk. Death may follow. Symptoms may develop in a matter of hours if the tainted food has been consumed without heating, or in four to eight days if the food is heated and the bacterium needs the time to grow.

The most common foodborne bacterial infections are caused by campylobacter, salmonella, and a type of ***Escherichia coli*** (E. coli) designated O157:H7. The latter is the cause of “hamburger disease.” A virus known as calcivirus or Norwalk-like virus also is a common cause of food poisoning.

Escherichia coli O157:H7 lives in the intestines of cattle. When it contaminates food or water, it can cause an illness similar to that caused by salmonella. However, in a small number of cases, a much more devastating illness occurs. A condition called hemolytic uremic syndrome produces bleeding, can lead to kidney failure and, in the worst cases, can cause death.

Food poisoning often affects numbers of individuals who have dined on the same meal. This enables forensic scientists to trace the contaminated food and, if needed, determine the specific type of bacterium that caused the illness.

SEE ALSO Poison and antidote actions.

Food supply

When investigating an illness outbreak or a death, one of the possibilities that a forensic investigator will assess is the involvement of food. The accidental or malicious contamination of food can be debilitating or, depending on the agent involved, fatal.

A variety of microorganisms or compounds produced by the organisms can contaminate food. As well, **inorganic compounds** in food can cause illness. Knowledge of the type of food and symptoms displayed can guide a forensic investigator in uncovering the source of the food contamination.

For example, if the nature of the last meal eaten and the symptoms demonstrated by the person affected are known, then forensic examination of the **blood** for the presence of a particular bacterial toxin may be a prudent step.

Food supplies can be compromised accidentally or deliberately. Since the terrorist attacks on United States soil in September 2001, much concern has focused on the susceptibility of food supplies to deliberate contamination.

Obtaining a strain of bacteria or virus that causes plant or animal diseases is much easier than obtaining a highly infectious human pathogen. Agricultural **pathogens** can even be obtained from the environment. For example, scraping the surface of infected leaves is sufficient to recover some disease-causing viruses. Both the former Soviet Union and Iraq are known to have experimented with agricultural pathogens.

Microorganisms can also be purchased from supply laboratories. An organization with convincing paperwork would be able to acquire microbes that are not considered to be highly infectious.

The advent of recombinant **DNA** technology in the 1970s—where a segment of genetic material coding for a protein of interest (i.e., a toxin) can be isolated and spliced into the DNA of a target microbe—holds the potential for the genetic modification of bacteria or viruses that are common in the environment. These genetic versions could spread quickly through the natural world.

Aside from deliberate contamination, food can harbor some types of harmful bacteria such as *Clostridium botulinum* and ***Escherichia coli*** O157:H7, and can cause illness when the food is eaten. Depending on the type of bacteria involved, the mere presence of the bacteria or its toxin may be sufficient to cause illness. Other bacteria need to grow to high numbers in the food before they become noxious. A well-known example is the bacterium *Staphylococcus aureus*, which has been identified in historical **food poisoning** outbreaks resulting from contaminated and improperly stored foods such as potato salad.

Different types of microorganisms contaminate different types of food. For example, the aforementioned *Clostridium botulinum* requires the absence of oxygen. Thus, improperly prepared (usually inadequately heated) canned foods are prone to contamination. The bacterium can produce a potent neurotoxin (a poison that acts upon the nervous system) that can paralyze and even kill a person who eats the contaminated food.

As well, *Clostridium botulinum* has the ability to form an environmentally resistant protective structure called a spore. The spore form of the organism can persist in a dormant state for very long periods of time. When conditions are more favorable for growth, resuscitation and toxin production can resume.

Following the September 11, 2001, terrorist attacks, the U.S. government moved to strengthen the country's defense against **bioterrorism**. This initiative culminated in the signing into law, on June 12, 2002, of the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (the Bioterrorism Act). The act authorized the Secretary of Health and Human Services to protect the nation's food supply. The U.S. Food and Drug Administration (**FDA**) is the lead agency in initiating the protective measures.

The U.S. measures are aimed at providing a system of accountability. For example, all businesses or growers who sell food for consumption in the U.S. must register with the government. As well, these firms will be required to maintain records of their food handling and processing activities. In the event of a deliberate contamination, this information would allow the source of the contamination to be traced.

The surveillance of food also must include inspection of food entering the country. This involves the manual inspection of foods arriving by air, sea, rail, and surface routes. Inspections typically consist of the visual examination of foods, although the use of portable devices that detect microorganisms or their products is being used experimentally. Other such devices are in the laboratory stage of testing, and have produced accurate results in laboratory settings.

Widespread alerts are often quickly recognized, and contaminated food sources are removed from the food supply, usually before many people will have consumed the contaminated food. Consumer vigilance is an additional important measure to protect the food supply. For example, even if raw produce has been doused with a poison or an infectious microorganism, careful washing will usually remove the threat. Canned foods that are damaged or swollen should be identified and discarded.

SEE ALSO Aflatoxin; Bacteria, growth and reproduction; Bioterrorism; Botulinum toxin; Food poisoning; Pathogens; Spores; Toxins.

Forensic accounting

Over the years, the role of the certified public accountant (CPA) has changed dramatically, with some of today's CPAs becoming quasi-private investigators in order to keep up with demands for fraud examinations. These specialized individuals use investigative procedures in an effort to uncover fraudulent activities being perpetrated on a business. Forensic accounting is a term used to describe the work being performed by accountants in advance of litigation and may include bankruptcy, valuation, fraud, and a variety of additional services. It is estimated that each year approximately $400 billion is lost due to employee fraud. To determine the depth and scope of the crime, a fraud examination is conducted in order to find where it is being perpetrated and by whom. Often the auditor must delve into the psyche of the suspect to find a motive for the crime. There are three main reasons why an employee generally steals from his employer, making up what is termed a fraud triangle.

The key elements that comprise most every fraud triangle include opportunity, pressure, and rationalization. The first and most important segment of a fraud triangle is opportunity. Often, companies unknowingly and unwisely offer their employees the opportunity to commit fraud. Typically it is a lack of adequate control and monitoring of employee actions that afford the chance to steal. An example to demonstrate opportunity would be a cashier or accounts receivable person being responsible for the daily collecting and depositing of payments. Without adequate control measures to authenticate the employee's accuracy, funds could easily be embezzled without notice.

Of course, not all employees will seize the opportunity to steal, so what additional factors also figure in to a fraud triangle? Succumbing to pressure is very often the reason why someone chooses to steal when others do not. Financial pressure can arise from a myriad of sources such as personal debt, business losses, and lifestyle standards. Therefore, employees with known financial trouble should not be placed in positions involving money transactions or other duties that would offer a chance to commit fraud. Even peer pressure can be a factor in an employee choosing to steal.

Rationalization is the third element of the fraud triangle. Regardless of the reason for taking money, the thief must then try to rationalize why he or she committed the fraud. The employee who steals often attempts to justify the crime psychologically. Such rationalizations might include thinking the company has so much money that the theft would not be noticed, or the money is for a worthy endeavor such as college tuition or emergency medical expenses. In this way, the perpetrator often attempts to ease a nagging conscience about stealing. In most cases however, the employee makes a mistake or error that places a cloud of suspicion upon them. This is when the fraud examination is conducted.

A fraud examination generally consists of four successive segments: analyzing the available data, developing a fraud theory, revising it as necessary, and confirming the theory. The first step is analyzing financial information culled from the books and records. The particular type of fraud that is being investigated will determine which documents, files, records, and other information are needed for studying. Once the information has been gathered, sorted, and processed, the examiner begins to review and analyze the data in order to develop a theory of what could have happened and who was the perpetrator.

Usually the theory addresses one of three types of internal or occupational fraud: asset misappropriation, corruption, or fraudulent financial statements. The examiner goes through a series of tests and retests in order to determine if there is sufficient **evidence** to proceed further. The evidence must be substantial enough to stand up in a court of law. If the examination is sound and has merit, then the corporate legal counsel is apprised of impending litigation, interviews are ordered, and third-party and corroborative witnesses are questioned. The examination must be detailed, in depth, and substantiated with indisputable evidence in order to move to the next stage, which entails confronting the suspect or target. This procedure is called an admission-seeking interview, and involves a deliberate process that lays out the evidence to the target in a specific order. The questions must be precisely phrased and the answers correctly interpreted so as to avoid any confusion or misunderstanding. While these procedures help detect and find fraud, the more practical solution would be to prevent fraud from occurring.

The problem with prevention is that certified fraud examiners and forensic accountants cannot affect the internal and external controls that tend to lead to fraud. The problem of company fraud is a social issue, not an accounting issue, and without effective punishment measures, the practice is expected to rise. Punishment is often neither swift nor certain when is comes to fraudulent crimes. It is also difficult for courts and judges to determine the punishment when an accounting crime ended with the destruction of a company that had employed many individuals who lost pensions and retirement investments as well as jobs.

The idea of prevention would seem like the correct response to an ever-increasing crime wave. However, given the current methods of detection of fraud, the fraud examination, and employing the methodology of the fraud triangle, prevention suddenly becomes closer to invasion of privacy and targeting of persons. If the manager of a clinic tells his employer about his spouse being laid-off from work, should the employer then keep a close eye and ear on the manager in order to prevent the possibility of an opportunity to defraud the clinic by the manager? The idea of **profiling** an employee for any potential of defrauding a company is not consistent with ethical standards of business.

Fraud examination and the fraud triangle are two of the most effective and important procedures a CPA or auditor can use when determining the existence of fraudulent behavior or activities in a company. Both of these concepts constitute the science of forensic accounting and help to uncover any illegal activities. The modern day accountant must have working knowledge of forensic accounting in order to be a success in the field. The government binds an accountant by various laws and statutes in order to obligate them to report any financial mishaps or miscues on the part of the company.

SEE ALSO Document destruction; Document forgery; Evidence; Federal Rules of Evidence.

Forensic nursing

The field of forensic nursing has become increasingly popular since the last decade of the twentieth century, and is predicted to continue to be one of the fastest growing and most desirable nursing specialties.

In 1992, a group met in Minneapolis for the first convention of sexual assault nurses. One of the meeting's outcomes was the creation of the term, and the specialty, of forensic nursing. Another outcome was the inception of the International Association of Forensic Nurses (IAFN). The IAFN is the only international professional registered nurses' organization created with the specific goals of developing, advancing, and disseminating information about the science of forensic nursing. In 1995, forensic nursing was recognized as a clinical specialty by the American Nurses Association.

A growing number of schools of nursing offer **training**, certificates, or advanced degrees in the area of forensics. Some of the specialty areas within forensic nursing include: forensic clinical nurse specialist, forensic nurse investigator, nurse coroner/death investigator, sexual assault nurse examiner (SANE), sexual assault response team member (SART), legal nurse consultant, forensic gerontology specialist, forensic psychiatric nurse, and correctional nursing specialist.

Specialized forensic nursing coursework and practical training typically include advanced training in the identification of traumatic wounding, including training in recognition of patterned wounds, and injuries in various stages of healing (it is not uncommon in domestic violence situations to see victims with fresh, relatively new, and older healing injuries). Forensic nurses are trained to objectively, record a complete chronology of the injuries from the victim, patient, parent, legal guardian, or caregiver; they (forensic nurses) are often skilled at crime victim **photography**. This experiential combination makes them valuable **expert witnesses** in court proceedings.

In 2002 the Forensic Nursing Certification Board (FNCB) had its inception. The mission of the FNCB is to uphold the highest standards of both the science and the clinical practice of forensic nursing, via the creation, utilization, promulgation, and assessment of every aspect of the forensic nursing certification (and re-certification) process.

It is the stated philosophy of the FNCB that the clinical specialty of forensic nursing encourages attainment of the ultimate standards of nursing practice in order to deliver the best possible patient care. The FNCB seeks to standardize the coursework, training, and practice of forensic nursing in order to provide a common knowledge and experiential base. This, in turn, will lead to uniformly superior skill levels in the field. As a result of this professional standardization, the attainment of forensic nurse certification will be professionally (and legally) meaningful.

Quite often, work as a SANE or SART nurse provides an entry point into forensic nursing. Through the course of their work, SANE and SART nurses interact with coroners, members of law enforcement, judges, district attorneys, victims' advocates, criminal and civil attorneys; this is an ideal way to segue into forensic nursing. The SANE-A credential, a professional certification conferred by the FNCB, is given to sexual assault nurse examiners with adolescent and adult expertise. It indicates achievement of the most stringent standards of forensic nursing expertise in the field of sexual assault nurse examination, resulting in professional board certification.

Forensic nurses often interact with those involved in rape, child and elder abuse, domestic violence, and trauma associated with violent crimes. The work of forensic nurses can vary widely, from providing (typically emergency) care to both crime victims and perpetrators, to collecting or photographing **evidence** for law enforcement agencies, to performing death investigations, to providing support for emergency workers at crisis settings, to counseling schoolchildren who use weapons, to providing physical (and sometimes behavioral health) care in the correctional system, to acting as legal nurse consultants and expert witnesses in the court system.

They may provide direct nursing services to individuals, act as professional consultants to nursing, medical, legal, and law enforcement agencies, or provide expert witness testimony in court settings regarding trauma, questioned death investigations, adequacy, and appropriateness of service delivery, and offer diagnostic opinions on issues pertaining to specific nursing-related conditions.

Forensic nurses are particularly valuable in the emergency medical setting, as health care professionals are typically taught to clean and treat wounds and injuries, resulting in loss of valuable evidence and, sometimes, leading to an inability to prosecute crimes.

Nurse Lauren Guerira, who was involved with the investigation of the rape kit report of the alleged accuser, prepares to testify in the sexual assault trial of NBA basketball star Kobe Bryant in 2004. © ED ANDRIESKI/POOL/REUTERS/CORBIS

Forensic nurses are trained to photograph and meticulously document trauma and injuries, to collect, to preserve, and to properly package evidence.

Clinical forensic nursing involves applying standard clinical nursing theory and practice to the complex treatment of trauma, or to the investigation of death, of victims or perpetrators of criminal violence, child, elder, and domestic abuse, and traumatic accidents. Forensic nurses interact with the legal justice and law enforcement systems regularly.

Forensic nursing, a specialty field steadily gaining in both importance and popularity, is of significant importance whenever and wherever clinical nursing and the law enforcement (and legal) systems interact.

SEE ALSO Accident reconstruction; Careers in forensic science; Crime scene cleaning; Paternity evidence; Photography; Physical evidence; Rape kit.

Forensic science

Forensic science is a term used to describe the actions taken by investigators in multidisciplinary fields for the examination of crime scenes and gathering of **evidence** to be used in prosecution of offenders in a court of law. The main use of forensic science is for purposes of law enforcement to investigate crimes such as **murder**, theft, or fraud. Forensic scientists are also involved in investigating accidents such as train or plane crashes to establish if they were accidental or a result of foul play. The techniques developed by forensic science are also used by the U.S. military to analyze the possibility of the presence of chemical weapons or high **explosives**, to test for propellant stabilizers, or to monitor compliance with international agreements regarding weapons of mass destruction.

The main areas used in forensic science are biology, chemistry, and **medicine**, although the science also includes the use of physics, computer science, **geology**, or **psychology**. Forensic scientists examine objects, substances (including **blood** or drug samples), chemicals (paints, explosives, **toxins**), tissue traces (hair, skin), or impressions (fingerprints or tidemarks) left at the crime scene. The majority of forensic scientists specialize in one area of science.

The analysis of the scene of a crime or accident involves obtaining a permanent record of the scene (forensic **photography**) and collection of evidence for further examination and comparison. Collected samples include biological (tissue samples such as skin, blood, **semen**, or hair), physical (fingerprints, shells, fragments of instruments or equipment, **fibers**, recorded voice messages, or computer discs) and chemical (samples of paint, cosmetics, solvents, or soil).

Most commonly, the evidence collected at the scene is subsequently processed in a forensic laboratory by scientists specializing in a particular area. Scientists identify, for example, fingerprints, chemical residues, fibers, hair, or **DNA**. However, miniaturization of equipment and the ability to perform most forensic analysis at the scene of crime results in more specialists being present in the field. Presence of more people at the scene of crime introduces a greater likelihood of introduction of contamination into the evidence. Moreover, multi-handling of a piece of evidence (for example, a murder weapon) is also likely to introduce traces of tissue or DNA not originating from the scene of a crime. Consequently, strict quality controls are imposed on collection, handling, and analysis of evidence to avoid contamination.

The ability to properly collect and process forensic samples can affect the ability of the prosecution to prove their case during a trial. The presence of chemical traces or DNA on a piece of debris is also crucial in establishing the chain of events leading to a crime or accident.

Biological traces are collected not only from the crime scene and deceased person, but also from surviving victims and suspects. Most commonly, samples obtained are blood, hair, and semen. DNA can be extracted from any of these samples and used for comparative analysis.

DNA is the main method of identifying people. Victims of crashes or fires are often unrecognizable, but if adequate DNA can be isolated a person can be positively identified if a sample of their DNA or their family's DNA is taken for comparison. Such methods are being used in the **identification** of the remains in Yugoslav war victims, the World Trade Center terrorist attack victims, and the 2002 Bali bombing victims.

Biological traces, investigated by forensic scientists come from bloodstains, **saliva** samples (from cigarette butts or chewing gum) and tissue samples, such as skin, nails, or hair. Samples are processed to isolate the DNA and establish the origin of the samples. Samples must first be identified as human, animal, or plant before further investigation proceeds. For some applications, such as customs and quarantine, traces of animal and plant tissue have to be identified to the level of the species, as transport of some species is prohibited. A presence of a particular species can also prove that a suspect or victim visited a particular area. In cases of national security, samples are tested for the presence of **pathogens** and toxins, and the latter are also analyzed chemically.

A growing area of forensic analysis is monitoring non-proliferation of weapons of mass destruction, analysis of possible terrorist attacks, or breaches of security. The nature of samples analyzed is wide, but slightly different from a criminal investigation. In addition to the already-described samples, forensic scientists who gather evidence of weapons of mass destruction collect swabs from objects, water, and plant material to test for the presence of radioactive isotopes, toxins, or poisons, as well as chemicals that can be used in production of chemical weapons. The main difference from the more common forensic investigation is the amount of chemicals present in a sample. Samples taken from the scene of suspected chemical or biological weapons often contain minute amounts of chemicals and require very sensitive and accurate instruments for analysis.

Forensic chemistry performs qualitative and quantitative analysis of chemicals found on people, various objects, or in solutions. The chemical analysis is the most varied from all the forensic disciplines. Chemists analyze drugs as well as paints, remnants of explosives, **fire debris**, gunshot residues, fibers, and soil samples. They can also test for a presence of radioactive substances (nuclear weapons), toxic chemicals (chemical weapons), and biological toxins (biological weapons). Forensic chemists can also be called on in a case of environmental pollution to test the compounds and trace their origin.

The identification of fire accelerants such as kerosene or gasoline is of great importance for determining the cause of a fire. Debris collected from a fire must be packed in tight, secure containers, as the compounds to be analyzed are often volatile. An improper transport of such debris would result in no detection of important traces. One of the methods used for this analysis involves the use of charcoal strips. The chemicals from the debris are absorbed onto the strip and subsequently dissolved in a solvent before analysis. This analysis allows scientists to determine the hydrocarbon content of the samples and identify the type of fire accelerator used.

Physical evidence usually refers to objects found at the scene of a crime. Physical evidence may include all sorts of prints such as fingerprints, footprints, handprints, tidemarks, cut marks, tool marks, etc. Analysis of some physical evidence is conducted by making impressions in plaster, taking images of marks, or lifting the fingerprints from objects encountered. These serve later as a comparison to identify, for example, a vehicle that was parked at the scene, a person that was present, a type of manufacturing method used to create a tool, or a method used to break in a building or harm a victim.

An examination of documents found at the scene or related to the crime is often an integral part of forensic analysis. Such examination is often able to establish not only the author but, more importantly, identify any alterations that have taken place. Specialists are also able to recover text from documents damaged by accident or on purpose.

The identification of people can be performed by **fingerprint** analysis or DNA analysis. When none of these methods is viable, facial reconstruction can be used instead to generate a person's image. Television and newspapers then circulate the image for identification.

Pathologists and forensic anthropologists play a very important part in forensic examination. They are able to determine the **cause of death** by examining marks on the bone(s), skin (gunshot wounds), and other body surfaces for external trauma. They can also determine a cause of death by **toxicological analysis** of blood and tissues.

A number of analytical methods are used by forensic laboratories to analyze evidence from a crime scene. Methods vary, depending on the type of evidence analyzed and information extracted from the traces found. If a type of evidence is encountered for the first time, a new method is developed.

Biological samples are most commonly analyzed by **polymerase chain reaction** (**PCR**). The results of PCR are then visualized by gel **electrophoresis**. Forensic scientists tracing the source of a biological attack could use the new hybridization or PCR-based methods of DNA analysis. Biological and chemical analysis of samples can identify toxins found.

Imaging used by forensic scientists can be as simple as a light microscope, or can involve an electron microscope, absorption in ultraviolet to visible range, color analysis, or **fluorescence** analysis. Image analysis is used not only in cases of biological samples, but also for analysis of paints, fibers, hair, **gunshot residue**, or other chemicals. Image analysis is often essential for an interpretation of physical evidence. Specialists often enhance photographs to visualize small details essential in forensic analysis. Image analysis is also used to identify details from surveillance **cameras**.

The examination of chemical traces often requires very sensitive chromatographic techniques or mass spectrometric analysis. The four major types of chromatographic methods used are: **thin layer chromatography** (TLC) to separate inks and other chemicals; atomic absorption **chromatography** for analysis of heavy metals; gas chromatography (GC); and liquid chromatography (HPLC). GC is most widely used in identification of explosives, accelerators, propellants, and drugs or chemicals involved in chemical weapon production, while liquid chromatography (HPLC) is used for detection of minute amounts of compounds in complex mixtures. These methods rely on separation of the molecules based on their ability to travel in a solvent (TLC) or to adhere to adsorbent filling the chromatography column. By collecting all of the fractions and comparing the observed pattern to standards, scientists are able to identify the composition of even the most complex mixtures.

New laboratory instruments are able to identify nearly every element present in a sample. Because the composition of alloys used in production of steel instruments, wires, or bullet casings is different between various producers, it is possible to identify a source of the product.

In some cases chromatography alone is not an adequate method for identification. It is then combined with another method to separate the compounds even further and results in greater sensitivity. One such method is mass spectrometry (MS). A mass spectrometer uses high voltage to produce charged ions. Gaseous ions or isotopes are then separated in a magnetic field according to their masses. A combined GC-MS instrument has a very high sensitivity and can analyze samples present at concentrations of one part-per-billion.

As some samples are difficult to analyze with MS alone, a **laser** vaporization method (imaging laser-ablation mass **spectroscopy**) was developed to produce small amounts of chemicals from solid materials (fabrics, hair, fibers, soil, **glass**) for MS analysis. Such analysis can examine hair samples for presence of drugs or chemicals. Due to its high sensitivity, the method is of particular use in monitoring areas and people suspected of production of chemical, biological, or nuclear weapons, or narcotics producers.

While charcoal sticks are still in use for fire investigations, a new technology of solid-phase microextraction (SPME) was developed to collect even more chemicals and does not require any solvent for further analysis. The method relies on the use of sticks similar to charcoal, but coated with various polymers for collecting different chemicals (**chemical warfare** agents, explosives, or drugs). Collected samples are analyzed immediately in the field by GC.

SEE ALSO Computer forensics; Crime scene investigation; DNA; DNA recognition instruments; Document forgery; Gas chromatograph-mass spectrometer; Isotopic analysis; Thin layer chromatography.

Forensic science, careers SEE Careers in forensic science

Forensic Science Service (U.K.)

The Forensic Science Service (FSS) is the largest supplier of forensic services to police forces in England, Ireland, Scotland, and Wales, commonly referred to as the United Kingdom (U.K.). The FSS is also a major forensic source of consultancy, **training**, and support throughout the U.K and overseas. Internationally, the FSS has assisted over 60 countries in various areas of casework, consulting, research, and training, especially with regard to **DNA** research and development. In fact, its Research and Service Development unit is internationally acclaimed as one of the leading forensic science research organizations in the world.

The FSS was established as an executive agency of the Home Office of the U.K. government in April 1991 when several forensic laboratories in England and Wales were brought together. It was then merged with the Metropolitan Police Laboratory, London, England, in 1996 to become what is considered similar to the **FBI** (Federal Bureau of Investigation) Laboratory in the United States. Currently, the FSS is an executive agency of the U.K. Home Office with seven laboratories equipped with the latest technologies. Although the FSS is a critical part of the criminal justice system in the U.K., it performs all of its work independent from the police.

Although capable of providing an array of basic services for nearly any police investigation, the FSS has developed specialized solutions in the following important forensic areas: illegal drugs, high-technology crime, international crime, property crime (such as robbery and vehicle theft), road policing (including offenses of drinking-and-driving), and serious crime (such as **murder** and sexual offenses). In addition, the FSS pioneered the use of **DNA profiling** in forensic science when it set up in April 1995 the world's first national criminal intelligence DNA database, the National DNA Database (NDNAD). Under the guidance of the FSS for the Association of Chief Police Officers (ACPO), the NDNAD is a very successful international forensic database that contains well over two million individual DNA profiles and an excess of 200,000 crime scene profiles. In the years 2003 and 2004, personnel of the FSS have taken part in about 150,000 criminal cases, participated in approximately 1,700 crime scenes, and appeared around 2,600 times as **expert witnesses** in court cases.

SEE ALSO FBI crime laboratory.

Forgery, art SEE Art forgery

Fourier transform infrared spectrophotometer (FTIR)

A Fourier transform infrared spectrophotometer (FTIR) is an instrument used to examine specimens, both to detect the presence of target compounds and to measure the quantities of the compounds (quantification). FTIR can be an important analytical instrument in a forensic investigation.

A FTIR can be useful in detecting both organic chemicals (i.e., those that contain carbon) and inorganic chemicals. As with other forms of spectrophotometry, FTIR utilizes light. In this case, the wavelength of the light (the distance between a point of one light wave and the corresponding point of an adjacent wave) is in the infrared range. Infrared light lies in between the visible light and microwave portions of the **electromagnetic spectrum**. The infrared light that is nearest to visible light ("near infrared") has a wavelength of approximately 770 nanometers (nm; 10^{-9} meter). At the other end of the range, infrared light that is nearest to microwave radiation ("far infrared") has a wavelength of approximately 1,000,000 nm (1.0 millimeter).

The basis of FTIR is the absorption of the infrared light by various molecules in a sample. Depending on their chemical structure and three-dimensional orientation, the different sample molecules will absorb different portions of the infrared spectrum.

Depending on the nature of the chemical bond that absorbs the infrared light, a chemical bond will vibrate in varying ways. Reflecting the different types of bonds, a number of events can occur. For example, the input of vibrational energy can stretch the bonds between the carbon atom and the surrounding hydrogen atoms in CH_3. Also, the carbon-hydrogen linkages of CH_3 can remain the same length while the linked atoms are moved back and forth laterally to one another (rocking). Other chemical linkages, such as that between a silicon atom and CH_3 group, can be altered asymmetrically along their lengths, with some regions of the bond stretching and other regions contracting (asymmetric deformation).

The absorption of light by the sample will decrease the energy of the infrared light that exits the sample chamber or produce a wave that is "out of synch" with light that has not passed through the sample. A computational comparison of the frequency patterns of the incoming and exiting infrared light can be made as described subsequently and displayed as a series of peaks rising above the background baseline. The height of the peaks corresponds to the degree of absorption and/or to the nature of the chemical bond change (i.e., stretching, rocking, deformation).

Within the spectrophotometer, the incoming infrared light beam is split in two by a mirror. Half of the beam is directed through the sample. The aforementioned chemical interactions within the samples will produce an emerging light beam that is different in optical character from the portion of the light that has been directed away from the sample.

The two light beams will be out of phase will one another. Since light consists of waves, the out of phase waves can cancel one another or lessen the overall wave intensity through interference. The pattern that results from the interaction of the two beams is known as an interferogram.

The end result of the Fourier transform is the spectrum of peaks and valleys that is displayed to the analyst. The resulting absorption pattern can be compared to the millions of patterns that are stored in computer databases, both on-site and remotely via the Internet. If a matching spectrum is obtained, then the identity of the sample compound can be determined.

FTIR is a valuable forensic technique because of its detection sensitivity and versatility. Chemicals from a variety of sample types including **blood**, paints, polymer coatings, drugs and both organic and inorganic contaminants can be identified.

Liquid samples such as blood can be prepared for FTIR examination by placing a drop between two plates made of sodium chloride (salt). The salt molecules are transparent to the infrared light and so form convenient sandwiching layers to produce a thin layer of sample. Solid samples can be converted to a fine powder in combination with a carrier material like potassium bromide (KBr, which is also infrared transparent). Alternatively, solids such as polymers can be dissolved in a solvent such as methylene chloride and added to a salt plate. When the solvent evaporates, the sample forms a thin layer on the salt plate.

Solids as complex as soil have been successfully analyzed using FTIR in forensic studies.

FTIR is not a technique that can be done at the scene of a crime or accident. The spectrophotometer and ancillary computer equipment are too bulky and heavy for transport. Rather, samples need to be carefully collected and transported to a specialized laboratory that has the necessary FTIR equipment.

SEE ALSO Analytical instrumentation; Breathalyzer®; Gas chromatograph-mass spectrometer; Infrared detection devices; Micro-fourier transform infrared spectrometry; Spectroscopy.

Fracture matching

When an object has been torn, broken, or separated, one piece of it has the potential to match another piece of it when they are placed next to one another. In forensic investigations this is called fracture matching. Because both the composition of an object and the stress applied to break it are always unique, when something is broken, torn, or separated, the edges of the pieces will always have characteristics that identify them with each other. When the pieces fit together, an investigator can conclude they were originally part of the same object. For example, when a piece of paper is ripped in half the tear will never happen in exactly the same pattern twice. This is because each piece of paper has slightly different imperfections and the forces applied to the paper in order to rip it are never repeated identically. When the two halves of paper are put next to each other, it is obvious that they were originally part of the same object. Fracture match is such an important concept in collecting and presenting **evidence** that it is considered scientific evidence in courts of law.

Anything that can be torn, broken, or separated can fracture matched. Items commonly used for fracture match analysis include plastics, **glass**, metal, wood, metal, car parts, paper, currency, tape, cloth, and paint chips. Experts in fracture match examine the objects that are a potential match in either two or three dimensions, depending on the object. Paper, tape, and cloth are generally compared in two dimensions. Glass, metal, wood, and plastics are examined in three dimensions. The entire surface of the fracture, as well as the surfaces of the object, will be analyzed. There are four different fracture match criteria:

- The pieces have been broken apart.
- The pieces can be realigned.
- The pieces fit together along the fracture and the fit is verified by markings on the surface or within the three-dimensional structure of the fracture.
- The pieces contain unique shapes.

In order to fulfill these criteria, inspectors examine the shape of the break, any irregularities in the surfaces of the two pieces, and any striations that might have occurred during the break. They examine the composition of the pieces for similarities in age, texture, and deformation. They may also analyze the chemical composition of the pieces.

When working with glass, investigators can recover a considerable amount of information from reconstruction using fracture match. Glass pieces resist movement when they are placed next to pieces to which they were originally adjacent. Special ridges, called Wallner lines, are almost always aligned so that they curve in a concave manner towards the point of impact. When the impact is from a low-velocity object, the cracks in the glass will radiate out from the point of impact. If the object that breaks the glass is moving at higher velocities, the point of impact will be cone-shaped and the larger end of the cone indicates the exit side of the glass. Cracks that are smooth and curved and show no indication of a point of contact indicate that the crack was generated from thermal stress.

A variety of examples of the use of fracture match demonstrate its importance in solving crimes. An Iowa detective used fracture match with paper to identify the person who had made a bomb threat at a warehouse. The man claimed to have discovered a note on the windshield of his car that stated that a bomb was hidden in the warehouse. The note was on a piece of notebook paper from a spiral binder. The detective searched the man's car and found a spiral binder. When the note was ripped out of the spiral binder, pieces of paper were caught inside the metal spiral. The detective was able to make a fracture match to a piece of paper found inside the metal spiral and he arrested the suspect.

Tools are also often involved in fracture match. In Virginia, robbers stole the contents from night-deposit boxes in a series of crimes. In each case the boxes were forced open. At one crime scene, the police found a small piece of metal, which they saved as evidence. Eventually, the police identified suspects and searched their possessions. They found a variety of broken tools. One of these was a screwdriver that was a perfect fracture match to the piece of metal collected from the crime scene. The police were able to convict the criminals based on this evidence.

Fracture match of the ends of tape can also provide key information to criminal investigators. In 2003 in Florida, a woman was sexually assaulted and then murdered. Her body was wrapped in bed sheets, a shower curtain, and masking tape and dropped in the ocean. A man fishing off a bridge hooked the body on a line and pulled it up. After locating a suspect, police investigators fracture matched the end of the masking tape on the body to the end of masking tape on a roll in the suspect's house. The man was convicted of the assault and **murder** based on this fracture match as well as other corroborating evidence.

SEE ALSO Paint analysis; Tape analysis; Toolmarks.

Max Frei-Sulzer

1913–1983
SWISS
CRIMINALIST

Swiss criminalist Max Frei-Sulzer made many contributions to the field of **forensic science** in his lifetime, including founding the first Swiss **criminalistics** laboratory, and developing the tape life method of collecting **trace evidence**. He is also known for debatable findings he made in two high-profile **identification** cases, the authenticity of the **Hitler Diaries** and the Shroud of Turin.

Born in 1913, Frei-Sulzer worked as a freelance criminalist for many years in Switzerland. He also taught microscopical techniques at Zurich University, and in 1950, he was asked to create the first Swiss crime laboratory, the Zurich Police Scientific Laboratory. While director of the facility, he developed the tape lift method for **evidence** collection. By applying a piece of sticky tape to a surface, a scientist can collect particles that can then be examined under a microscope. The tape preserves the spatial relationship of the particles and fibers. This technique was a major advance in trace analysis, and is a method still used today.

In 1973, Frei-Sulzer served as a consultant to a commission investigating the authenticity of the famous Shroud of Turin, a cloth depicting the image of a crucified man that some believe to be the burial cloth of Jesus. Frei-Sulzer took samples from the cloth using the tape lift method, and studied the samples for two years. After analysis, he reported finding pollens originating from plants grown in Palestine during the time of Christ, thus supporting the theory of the Shroud being authentic. After Frei-Sulzer's report, however, other scientists conducted similar tests on the Shroud and disagreed with his findings. While many people now question Frei-Sulzer's credibility in the case, the debate regarding the authenticity of the Shroud still goes on. Frei-Sulzer's role in the Shroud investigation is documented in many books and journal articles.

Later in his career, Frei-Sulzer's credibility was again questioned when he performed a **handwriting analysis** of the Hitler Diaries, purported to be the personal writings of Nazi leader Adolf Hitler. Frei-Sulzer pronounced the diaries as genuine, but shortly thereafter the diaries were proved to be fake. It is believed that Frei-Sulzer's incorrect analysis resulted from him performing a comparison analysis with other forgeries, instead of actual Hitler writing samples.

SEE ALSO Ancient cases and mysteries; Document forgery; Locard's exchange principle; Palynology.

Friction ridge skin and personal identification: a history of latent fingerprint analysis

In 1904, the World's Fair was held in St. Louis, Missouri. A special exhibit of the British crown jewels sailed from London for exhibit at the fair, sent by Queen Victoria of England. Naturally, such valuable jewels could not travel and display in the exhibition unguarded. Sergeant John Kenneth Ferrier of Scotland Yard traveled with this British treasure to ensure that no theft would occur. However, he brought more with him than the crown jewels. Ferrier knew about a new concept that had not yet traveled to America; fingerprints, classifying them, and how they could be used for personal **identification**. Ferrier was so committed to the potential of **fingerprint** identification that he shared his knowledge by holding demonstrations of fingerprinting techniques for foreign police chiefs gathered at the fair, and training several American police officials afterwards.

By the mid 1880s, fingerprints had been studied by **Henry Faulds** (1843–1930), a Scottish medical missionary in Tokyo, Japan; by William Herschel (1738–1822), a British chief administrative officer assigned in Bengal, India; and by **Francis Galton** (1882–1911), an English biologist and cousin to the British naturalist Charles Darwin (1809–1882). These men considered fingerprints to be both individual to each person and permanent throughout life. Faulds even considered using fingerprints for identifying criminals at a crime scene and had successfully done so. By the time of the World's Fair in 1904, the industrial revolution had peaked, and the world was awash with new technologies. Telephones were fairly usual, automobiles were becoming more common, and the Wright brothers had just made their successful flight at Kitty Hawk less than a year earlier. New ideas and technologies excited Americans. Fingerprints became an important feature in this new technological world. Additionally, palm prints and footprints could also be used for personal identification

The skin on the palmar surface of the hands and plantar surface of the feet is specialized. It is called *friction ridge skin* because the skin occurs in a corrugated fashion with elevated ridges broken up by lower furrows. In other words, this skin is not flat and smooth like other skin. Friction ridge skin is slightly elastic in nature and assists in gripping objects and surfaces.

Friction ridges form in the uterus by the fourth month of fetal development and remain unchanged and absolute for a person's lifetime, only decomposing after death. These unique factors make friction ridge skin ideal for use in personal identification. Once friction ridge skin was recognized as valuable and reliable for personal identification, different people began to work on systems for taking these prints and then organizing them. Faulds had previously used printer's ink to take the fingerprints of his subjects. In the early twentieth century, American chemical engineer John A. Dondero (1900–1957) developed new inks for the purpose of recording prints, including special ink for footprinting newborns. Edward Henry, with the assistance of two Indian civil servants, developed a system for classifying and filing mass quantities of fingerprint cards. This system is the one shared by Ferrier and is still known today as the Henry System. With the advent of automated identification systems, use of Henry's system has declined.

While prints could now be documented for future identification, how would prints left at crime scenes be used? As with other technologies, an application of other sciences began to play an increasingly larger role. Prints left at crime scenes or on items are generally referred to as latent prints. The word latent is from Latin and means to be hidden or not visible to the naked eye. Such a print is left as a result of a person touching a surface and transferring oils, perspiration, and other materials to the surface; or by the touch actually removing material from the surface. A print that is visible is called a patent impression. Patent impressions can be found in substances such as **blood**, motor oil, grease, or other contaminants left, for instance, on a wall or door frame. Prints or impressions left in a semi-soft substance like window putty or butter are called plastic impressions because they are molded in the substance. The vast majority of crime scene impressions, however, are latent impressions, and must be developed in some manner to make them visible. In the early half of the twentieth century, much work was done in inventing different colored powders that could be dusted on a surface to develop the print and make it visible for **photography**. It wasn't until much later that latent prints were actually lifted with a special tape and placed on a backing card with documentation.

Initially, the study of friction ridge skin involved the science of embryology and anatomy. The practice of photography obviously became more and more important, as did the use of magnifiers and specialized lenses. Additionally, with the development of inks and powders, chemistry began to play an ever-larger role. By the 1950s, iodine was used for fuming evidential items in a chamber; and chemicals that reacted with amino acids (secreted in sweat) were used on porous items such as paper. This was only the beginning. By the 1980s, cyanoacrylate ester (more commonly known by the trade name of Superglue®) found its way into usage. Additional research brought the development of fluorescing chemicals that could be applied after cyanoacrylate ester. Next, physics found its place in **latent fingerprint** examination as lasers and other light sources allowed the application of different wavelengths of light to make such chemistry fluoresce (emit visible light), thus allowing for photography. Another role of physics involves utilizing high vacuum for coating items with metals such as gold and zinc in specialized vacuum chambers. Particular chemical and mechanical techniques continue to be developed each year for working with difficult surfaces such as adhesive tapes, human skin, distinctive plastics, and highly colored backgrounds. While some chemistry is especially effective on dry surfaces, other chemistry makes it possible to deal with wet surfaces. All these techniques optimize the opportunity to develop latent impressions on a wide variety of backgrounds and surfaces or substrates.

The 1990s firmly established the science of **biometrics**, which boomed with the improvement of computers and refinement of software programs. By the beginning of the twenty-first century, computers were able to scan fingerprints and palm prints, and store images of those prints in automated identification databases.

Once an impression is rendered visible, documented, and recorded; it must be compared with a known-recorded print of an individual in order to identify it. The recorded impression, whether inked or scanned, is considered an ideal impression. This is due to the fact that the print can be repeatedly documented to get the very best recording of the friction ridges. While computers can record and scan impressions, they can never make a positive identification. Computers only make tentative matches. Identification will always require a trained and skilled human being to make the physical comparison. Identification is established by analyzing, comparing, and evaluating the arrangement of friction **ridge characteristics** in the latent print to those in the known impression and finding a match to the exclusion of all other prints.

Forensic identification of latent prints is a specialized field of study that encompasses many sciences. Commitment to a career in this **forensic science** requires an understanding and application of the scientific method. Knowledge of the biological formation of friction ridge skin, the nature of this specialized skin, and an awareness of the various technologies and methodologies employed in developing latent impressions is also required. Of the utmost importance, a forensic scientist must have a solid sense of professionalism, including high personal ethics and integrity in assuming responsibility for forming qualified opinions of identification of individuals.

SEE ALSO Biometrics; Fingerprint; Fingerprint analysis (famous cases); Identification; Integrated automated fingerprint identification system; Latent fingerprint; Superglue® fuming.

Frye standard

The *Frye* standard is critical to the legal presentation of the findings of a forensic examination. Forensic **evidence** is based on science. Some of the scientific methods have been long-established and readily pass legal muster. Other, more modern techniques may potentially not have had the time necessary for rigorous evaluation and scientific debate. Generally, cutting-edge techniques will be used more in the research laboratory setting. But, if contemplated for a forensic examination, then the *Frye* standard can become very important.

The *Frye* standard rose out of a 1923 legal decision (*Frye v. United States*). The heart of the ruling was as follows: "Just when a scientific principle or discovery crosses the line between experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while the court will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs."

In the case of the ruling, the court found that an expert testimony to the jury on the use of a systolic blood pressure test at that time had not yet gained credibility in the scientific community, and so the evidence from the procedure was denied.

In modern times, the sophisticated molecular technologies that sequence deoxyribonucleic acid (**DNA**) and determine the DNA profile of an individual can be held up to the legal scrutiny of the *Frye* standard. Typically, observance of defined and accepted protocols of sample collection, handling and analysis are sufficient to ensure the legal admissibility of the evidence.

The *Frye* standard also applies to the testimony of someone deemed to be an expert in a field that is relevant to the case (i.e., a **ballistics** expert). If the information is not presented in a convincing fashion (including citing scientific literature on the approach, use of the procedure, limitations of the procedure and general acceptance in the scientific community) or if the qualifications of the expert can be called into question, then the evidence can be ruled inadmissible.

As an example, in the 2004 *Grady v. Frito-Lay* trial in Pennsylvania, an associate professor of chemical engineering testified that the shape of the manufacturer's tortilla chip was a hazard, which could inflict injury to the mouth. The state Supreme Court used the *Frye* standard to rule that the expert's testimony was not generally accepted in the scientific community, and in fact represented inadmissible "junk science."

SEE ALSO DNA; DNA profiling.

G

Francis Galton

2/16/1822–1/17/1911
ENGLISH
SCIENTIST, EXPLORER, BIOMETRICIAN

The English scientist, biometrician, and explorer Sir Francis Galton founded the science of eugenics and introduced the theory of the anticyclone in **meteorology**. **Forensic science** has benefited from Galton's pioneering anthropometric research. The system of fingerprinting in use today resulted from his work.

Francis Galton was born in Birmingham, England, the son of Samuel Galton, a businessman, and Violetta Galton. After schooling in Boulogne, he began to study **medicine** in 1838 and also read mathematics at Trinity College, Cambridge.

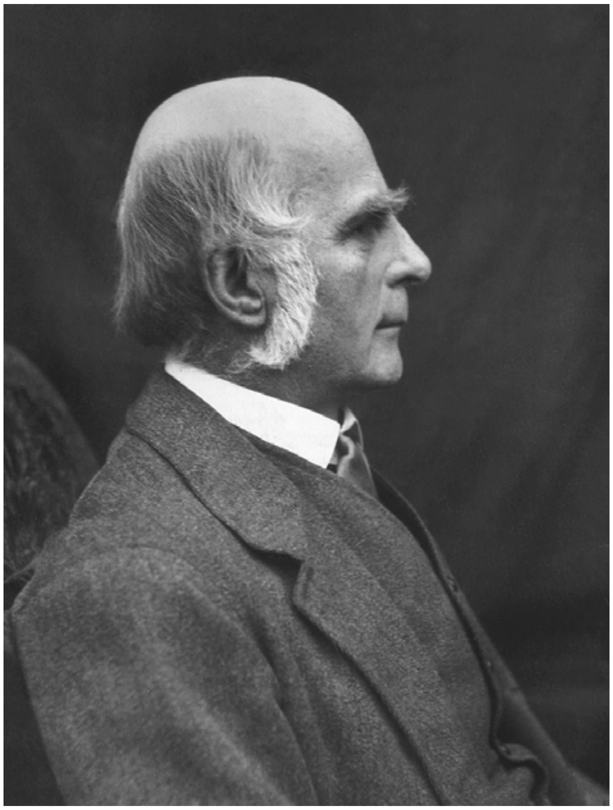
The death of his father in 1844 left Galton with considerable independent means, and he abandoned further medical study to travel in Syria, Egypt, and south West Africa. As a result, he published *Tropical South Africa* (1853) and *The Art of Travel* (1855). His travels brought him fame as an explorer, and in 1854 he was awarded the Gold Medal of the Geographical Society. He was elected fellow of the Royal Society in 1856.

Turning his attention to meteorology, Galton published *Meteorographica* (1863), in which he described weather mapping, pointing out for the first time the importance of an anticyclone, in which air circulates clockwise round a center of high barometric pressure in the Northern Hemisphere. Cyclones, on the other hand, are low-pressure centers from which air rushes upward and moves counterclockwise.

Meanwhile, Galton had developed an interest in heredity, and the publication of the *Origin of Species* (1859) by Charles Darwin won Galton's immediate support. Impressed by evidence that distinction of any kind is apt to run in families, Galton made detailed studies of families conspicuous for inherited ability over several generations. He then advocated the application of scientific breeding to human populations. These studies laid the foundation for the science of eugenics (a term he invented), or race improvement, and led to the publication of *Hereditary Genius* (1869) and *English Men of Science: Their Nature and Nurture* (1874).

Finding that advances in the study of heredity were being hampered by the lack of information, Galton started anthropometric research, devising instruments for the exact measurement of every quantifiable faculty of body or mind. In 1884, he finally set up and equipped the Biometric Laboratory at University College, London. He measured such human traits as keenness of sight and hearing, color sense, reaction time, strength of pull and of squeeze, and height and weight. The system of fingerprints in universal use today derived from this work.

The developed presentation of Galton's views on heredity is *Natural Inheritance* (1889). A complex work, it sets out the "law of 1885," which attempts to quantify the influence of former generations in the hereditary makeup of the individual. Parents each contribute one-quarter, grandparents each one-sixteenth, and so on for earlier generations. For Galton, evolution ensured the survival of those members of the race with most physical and mental vigor. By applying eugenics, he desired to see this come about in human society



Francis Galton (1822–1911). © BETTMANN/CORBIS

more speedily and with less pain to the individual. Evolution was an ongoing progression; the nature of the average individual being essentially unprogressive.

Galton's application of exact quantitative methods gave results which, processed mathematically, developed a numerical factor he called correlation and defined thus: "Two variable organs are said to be co-related when the variation of the one is accompanied on the average by more or less variation of the other, and in the same direction. Co-relation must be the consequence of the variations of the two organs being partly due to common causes. If wholly due ... the co-relation would be perfect." Co-relation specified the degree of relationship between any pair of individuals or any two attributes.

Galton used his considerable fortune to promote his scientific interests. He founded the journal *Biometrika* in 1901, and in 1903 he established the Eugenics Laboratory in the University of London. He died at Haslemere, Surrey, in 1911, after several years of frail health. He bequeathed £45,000 to found a professorship in eugenics in the hope that his disciple and pupil Karl Pearson might become its first occupant. This hope was realized.

SEE ALSO Anthropometry; Fingerprint; Integrated automated fingerprint identification system.

Gang violence, forensic evidence

Organized street gangs are any social alliance in a group, usually consisting of juvenile and young adult members, whose primary purposes are for material gain for the group (often resulting in violence against the local community) and for retaliation or revenge against other groups (resulting in violence between rival gangs). To successfully learn more about gang violence, forensic experts must be aware of the different investigative approaches, especially with regard to forensic **evidence**, in dealing with both categories of gang violence.

Gangs were once loosely based groups of juveniles and young adults who committed minor crimes. However, such gangs have developed into powerful, well-organized groups. In fact, there was a dramatic increase in gang activity throughout the United States during the 1980s and 1990s, which caused an increase in violent crime along with extortion, harassment, and intimidation. By the beginning of the twenty-first century, street gang violence existed in nearly every suburban, metropolitan, and inner-city community in the United States.

When violence is involved, such gangs are classified as either violent or delinquent by forensic investigators in order to separate and identify evidence associated with each group. Violent gangs often contain members who have unstable and aggressive personalities, which can easily lead to violent disputes centered on territorial (turf) control or overall gang warfare, sometimes with deadly consequences. Delinquent gangs are usually small but cohesive groups who carry out minor criminal acts, such as muggings and petty thievery. When violence is used, it is usually not deadly or as serious in nature as with the violent groups. In most cases, material gain is the primary purpose of delinquent gang actions. In both types of gangs, criminal activities include dealing illegal drugs; performing assaults, extortions, robberies, and other felonies; and terrorizing neighborhoods.

Forensic evidence is often used to identify gang members when criminal activities are suspected within street gangs. Photographs, jewelry (along with badges, insignia, and other artifacts), stylized haircuts, and body piercing are among some of the more obvious physical traits that forensic investigators consider when **profiling** gangs. Other means of identifying gang members are by their tattoos and other types of burns and scars on their bodies, clothing (style, type, and color; and how it is worn), nicknames (or monikers), vehicles driven, common types of illegal activities, and communication styles such as graffiti, slang, and sign languages.

SEE ALSO Criminal profiling.

Gas chromatograph-mass spectrometer

In a forensic examination, some sample material can be evaluated at the scene of the accident of crime. Other material, however, needs to be collected and taken to a dedicated laboratory for more sophisticated analyses using a variety of analytical instruments. In 1976, scientists William Keith Hadley and J. A. Zoro, in the United Kingdom, first suggested the use of gas chromatography/mass **spectroscopy** for forensic purposes and the instrument is now used for a variety of forensic purposes.

The GC/MS instrument helps separate and determine the individual elements and molecules in a sample. The GC/MS provides forensic investigators the ability to identify individual substances that may be found within a very small test sample. Forensic applications of GC/MS include **identification** and detection of **explosives**; investigations of **arson**, fire, and blasts or explosions; environmental analysis; and drug detection. In recent years, GC/MS has begun to be used in airport security areas as a means of detecting dangerous substances in luggage, on animals who are traveling, or on human beings. Because of its great sensitivity, gas chromatography/mass spectroscopy can be utilized to identify trace elements in either minute amounts of substances or in substances that were believed to be contaminated or to be degraded beyond usability.

The GC/MS is comprised of two parts: the gas chromatograph and the mass spectrometer. The gas chromatograph functions by separating the molecules within the sample compound into their most elemental particles, allowing some types of molecules to pass into the mass spectrometer more rapidly than others. When the molecules move into the mass spectrometer, they are broken down into ionized fragments, and then each molecule is specifically identified based on mass and ionic charge.

Gas chromatography is a technique for separating closely related compounds (solutes) from a liquid or gaseous mixture. (Solids must be vaporized or liquefied before analysis.) Gas chromatography is most commonly used to separate and detect volatile and semi-volatile **organic compounds** (VOCs and SVOCs) with molecular weights less than 500 atomic mass units (amu). Although chemists have probably used rudimentary **chromatography** to separate mixtures since the Middle Ages, the modern chromatograph was not developed until 1941, when British biochemists Archer Martin and Richard Synge invented a chromatographic method that allowed for precise partitioning and detection. Martin and Synge were awarded the 1952 Nobel Prize in Chemistry for their efforts.

The GC component of a GC/MS system includes a carrier gas supply, a sample introduction inlet, a capillary column coated with a stationary liquid or solid, and an outlet to the detection system, in this case a mass spectrometer. To begin analysis, a GC/MS technician vaporizes the sample, or analyte, and introduces it into the chromatograph by syringe injection through a rubber septum. A flow of inert carrier gas like helium, argon, or nitrogen moves the analyte into the separation column. Partitioning occurs as the gaseous components of the original analyte assume different velocities when confronted with the column's liquid or solid coating. Partitioning behavior is temperature dependent, and precise temperature control is an important part of the GC process. A filter removes the separated compounds from the carrier gas at the end of the column before they are fed into the mass spectrometer for individual analysis.

Mass spectroscopy is a method of determining the molecular weights of a chemical compound's component ions. (Ions are electrically charged atoms or groups of atoms, and sub-particles of molecules.) The MS instrument, which has been called the smallest scale in the world, provides a graph, or mass spectrum, with peaks that indicate the relative amount of each type of ion within a compound. Today's MS systems are based on Sir J. J. Thomson's research at the Cavendish Laboratory at the University of Cambridge. Thomson discovered the electron in 1897, and went on to observe that the parabolic paths of ions traveling through electrical and magnetic fields vary according to the ions' mass-to-charge (m/z) ratios. His experimental instruments were the first mass spectrometers, and he was awarded the 1906 Nobel Prize in Physics for his discoveries.

Mass spectroscopy instrumentation has become increasingly accurate and complex since Thomson's time, but the principles of the technique and its basic components have remained the same. The MS component of a GC/MS system includes a sample inlet into a vacuum-sealed chamber that houses an ionization source, a mass analyzer, and an ion detector. In a GC/MS system, the input sample is always a chemically-homogenous gas produced by the GC component that can be introduced directly to the ionizer. Once ionized, the partitioned compound moves into the mass analyzer where the ions travel through an electrical or magnetic field that sorts them according to their m/z ratios. The detector measures the beam of now-separated ions arriving at the end of the analyzer, and converts changes in its intensity to produce the mass spectrum. A sample's mass spectrum is then displayed, catalogued, and compared to a library of known mass spectra by a computer data system.

Improvements in the individual GC and MS components, electronic automation, and computer data analysis and storage have led to machines that can analyze ever more complex, fragile, and tiny chemical components; GC/MS can now be used to quickly analyze proteins, **DNA**, and even viruses, and has become a common technique in molecular biology and medical science. GC/MS instruments are also becoming smaller and less expensive, and field laboratory and even portable, suitcase-sized systems that can be used to analyze forensic samples on site now exist.

One of the reasons that the GC/MS test has a great deal of value in the world of forensic substance identification has to do with its specificity: the GC/MS can positively identify the presence of a suspected poison or other substance. The portability of GC/MS test equipment allows it to be taken directly from a crime scene to the area where a suspect is detained to immediately perform tests on a suspect's tissue, **serology** (**blood**), clothing, etc.

SEE ALSO Accelerant; Analytical instrumentation; Arson; Breathalyzer®; Chemical and biological detection technologies; Control samples; Fourier transform infrared spectrophotometer (FTIR); Micro-fourier transform infrared spectrometry.

Gene

Molecular techniques that detect the presence and even the activity of genetic material are now a central part of **forensic science**. Exquisitely sensitive techniques can amplify and detect even small regions of deoxyribonucleic acid (**DNA**) that are present on objects such as cigarette butts or **glass**, or found underneath fingernails, as three examples.

Besides identifying the genetic material, modern-day forensic science techniques permit the detection of the fundamental unit of heritable genetic information (the gene), and can use genes to single out a person.

A gene is an individual element of an organism's genome and determines a trait or characteristic by regulating biochemical structure or a metabolic process.

Genes are segments of nucleic acid, consisting of a specific sequence and number of the chemical units of nucleic acids, the nucleotides. In most organisms the nucleic acid is DNA, although in retroviruses the genetic material is composed of ribonucleic acid (RNA). Some genes in a cell are active more or less all the time, which means that they are continuously transcribed and provide a constant supply of their protein product. These are the "housekeeping" genes that are always needed for basic cellular reactions. Others may be rendered active or inactive depending on the needs and functions of the organism under particular conditions. The signal that masks or unmasks a gene can come from outside the cell, for example, from a steroid hormone or a nutrient, or it can come from within the cell itself as a result of the activity of other genes. In both cases, regulatory substances can bind to the specific DNA sequences of the target genes to control the synthesis of transcripts.

In a paper published in 1865, Gregor Mendel (1823–1884), advanced a theory of inheritance dependent on material elements that segregate independently from each other in sex cells. Before Mendel's findings, inherited traits were thought to be passed on through a blending of the mother and father's characteristics, much like a blending of two liquids. The term "gene" was coined later by the Danish botanist Wilhelm Johannsen (1857–1927), to replace the variety of terms used up until then to describe hereditary factors. His definition of the gene led him to distinguish between genotype (an organism's genetic makeup) and phenotype (an organism's appearance). Before the chemical and physical nature of genes were discovered they were defined on the basis of phenotypic expression, and algebraic symbols were used to record their distribution and segregation. Because sexually reproducing, eukaryotic organisms possess two copies of an inherited factor (or gene), one acquired from each parent, the genotype of an individual for a particular trait is expressed by a pair of letters or symbols. Each of the alternative forms of a gene is also known as an allele. Dominant and recessive alleles are denoted by the use of higher and lower case letters. It can be predicted mathematically, for example, that a single allele pair will always segregate to give a genotype ratio 1AA:2Aa:1aa, and the phenotype ratio 2A:1aa (where A represents both AA and Aa since these cannot be distinguished phenotypically if dominance is complete).

In 1910, the American geneticist Thomas Hunt Morgan (1866–1945) began to uncover the relationship between genes and chromosomes. He discovered that genes were located on chromosomes and that they were arranged linearly and associated in linkage groups, all the genes on one **chromosome** being linked. For example, the genes on the X and Y chromosomes are said to be sex-linked because the X and Y chromosomes determine the sex of the organisms; in humans X determines femaleness and Y determines maleness. Nonhomologous chromosomes possess different linkage groups, whereas homologous chromosomes have identical linkage groups in identical sequences. The distance between two genes of the same linkage group is the sum of the distances between all the intervening genes. A schematic representation of the linear arrangement of linked genes, with their relative distances of separation, is known as a genetic map. In the construction of such maps, the frequency of recombination during crossing over is used as an index of the distance between two linked genes.

The molecular structure and activity of genes can be modified by mutations and the smallest mutational unit is now known to be a single pair of nucleotides, also known as a muton. Mutations used to be detected biochemically, typically by the failure of an organism to grow in a given food source due to the presence of the non-functional gene. Now, machines that automatically determine the arrangement of the nucleotide building blocks in the genetic material (a process called **sequencing**) allow mutations to be detected and, potentially, to match DNA with a victim or suspect.

SEE ALSO DNA; DNA fingerprint; Genetic code; PCR (polymerase chain reaction).

Genetic code

Some forensic **identification** techniques that detect living organisms or their products (e.g., **toxins**) rely on the detection of genetic sequences within the organism's genetic material. These tests can be exquisitely sensitive, allowing the detection of only a few organisms.

For example, tests have established that less than a dozen ***Escherichia coli*** bacteria can be detected in samples such as food and water. To put that in perspective, over a million bacterial cells will fit into the period at the end of this sentence.

A fundamental understanding of the genetic code is essential to understanding the molecular basis of advanced deoxyribonucleic acid (**DNA**) and the genetic tests that are increasingly important in **forensic science** and identification technology.

The genetic information that is passed on from parent to offspring is carried by the DNA of a cell. The genes on the DNA code for specific proteins that determine all aspects of the organism. In order for a **gene** to produce the proteins, the gene must first be transcribed from DNA to RNA (specifically, a type of RNA called messenger RNA; mRNA) in a process known as transcription. Translation is the process in which genetic information, carried by the mRNA, directs the synthesis of proteins from amino acids. The primary structure of the protein is determined by the nucleotide sequence in the mRNA.

The elements of the encoding system, the nucleotides, differ by only four different bases. These are known as adenine (A), guanine, (G), thymine (T) and cytosine (C), in DNA or uracil (U) in RNA. Thus RNA contains U in the place of C.

Proteins found in nature consist of 20 naturally occurring amino acids. One important question is, how can four nucleotides code for 20 amino acids? If a single nucleotide coded for one amino acid, then only four amino acids could be provided for. Alternatively, if two nucleotides specified one amino acid, then there could be a maximum number of 16 (4^2) possible arrangements. If, however, three nucleotides coded for one amino acid, then there would be 64 (4^3) possible permutations, more than enough to account for all the 20 naturally occurring amino acids. The latter, which was proposed by the Russian born physicist, George Gamow (1904–1968), was proved to be correct.

It is now well known that every amino acid is coded by at least one nucleotide triplet or codon, and that some triplet combinations function as instructions for the termination or initiation of translation. Three combinations in tRNA, UAA, UGA, and UAG, are termination codons, while AUG is a translation start codon.

The genetic code was solved between 1961 and 1963. The American scientist Marshall Nirenberg (1927–), working with his colleague Heinrich Matthaei, made the first breakthrough when they discovered how to make synthetic mRNA. They found that if the nucleotides of RNA carrying the four bases A, G, C and U were mixed in the presence of the enzyme polynucleotide phosphorylase, a single stranded RNA was formed in the reaction, with the nucleotides being incorporated at random. This offered the possibility of creating specific mRNA sequences and then seeing which amino acids they would specify. The first synthetic mRNA polymer obtained contained only uracil (U) and when mixed *in vitro* with the protein synthesizing machinery of *Escherichia coli* it produced a polyphenylalanine—a string of phenylalanine. From this it was concluded that the triplet UUU coded for phenylalanine. Similarly, a pure cytosine (C) RNA polymer produced only the amino acid proline, so the corresponding codon for cytosine had to be CCC. This type of analysis was refined when nucleotides were mixed in different proportions in the synthetic mRNA and a statistical analysis was used to determine the amino acids produced. It was quickly found that a particular amino acid could be specified by more than one codon. Thus, the amino acid serine could be produced from any one of the combinations UCU, UCC, UCA, or UCG. In this way the genetic code is said to be degenerate, meaning that each of the 64 possible triplets have some meaning within the code and that several codons may encode a single amino acid.

This work confirmed the ideas of the British scientists Francis Crick (1916–2004) and Sydney Brenner (1927–). Brenner and Crick were working with mutations in the bacterial virus bacteriophage T4 and found that the deletion of a single nucleotide could abolish the function of a specific gene. However, a second mutation in which a nucleotide was inserted at a different, but nearby position, restored the function of that gene. These two mutations are said to be suppressors of each other, meaning that they cancel each other's mutant properties. It was concluded from this that the genetic code was read in a sequential manner starting from a fixed point in the gene. The insertion or deletion of a nucleotide shifted the reading frame in which succeeding nucleotides were read as codons, and was thus termed a frameshift mutation. It was also found that whereas two closely spaced deletions, or two closely spaced insertions, could not suppress each other, three closely spaced deletions or insertions could do so. Consequently, these observations established the triplet nature of the genetic code. The reading frame of a sequence is the way in which the sequence is divided into the triplets and is determined by the precise point at which translation is initiated. For example, the sequence CATCATCAT can be read CAT CAT CAT or C ATC ATC AT or CA TCA TCA T in the three possible reading frames. Sometimes, as in particular bacterial viruses, genes have been found that are contained within other genes. These are translated in different reading frames so the amino acid sequences of the proteins encoded by them are different. Such economy of genetic material is, however, quite rare.

The same genetic code appears to operate in all living things, but exceptions are known. In human mitochondrial mRNA, AGA and AGG are termination or stop codons. Other differences also exist in the correspondences between certain codon sequences and amino acids.

SEE ALSO Analytical instrumentation; Anthrax, investigation of 2001 murders; Bacterial biology; Biological weapons, genetic identification; DNA fingerprint; DNA sequences, unique; Mitochondrial DNA analysis; Pathogen genomic sequencing; PCR (polymerase chain reaction); RFLP (restriction fragment length polymorphism).

Geographic profiling

Criminal profiling is made up of psychological **profiling** and geographic profiling. The latter is a phrase coined by the Canadian criminologist Kim Rossmo in the early 1990s to describe the use of computers to generate predictions on a serial offender's place of residence or base of operations. The software used for geographic profiling—Rigel Profiler and Rigel Analyst (both created by Rossmo's Vancouver-based company), CrimeStat, and Dragnet—has changed the face of serial crime investigation in large urban centers.

It wasn't long ago that each briefing room across the country contained a map of the local detachment area and surrounding land, and on it crimes would be recorded by pins. Pin maps have a limited usefulness. If an area has heavy crime rates, the map becomes littered with holes and, with the exception of color-coded pins, essentially only one type of crime can be plotted. Updating the map means removing the pins and losing data from the past period of crime.

In the late 1980s, on the west coast of Canada, researchers at Simon Fraser University realized that humans follow patterns in their movements. People have mental maps of their surroundings, created through experience and familiarity with the location of sources for their daily needs. This mental map contains access routes to food, school, work, transportation systems, and at the heart of the mental map is their location of primary residence. Psychologists call this theory the principle of least effort.

Around the same time, Kim Rossmo, of the Vancouver Police, started to pursue his Ph.D. in Criminology at the same university. Through an interest in hunting behavior of animals, and his knowledge of the criminal field, Rossmo formed a theory that, like animals, criminal predatory behavior could be predicted. Offenders preferred to use familiar territory for their crimes. However, their anonymity was paramount and so there would be a buffer zone of no criminal activity around their place of primary residence for fear of being recognized. Rossmo also realized that the offender must have come across his victim at some point within his own mental map area. He developed a mathematical algorithm into which he could feed information on the crime and opportunities for interception between victim and offender, and obtain a rough prediction of the area in which the offender likely resided. This mathematical algorithm was subsequently patented by Rossmo and is at the heart of his geographic profiling software.

Geographic profiling brings the science of geography, criminology, mathematical modeling, statistical analysis, and environmental and forensic **psychology** into the realm of criminal investigation. It replaces the pin map and "hunches" on the whereabouts of the offender with a much more user-friendly, easy to read, and adaptable output map that uses science to indicate the most likely area that police agencies might focus their investigations in order to locate the serial offender. From the Rigel software, this map can be a two-dimensional or three-dimensional rendering of the geographical area under investigation. These maps are called jeopardies and use color-coding to indicate the area of highest probability to include the offender's place of residence.

Rigel system literature states that, "A Rigel analysis starts with a street map of the study area, the geographic coordinates of the crimes, and any database that the profiler wants to prioritize." Rigel is used in conjunction with **GIS** (geographic information systems) and is portable and usable in any mapped area in the world.

As well as its ability to predict the location of the offender's base (being able to "reduce the search area for a suspect's home by 90 per cent" states Kim Rossmo in his 1999 book, *Geographic Profiling*), Rigel software has gained enthusiastic responses from police agencies for its ability to help organize the vast amounts of data created when investigating a linked series of crimes. In the 1992 Washington DC sniper case, Rossmo aided investigators by using geographic profiling. Although the profiling did not lead to the location of the offenders, it did aid the police to the point that Assistant Police Chief Deirdre Walker of Montgomery County, Maryland, released a statement saying, "The joint task force found geographic profiling a helpful and useful tool in strategically prioritizing information in this investigation." And indeed, that is what geographic profiling is, a tool. It is a tool to be used along with other aspects of police investigations and it relies heavily upon work already done by the primary investigation team. Elly Abru, in her February 2004 article "Coordinates of Crime" published in Australia's *Police News*, writes, "Yoking together the power of GIS and computing, geographic profiling has enormous potential as a tool for sifting, matching, clarifying and analyzing information. It has yet to reach its peak."

Geographic profiling is most useful in tracking serial criminals. As of 2005, it is not useful for solitary crimes, crimes where offenders travel great distances between offenses, or for small rural forces where major serial crimes are unlikely. There are areas for improvement in the software, but as the field of geographic profiling continues to develop and its software capabilities continue to improve, the demand for geographic profiling technology is expected to grow.

SEE ALSO Criminal profiling; GIS; Profiling; Psychological profile.

Geology

Geology, the study of planetary processes and histories, has applications in **forensic science** that date back to the 19th century fictional detective Sherlock Holmes. The principles and techniques of geology are most commonly used to identify the sources, or provenance, of rock or soil particles associated with a crime. Other applications include the use of principles borrowed from stratigraphy (the study of sequences of rocks) and structural geology (the study of deformed rocks) to infer a series of events that may be important in civil and criminal cases. Experts in the geology of specific regions can also help to identify locations using their knowledge of rock types and landforms.

Sherlock Holmes, the fictional detective created by the British author **Arthur Conan Doyle** (1859–1930), was able to distinguish different types of **soils** and use this information to infer the places to which suspects had traveled. The first known non-fictional use of geological techniques in a criminal investigation, however, did not occur until 1904. In that year, German chemist **Georg Popp** helped to identify a murder suspect by matching coal dust and particles of the mineral hornblende found on a handkerchief to the same substances at a coal processing plant and quarry that employed the suspect. Several years later, Popp matched layers of goose droppings, distinctive red sandstone fragments, and a mixture of coal, brick, and cement dust to materials at a murder victim's home, the place where the body was found, and the place where the murder weapon was found. Just as importantly, Popp determined that the suspect's shoes contained no distinctive quartz particles from field where the suspect claimed to be walking at the time of the murder. Popp's work, like the work of modern day forensic geologists, made use of the geologic concept of provenance, which is a description of the origin and history of a soil or rock particle, to place suspects in specific locations and disprove an alibi. His use of the sequence of layered goose droppings, sandstone fragments, and dust to infer the sequence in which the suspect visited those locations was an application of the principles of stratigraphy.

Geologists can often determine the geographic source and history, or provenance, of sand grains or soil particles found at a crime scene, especially if distinctive **minerals** or microfossils are found. This usually involves microscopic examination of soil or rock samples using magnifying glasses, reflected light **microscopes**, polarized transmitted light microscopes, and, in some cases, sophisticated instruments such as electron microscopes or microprobes. Even if details are not visible to the naked eye, microscopic examination can show that two seemingly similar samples of sand are composed of particles with different chemical composition, size, or shape. In some cases, the geologic details may be specific enough to place a suspect at a certain outcrop or in a specific watershed. This kind of information can be presented as **evidence** by geologists acting as **expert witnesses** in civil and criminal cases.

One of the most widely known uses of sand provenance studies in a forensic investigation involves balloons carrying explosive and incendiary bombs over the United States during World War II. Meteorological information was used to determine that the balloons were being launched in Japan and carried across the Pacific Ocean by the jet stream. The balloons carried sand-filled bags as ballast, some of which were automatically released to maintain altitude as temperature dropped each night, and the U.S. Geological Survey was asked to identify the source of the ballast sand found at balloon crash sites. The sand contained an unusual mixture of mineral grains, diatoms, and foraminifera (single celled organisms that secrete siliceous and calcareous shells), and mollusk shell pieces but no coral fragments. Government geologists studied maps and reports published before the war, and determined that sand with that unique composition existed at only two places along the Japanese coast. Those locations turned out to be very close to the actual launching points. **Identification** of sand grains and soil particles has been an important part of high-profile criminal cases such as the 1978 kidnapping and murder of Italian prime minister Aldo Moro and the unsuccessful attempt by Mexican federal police to cover up the 1985 kidnapping, torture, and murder of U.S. Drug Enforcement Agency operative Enrique Camarena Salazar and his pilot Alfredo Zavala Avelar.

Geologic details in images can also help investigators determine the locations in which photographs or video recordings were made. In the days after the September 11, 2001, terrorist attacks on New York City and Washington, D.C., for example, American geologists who had worked in Afghanistan were able to identify rock outcrops shown in video tapes of the terrorist leader Osama bin Laden, placing him in a certain part of that country. This use of geologic information was widely publicized and subsequent tapes were made against a cloth background in order to make identification more difficult.

SEE ALSO Forensic science; Geospatial imagery; GIS; Meteorology; Minerals; Physical evidence.

Geospatial imagery

Geospatial imagery depicts the locations and characteristics of features, both natural and constructed, on Earth's surface. The general term can encompass aerial photographs, multispectral or hyperspectral images based the response of a sensor to specific portions of the **electromagnetic spectrum**, shaded relief images produced from digital elevation models, and maps. Geospatial imagery can be combined with other kinds of information, for example databases showing the addresses of convicted criminals or hazardous chemical storage facilities, within geographic information system (**GIS**) software to visualize spatial patterns that may be important in civil and criminal investigations.

The first widely used type of geospatial imagery was aerial **photography**, which can now be obtained using **cameras** mounted in aircraft, spacecraft, or satellites. If the photographs are taken from a spacecraft or satellite, however, they are likely to be described as space or satellite images in order to distinguish them from photographs taken from aircraft. Aerial photographs can be taken either vertically or obliquely, and overlapping photographs taken from slightly different positions can be viewed stereoscopically in order to emphasize topographic features. Multispectral or hyperspectral imagery is created using instruments that are sensitive to specific portions of the electromagnetic spectrum, including portions that lie beyond the range of human vision. Multispectral images typically consist of several bands or ranges of information (in many cases infrared, red, blue, and green bands). Hyperspectral imagery, in contrast, can consist of 200 or more bands and can be processed to emphasize the occurrence of specific **minerals** or plant types. Bands that fall outside the range of human vision must be assigned visible colors in order to be seen, and the resulting images are known as false-color images. Like aerial photographs, multispectral and hyperspectral images can be obtained from instruments in aircraft, spacecraft, or satellites.

Publicly available geospatial imagery obtained from space was, for many years, not detailed enough to be used in most criminal and civil investigations because its resolution was too low. Landsat satellites launched in the 1970s, for example, had a maximum resolution of 30 meters per pixel. Because it takes many pixels to create a recognizable image of an object such as a building or an automobile, the smallest features than can be clearly seen in an image are many times larger than the maximum resolution. As of 2005, some modern commercial satellites had panchromatic (black and white) image resolution of less than 1 meter per pixel, which is at the limit of utility for forensic investigations in which individual buildings or vehicles must be identified.

One well known forensic investigation in which geospatial imagery played an important role was the search for the body of Xiana Fairchild, a 7-year-old girl who disappeared from her California home in late 1999. Her **skull** was found and identified using **DNA** analysis more than a year later, and investigators requested detailed maps and aerial photographs that could be used in the search for her body. Digital orthophotoquads, which are electronic versions of aerial photographs that are corrected to remove distortion (orthorectified) and then referenced to map coordinates, were provided to searchers for use on laptop computers in the field. Although her body was never found, a suspect was arrested and charged in 2004.

After it was refused permission to revisit a Dow Chemical plant after an initial inspection during the 1970s, the U.S. Environmental Protection Agency (EPA) used aerial photographs to monitor activity at the facility. Although the company had concealed its activities from observers at ground level, many parts of the facility were visible from the air. The company argued that aerial photography constituted an illegal search that violated the Fourth Amendment of the U.S. Constitution, but the Supreme Court ultimately ruled in favor of the EPA. This case is often cited as a precedent because it gave a government agency the authority to use geospatial imagery to monitor potentially illegal activities. In a different case, related to a Superfund pollution cleanup investigation, the Nutra Sweet Company used a series of aerial photographs to show that contaminants had been dumped on nearby land owned by the X-L Engineering Company and transported beneath Nutra Sweet's property by groundwater. The photographs were one piece of information used to establish that X-L Engineering, not Nutra Sweet, was responsible for the groundwater contamination.

Geospatial imagery can also be used to resolve unsettled questions about international atrocities such as the Katyn Forest Massacre, in which 4500 Polish officers and soldiers were killed during the early days of World War II. German forces discovered mass graves near the Russian city of Smolensk in 1943, and the German government accused the Soviet government of mass murder. Soviet leader Josef Stalin refuted the charge and accused Germany of the atrocity. Despite evidence suggesting otherwise, the United States and Great Britain accepted Stalin's explanation and resisted further investigations. Aerial photographs taken by the German air force (Luftwaffe) during the war, which were captured and held as classified documents by the U.S. National Archives until 1979, provided important evidence in the form of images taken before, during, and after the area was occupied by German forces. A set of aerial photographs taken by the Germans in 1944, after the area had been recaptured by the Soviets, showed the bodies being removed and evidence of the massacre being destroyed by Soviet bulldozers. More recently, satellite images showing destroyed villages were used to assess the effects of civil unrest and document possible genocide in the Darfur region of Sudan in 2004.

SEE ALSO Cameras; Crime scene investigation; Digital imaging; Imaging; Remote sensing.

Gestational age, forensic determination

Estimating gestational age when a fetus dies is a specialized task in forensic **medicine**. Techniques for determining the gestational age of fetal or perinatal (around the time of birth) remains are mainly aimed at calculating the time since conception, and at determining if a specific disease could be the cause of fetal loss. In some cases, the time of conception cannot be known with certainty, as calculations based on last normal menstrual period may lead to an error of as much as two weeks.

The World Health Organization has set the viability threshold at 20 weeks gestation. Fetal death is defined as the death of a product of conception (fetus) before complete expulsion or extraction from its mother, regardless of the duration of pregnancy. Fetal death is divided into three categories: early, intermediate, and late. Early fetal death occurs at less than 20 completed weeks of gestation; intermediate fetal death occurs from week 20 through week 27 of gestation; and late fetal death occurs at 28 or more completed weeks of gestation. Proper classification of the fetal age into the correct classification has important ethical, legal, and also clinical implications.

Depending on the general condition of fetal remains, forensic specialists might face difficulties with age estimation. The whole skeletal length was probably the first marker used for fetal assessment and is considered valuable for diagnosing various syndromes and skeletal dysplasias (abnormal development) as well as for assessing fetal development. However, even if still considered a marker of developmental age, the whole skeletal length may be affected in post mortem (after death) assessment by the putrefactive (**decomposition**) process. In particular, body length increases slightly with maceration (tissue softening in liquid), whereas body weight and head circumference seem to be unaffected. For this reason, long bone length is considered a more stable and reliable marker than full-body measurements. Several investigators have produced linear regression formulas based on crown-heel length, crown-rump length, or body diameters to determine gestational age.

The advent of ultrasonography about three decades ago, especially high-resolution real-time ultrasonography, allowed a more accurate determination of fetal gestational age (crown-rump length or biparietal diameter and/or femur length). This technology is useful in forensic measurement of bones from standardized post-mortem radiographs in cases of questionable gestational age and can be compared with previous ultrasonographic measurements. Reference tables correlated with *in vivo* (in life) ultrasound measurements are widely available for complete fetuses and fetal remains including soft tissues, but the forensic specialist would also need methods for estimating gestational age estimation for osseous (skeletal, bone) remains.

One relatively accurate radiographic (x ray or other radiographic image) protocol for estimating fetal gestational age at death is based on femur (the long bone in the leg) diaphyseal (shaft) length, and compares images of fetal femur measurements with measurements of the same bones at **autopsy**. As several organs show major changes in developmental patterns throughout fetal development, maturation of fetal tissues and organs has been also proposed for gestational age estimation. One study evaluated the histological maturation of several soft tissues (skin, thymus, lungs, thyroid gland, kidneys, adrenal glands, and central nervous system) from 448 normal fetuses between 12–40 weeks gestation, and compared the estimated gestational age with that obtained by long bone measurement. Skin, lung, and kidney tissue (each with unique but distinguishable stages of development) were found to be useful for a more accurate assessment of gestational age when integrated with long bones measurements. In another study, the adrenal glands were found to be useful to define fetal age and maturation. Finally, another study reported that fetal development is constant and is not affected by intrauterine malnutrition and chromosomal abnormalities. Patterns of fetal skin development vary by site, with a range of 1–2 weeks in different regions of the body, and can sometimes give a rough suggestion of gestational age.

The growth of fetal long bones is affected by several conditions that might lead to growth retardation of the fetus in the womb. For this reason, many studies about estimating post-mortem gestational age have addressed the need for identifying new technologies and new targets to measure, aside from the long bones.

In conclusion, macroscopic examination (with the eye)or radiographic (x ray) examination are the most common methods used to estimate fetal age. Examination of the tissues and organs is also important for a better definition of fetal age.

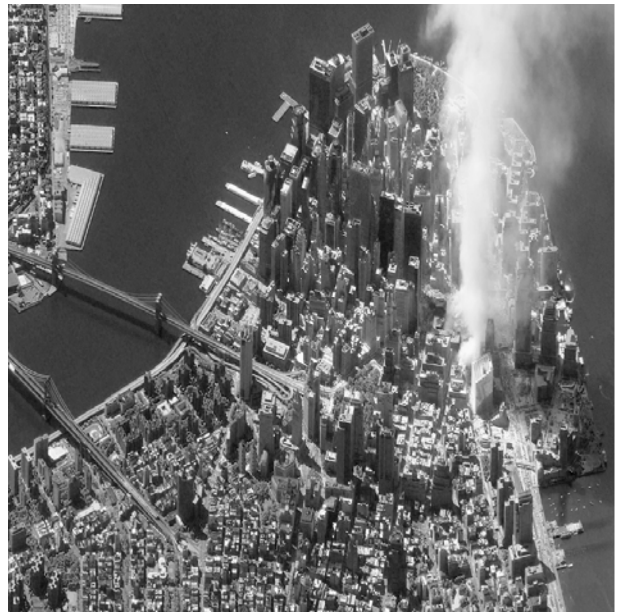
SEE ALSO Autopsy; Coffin birth; Skeletal analysis.

GIS

GIS is an acronym for Geographic Information System, a type of computer software that stores, manipulates, and displays maps and other spatial data. In **forensic science**, GIS software can be used to display and analyze patterns in maps showing crime scene locations, transportation routes, and potentially important forensic information such as bedrock or soil types. Some proponents have expanded the original definition of GIS to Geographic Information Science in reference to the body of knowledge about the techniques and applications of GIS software in addition to the software itself, but this article uses the original definition.

The October 2002 sniper shootings around Washington, D.C., are a high-profile example of a criminal case in which GIS software was used as a forensic tool. As the shootings occurred, detailed maps of the shooting locations were created and concentric circles were drawn at 1/4 and 1/2 mi (0.4 and 0.8 km) radii around the location of each incident. This allowed investigators to inventory buildings and other features that may have hidden the snipers, identify roads that the snipers may have used to arrive at or leave the scenes, and analyze similarities and differences among the shooting locations. At the time that two suspects were arrested, there were plans to expand the use of GIS to quantify the ease of access to each crime scene, analyze demographic and economic information about the areas in which the shootings occurred, and create three dimensional renderings of the crime scenes in order to identify similarities and perhaps predict the likely locations of future shootings. One of the difficulties encountered in this case was that the shootings occurred in different counties and states, and much effort was required to combine data from the different jurisdictions. Similar techniques have been used to solve serial rape cases in several large cities.

The use of geographic information to help identify suspects is known as **geographic profiling**. Although it is sometimes portrayed in the popular media as a highly developed discipline, geographic profiling is an imperfect practice that is continually evolving. Geographic profiling computer programs available in 2005 were based upon the results of research conducted in the 1980s and 1990s. The results suggested that most offenders commit crimes close to their homes; crime patterns follow a distance-decay function (the number of crimes committed decreases with distance from the offender's home); juvenile crimes are more highly clustered than adult crimes (because juveniles lack easy access to transportation); and the distance traveled varies according to the kind of crime. The output of geographic profiling programs consists of so-called hit score maps that use colored contour maps or three–dimensional surface maps to indicate the likelihood that a perpetrator lives in a certain area. Hit score maps can be combined with additional information, for example the addresses of known offenders or other suspects, and displayed using GIS software. Because of the amount of information required, geographic profiling works best in large cities where many crimes are committed. It can also require officials to recognize that a series of crimes are related and have likely been committed by the same person. Geographic profiling may fail in cases where a suspect travels great distances to commit crimes.



Dust and smoke in lower Manhattan, New York, is shown where the World Trade center towers once stood in an image taken by Space Imaging's IKONOS satellite on September 12, 2001. AP/WIDE WORLD PHOTOS/SPACE IMAGING. REPRODUCED BY PERMISSION.

GIS software is also used by many agencies for so-called hot spot analysis, in which the locations of crimes such as murder, burglary, and auto theft are plotted on maps. Specialized computer programs available to law enforcement agencies can then be used to find clusters of crime scenes, or hot spots, that may help to identify areas for undercover operations or increased police patrols. Although the two share some similarities, hot spot analysis is different from geographic profiling. Hot spot analysis identifies locations in which crimes are committed whereas a geographic profile is intended to identify the person committing the crimes that, like hit score maps, can be linked to the home or work addresses of suspects using GIS software. GIS analysts can then add other information such as the location of forested areas that might provide an avenue of escape or the occurrence of soil identical to samples obtained from a suspect's shoes. Some jurisdictions make crime location data available over the Internet, allowing citizens to interactively query databases and produce maps of reported crimes or the registered addresses of convicted sex offenders.

When combined with global positioning system (GPS) receivers and transmitters, GIS software can be used to track the movements of criminals released on parole or probation to determine if they are related to newly reported crimes. GPS receivers installed in police vehicles can likewise transmit their locations and help to more efficiently dispatch law enforcement officials in the minutes after a crime has been committed. In 2005, some transit police in San Francisco were equipped with wireless personal digital assistants (PDAs) that allowed them to use GIS information while on foot or in trains and laptop computers for use in patrol cars.

SEE ALSO Computer modeling; Crime scene investigation; Geology; Remote sensing.

Glass

Glass is a product of inorganic materials that solidified, but did not crystallize. Glass is mainly composed of silicon dioxide (SiO_2), and is extremely prevalent in everyday life. Often, windows are the most fragile elements of a building or a vehicle, and are thus broken by thieves or criminals in order to penetrate the premises or the vehicle. When glass breaks at the scene of a crime, small particles of glass are projected not only forward, but also backward, onto the perpetrator and into the immediate environment. These particles can later be retrieved and used to establish a link between a suspect and a crime scene.

Glass can be classified either by chemical composition or by use. There are four main chemical compositions of glass: soda-lime, lead, borosilicate, and special glass. While glass is mainly composed of silicon dioxide (SiO_2), it also contains modifiers that are used to vary the quality and properties of the glass. Soda-lime glass is obtained by adding a certain amount of soda (Na_2CO_3) and lime (CaO). It is this glass that constitutes most windows and bottles. Borosilicate glass is made by the addition of boron oxide and is much more resistant to heat. Different colors of glass are achieved by introducing small amounts of additives. For example, chromium (Cr) is used to give a green tint, cobalt (Co) for a blue tint.

Almost all types of glass are commercially available. Window glass is probably the most common type of glass, and is usually found as a flat, transparent piece composed of soda-lime glass. This type of glass does not resist high temperatures, quick temperature changes, or corrosive substances. Most of flat glass is now prepared using the floating process. This consists of laying the molten glass onto a bath of molten tin in an inert atmosphere in order to achieve a perfectly flat surface. Tempered glass is another type of glass that is much stronger than regular glass. This particular strength is achieved by introducing extra forces on both sides of the glass through rapid cooling and heating during the manufacturing process. This glass will shatter in very small pieces when it breaks. It is used on side and rear windows of cars. Laminated glass is a glass composed of multiple sheets of glass bonded together with a plastic film such as polyvinyl butyral.

When a criminal breaks glass during a criminal act, some small particles are projected onto his/her clothing, hair, or shoes. If the suspect is apprehended within a relatively short time span after the crime, these small particles of glass can be found on the hair, clothing, shoes, or inside pockets. At the crime scene, the crime scene investigator usually collects some of the broken glass as **evidence** for further comparison with any glass fragments found on a suspect. The comparison process might lead to the exclusion of a common origin between the glass from the suspect and the glass from the crime scene. Conversely, it might also show that the characteristics are similar and the two samples cannot be differentiated, thus supporting the hypothesis that the two samples of glass come from the same origin. It is important to apprehend the suspect shortly after the glass was broken, because the number of glass fragments on the clothing or shoes of the suspects diminishes very quickly after the activity. About 90% of glass fragments are shed from clothing within 24 hours.

Glass is characterized according to its physical and chemical characteristics. When investigating glass, the first examination is visual. The investigator observes its color, its thickness (if the fragments are big enough), its patterns, and its fluorescing (light-emitting) properties. Pieces of the glass can often be reassembled, revealing patterns that can be compared to crime scene samples. Demonstration of origin by assembly is the only way the common origin between two fragments of glass can be clearly established. The refractive index of the glass fragments is then measured. This is typically achieved by immersion of the fragment in oil and observing the lines of refraction at different temperatures. Finally, elemental composition of the glass is determined.

The interpretation of glass is complicated by the fact that the characteristics exhibited by a large piece of glass (such as a window) might vary from one end to the other. Thus, the analyst needs to determine the extent of the intravariability (variations of characteristics within a same sample) before it can be compared to a different sample. If the variation exhibited between the two samples is greater than the variation exhibited within one sample, then the two samples can be excluded as having a common origin. On the contrary, if the two samples cannot be differentiated, then this supports the hypothesis that they have a common source. However, it does not indicate that they have the exact same common source. Again, the characteristics exhibited by the samples might be very common and found in many other pieces of glass. Thus, the analyst usually expresses his/her findings using statistics.

SEE ALSO Criminalistics; Minerals; Monochromatic light.

Calvin Hooker Goddard

1891–1955
AMERICAN
FORENSIC SCIENTIST

Over the course of his career, Major Calvin H. Goddard was responsible for a number of important advancements in the field of **ballistics**. With the aid of others, he created one of the most comprehensive ballistics databases of its time, and adapted the **comparison microscope** for use in bullet comparison. Goddard also helped established the first independent forensic crime laboratory in the United States. Because of his high level of knowledge, police often called for his help in investigations, including the high profile cases of Sacco and Vanzetti and the St. Valentine's Day Massacre.

Goddard earned a reputation as a **forensic science** pioneer because of his role in the creation of two major advancements in the field. He was especially interested in the research and study of ballistics, and, with the help of Charles Waite, began to research and collect data from all known gun manufacturers. They compiled the results and created a database of the information, one of the most comprehensive ballistics databases of its time. About this same time, Goddard and fellow scientists Waite, Phillip O. Gravelle, and John H. Fisher adapted the comparison microscope so that it could be used for bullet comparison. This capability made it much easier for examiners to identify matching bullet striations.

As Goddard became known as one of the United States's foremost ballistics experts, the police sought him out to assist on investigations across the country. In 1927, Goddard was called to help investigators with the Massachusetts robbery/murder case of Sacco and Vanzetti. By using the comparison microscope to analyze bullets from Sacco's revolver and those found at the crime scene, Goddard confirmed that Sacco's gun was used in the robbery. His conclusions were upheld in a reexamination thirty years later. Goddard was also involved in the 1929 investigation following the St. Valentine's Day Massacre in Chicago. The case revolved around the murder of seven gangsters by men dressed in Chicago police uniforms. It was unclear whether the killers were actually police officers or rival gang members dressed as police officers. Goddard, working as an independent investigator, tested the machine guns used by the Chicago police and concluded that they were not used in the murders. Later that year, after a raid on the home of one of Al Capone's hit men, two machine guns were recovered. Goddard tested these weapons and proved that they were used in the murders.

As a result of Goddard's work in the St. Valentine's Day Massacre, he was asked to head the country's first independent forensic science crime laboratory, at Northwestern University. The lab provided testing of ballistics, fingerprinting, **blood** analysis, and **trace evidence**. In 1932, following the lead of Northwestern's lab, the Federal Bureau of Investigation set up its first crime laboratory, under the guidance of Goddard.

SEE ALSO Ballistic fingerprints; Sacco and Vanzetti case.

Hans Gross

12/26/1847–1915
AUSTRIAN
CRIMINALIST

Austrian professor and judge Hans Gross is often considered one of the founders of **criminalistics** for his research on the subject and the release of his 1891 book, *Criminal Investigation.* It was the first work of its kind to be published. Gross went on to publish other important research in the field of criminalistics. He also opened the first criminological institute in the world, at the University of Graz, Austria.

Gross was a driven young man, attending universities in Vienna and Graz, and earning his law degree in 1869. He worked as a magistrate for the criminal court at Czernovitz, Austria, and was also hired as a professor of criminal law at the University of Czernovitz. He later taught criminal law at both the German University at Prague and the University of Graz.

In 1891, Gross published his ground-breaking text *Handbuch fur Untersuchungsricter als System Der Kriminalistik*, with an English version entitled *Criminal Investigation* published in 1907. With this book Gross is credited for coining the term "criminalistics." The text provides the theoretical foundations for the science of **criminology**. He also founded and edited the *Archive for Criminology*, a journal that was continually published for more than one hundred years. In 1912, Gross opened the Imperial Criminological Institute at the University of Graz, the first of its kind. He considered it a major accomplishment in having criminology recognized as a serious academic discipline. The Hans Gross Criminological Museum, also part of the university, is still open today.

Gross is also known for a public conflict he had with his son, psychoanalyst Otto Gross. In 1913, Hans Gross ordered the arrest of Otto Gross because he considered him legally incompetent. Otto Gross was institutionalized then, and many times thereafter. One of Otto Gross's close friends was the writer Franz Kafka, who also was at one time a law student of Hans Gross. Kafka used information from *Criminal Investigation* in his notable novel *The Trial.* The book also makes references to Gross's arrest in the first chapter, and contains a character loosely modeled after Hans Gross.

SEE ALSO Careers in forensic science; Literature, forensic science in.

Gunshot residue

A powdery residue is created when a firearm is discharged. The residue can be helpful in forensically linking a suspect to the scene of the gunshot.

A bullet is propelled out of a gun or rifle at very high speed when the gunpowder in the barrel of the firearm is ignited. The ignition converts the solid gunpowder to a gas, which creates the pressure that propels the bullet outward. As the bullet emerges from the gun barrel, the gunshot residue is also propelled outward at high speed. The residue fans outward, forming a cone shape. Nearer the gun barrel, the residue is very concentrated. With increasing distance from the gun barrel, the residue becomes progressively less concentrated.

Gunshot residue can travel out from the gun to distances of 3–5 feet (0.3–1.5 meters) or even farther. At the farthest distance, only a few trace particles may be present. This information can be useful in determining if someone was involved in the firing of the gun. Close to the gun barrel, the residue deposits more heavily on surfaces like skin and clothing, to the point of being visible as a dark stain. Detection of a significant amount of residue, therefore, is a powerful piece of forensic **evidence** that the particular person was very near to, even holding, the gun when it discharged.

Residue can also be deposited on skin or clothing when a person briefly contacts a victim. In this case, only a light application of residue will be detectable.

This pattern can be critical in exonerating a suspect. For example, in 2005 actor Robert Blake, star of the 1970s television hit show *Baretta*, was found not guilty of the shooting **murder** of his wife. One of the important pieces of evidence was the absence of all but a trace of gunshot residue. It was successfully argued that the residue could have resulted from his handling of his wife's body or touching the interior of the car in which she was found.

Gunshot residue consists of tiny balls, flakes, or discs of the expelled gunpowder. The various shapes can be revealed by microscopic examination. The shape of the residue is governed in part by the composition of the gunpowder. Determining the type of gunpowder in the suspect firearm is a helpful step in a forensic investigation. In particular, the use of a scanning electron microscope equipped with an elemental analyzer permits the determination of the elemental composition of the residue.

Depending on the gunpowder, gunshot residue can contain lead residue, although lead-free ammunition is becoming more popular. As well, modern smokeless gunpowder residue can contain traces of nitrate, charcoal, and sulfur. Nitrocellulose and nitroglycerin may also be present.

SEE ALSO Ballistics; Firearms; Scanning electron microscopy.

H

Habeas corpus

The formal term, writ of *habeas corpus ad subjiciendum* is Latin for "you shall have the body subjected to examination." Commonly stated as writ of *habeas corpus*, it is generally defined as a judicial order that is issued by a judge on the behalf of a prisoner, and directed to an official of a prison or other detention facility that has custody of the prisoner. The legality of the writ of *habeas corpus* is formally contained in state constitutions and within the United States Constitution: "The privilege of the writ of *habeas corpus* shall not be suspended, unless when in cases of rebellion or invasion the public safety may require it." [Article 1, Section 9, http://www.usconstitution.net/const.html#A1Sec9]

The writ of *habeas corpus* has a long history that probably originated in twelfth-century England as a way to release illegally detained persons. It was used over the next several centuries as part of common law within the English government. In 1679, the *Habeas Corpus* Act was passed by the English Parliament in order to guarantee this mandate in law. Today, in the United States and other countries around the world (in various forms), the writ of *habeas corpus* is a fundamental liberty that guarantees due process to prisoners without deciding innocence or guilt.

Before petitioning for a writ of *habeas corpus*, a prisoner must prove that all other available means have been attempted. In order to hold a valid writ of *habeas corpus*, the prisoner must demonstrate that a real or legal mistake was made by the court ordering the original detention or imprisonment. When approved, a writ orders a law enforcement official to deliver a detainee to a specified judge's court at a specific time in order to determine whether the prisoner should be released from custody or continue to be imprisoned. In most cases of present-day usage, the writ is used to appeal state criminal convictions to the federal courts. In some other cases, a writ may be used against a private individual detaining another private individual. For example, people who have been denied custody of children in divorce and adoption proceedings may file a writ of *habeas corpus* with the court system.

SEE ALSO Latin forensic terms.

Hair analysis

The scientific study of hair is called trichology and this field dates to the mid 1800s. Forensic scientists perform three major types of hair analysis. Chemical assays are used to assess the use of illegal drugs, to screen for the presence of heavy metals in the body, and to test for nutritional deficiencies. The root of the hair has cells that contain **DNA**, which can be used for DNA analyses. Microscopic comparison of hair collected from two different places is used to determine if the hairs are from the same person or animal.

Because hair can be moved from location to location by physical contact, the presence of a specific person's hair can link a suspect or a victim to a crime scene. If hair is transferred directly from the region of the body from which it originates, it is considered a primary transfer. Approximately 100 head hairs are lost per person per day. These hairs usually end up on clothing, furniture, or on other items in the environment. Transfer of hair from these items is called secondary transfer. Secondary transfer of hair is very common with animal hairs, which are commonly found on pet owners and in the environment of pet owners and can be used to link suspects to crime scenes.

Hair grows out of living cells in epidermis of mammals. It is almost entirely made up of the protein keratin. The club-shaped hair root is anchored in a follicle, which has associated muscles, called *arrector pili.* When these muscles contract, hair becomes oriented nearly perpendicular to the skin. The hair itself is composed of three layers: the medulla, the cortex, and the cuticle. The medulla is the innermost canal that extends through the hair. In humans it can be continuous or discontinuous, interrupted by a series of empty spaces. Surrounding the medulla is the cortex, which makes up the majority of the mass of the hair. The outermost layer is the cuticle, which is a single layer of scales. In humans these scales overlap quite a bit and cling tightly to the cortex.

Pigments are found in both the cortex and the medulla, but they are absent from the cuticle. In humans, the pigments tend to be distributed toward the outer edges of the cortex, but this can vary depending on ethnicity. In human hair, the medulla is generally narrow, taking up less than a third of the diameter of the entire shaft. In hairs from animals, the diameter of the medulla is larger than half the diameter of the entire shaft. The cross section of human hair is most often circular, but occasionally oval.

Using morphologic features, forensic scientists classify six different types of hair on the human body: head hair, eyebrow and eyelash hair, beard and moustache hair, body hair, pubic hair, and axillary hair. Biochemical studies show that there are no significant differences in chemical structure among the hair types. Animals also produce different types of hair. They often have coarse guard hair external to softer fur hairs. They also produce whiskers and longer hairs in such places as the tail and mane.

In humans, hair undergoes cyclical phases of growth (anagen), transition (catagen), and resting (telogen). During the growth phase, the cells of the follicle actively divide and grow upward. The average anagen phase lasts about 1,000 days. During the telogen phase, the cells of the follicle are dormant and hairs naturally fall out. This phase usually lasts for 100 days. At any time, between 10 and 18% of all the hairs on a human head are in the telogen phase; about 2% are in the catagen phase and the rest, between 80 and 90% are actively growing. There is no pattern to determine which hairs on the head are in any phase at a given time.

Because hair grows out of follicles in the skin, materials in the body are incorporated into the hair. Hair grows relatively slowly, so it takes several weeks for materials in the body to be reflected in the composition of the hair. Hair that is collected for the presence of drugs, heavy metals, and nutritional insufficiencies is usually clipped from the nape of the neck. About a spoonful is necessary for analysis.

Results from hair composition analysis are somewhat controversial. A variety of factors impact the results, including the location on the body from where the hair was removed, the color of the hair, and the person's age and race. Standards vary as to methods of washing, cutting, and collecting hair. Standards for analysis also vary and a single lab may report different results from subsamples of the same sample. False-positives for illegal drugs are not uncommon and can occur when someone is in the presence of second hand smoke from marijuana or crack cocaine. External substances such as air pollution, composition of the water used to wash hair, and materials used to treat hair such as shampoo, hairspray, and hair dyes may also skew results. Hair analyses that do report the presence of illegal drugs or heavy metals should be verified with **blood** or urine tests.

Microscopic hair analysis has two components. The first is to identify characteristic features of the hair in question. The second is to then compare these features in the questioned hair and hair from a known origin. In particular, the hair in question may be collected as **evidence** from a crime scene and the known hair may be collected from a suspect or from a suspect's possessions. Microscopic hair comparison in forensic laboratories usually involves the use of two compound **microscopes** that are optically connected so that the hair in question and the hair from a known origin are in the same field of view. The hair is usually magnified between 40x and 400x.

The first step of the examination involves verifying whether the hair in question is that of a human or an animal. If the hair is from an animal, the examiner can potentially identify the species from which it originated, but it is usually impossible to assign the identity of a hair to a particular animal. In the case of dogs, most examiners can attribute hairs to given breeds. If the hair is from a human, the examiner will

Preparing a hair sample for analysis. © JIM CRAIGMYLE/CORBIS

determine the part of the body from which it originated. Some of the features that the examiner uses include length, shape, size, color, stiffness, curliness, pigmentation, and the appearance of the medulla. The majority of hairs examined in forensic investigations originate from the head and the pubic areas.

Microscopic hair examiners can categorize hair into three different racial groups based on established models. These groups are European ancestry, Asian ancestry, and African ancestry. Hairs from people of European ancestry are generally straight or wavy, have cross-sections that are round or oval and have fine to medium-sized pigment granules that are distributed evenly. Hairs from people of Asian ancestry are straight, have circular cross-sections and have medium-sized pigment granules that are grouped in patches. They may also have a thicker cuticle than in the hairs of other races. Hairs from people of African ancestry are usually curly or kinky and they have an oval cross-section. The pigment granules are large and are found clumped in groups. The hair shaft may twist or buckle and commonly splits. Head hair shows the most distinguishing characteristics for determining race, however other body hairs also evidence identifying characteristics. Complications with the assignment of race involve analysis of hair from infants and from people of mixed race.

The determination of age from hair is usually not possible by microscopic examination. Some general information may be surmised however, as the hair of infants is usually fine and contains few racial indicators. Hair of the elderly shows signs of pigment loss and often has variable diameter. The follicle of hairs contains chromosomes that can be stained to determine the sex of the individual. However, sex is usually determined from DNA testing.

Examination of the root can provide information as to the nature of a crime, especially if violence is suspected. If hairs fall out naturally during the telogen (resting) phase, the root will have a club shape. If hair is pulled out with force, the root will be stretched or broken and may have tissue attached. Examiners can also determine if hair has been burned, cut, or crushed.

A variety of factors influence the microscopic analysis of hair, including the experience and technique of the examiner. Because microscopic hair analysis is subjective, no statistics can be assigned to the probability that a hair belongs to an individual. The analogy often referred to is that an individual can recognize the face of a friend among a group of people even though all of them have the same features: eyes, nose, and mouth. In the same way, an experienced hair examiner can recognize those features of hair that determine whether or not it belongs to a specific individual.

DNA from cells associated with the root can be extracted and used for DNA analysis. Analysis of the DNA in the nucleus of the cell can be used for determining identity and DNA from the y-chromosome focuses on questions of paternity. Mitochondrial DNA is useful for establishing maternity. In theory, a single cell contains sufficient DNA to use for DNA analysis and so a single hair should provide the material required. In practice, a variety of complications make DNA testing of hair more complex. Roots of hair in the anogen (growth) phase contain more DNA than hairs from the telogen (resting) phase. However, hairs in the telogen phase are more likely to fall out passively. In addition, contamination issues are important as dead skin cells, which are also shed passively, contain DNA and may be collected from surfaces along with hair. If a hair from the telogen phase is collected, it may not contain enough nuclear DNA for analysis, but it might contain mitochondrial DNA. If the hair has been forcibly removed, then pieces of tissue may be attached and DNA analyses can usually be run easily on these tissue cells.

SEE ALSO Crime scene investigation; DNA fingerprint; Microscope, comparison; Mitochondrial DNA analysis; STR (short tandem repeat) analysis.

Handwriting analysis

The history of handwriting analysis to assess personality, today called graphology, could be said to extend back to Confucius, who wrote: "Beware of the man whose writing sways like a reed in the wind." The first extensive work on handwriting analysis dates to 1622, when an Italian physician named Camillo Baldi published *A Method to Recognize the Nature and Quality of a Writer from His Letters.* In this book, Baldi stated the fundamental premise that continues to guide handwriting analysis today: "It is obvious that all persons write in their own peculiar way . . . Characteristic forms . . . cannot be truly imitated by anybody else." In other words, like snowflakes, every person's writing is unique.

Over the following three centuries, Italian, French, and German investigators attempted to place the fledgling science of graphology on a firmer scientific footing. In particular, they linked graphology with Gestalt psychology, maintaining that handwriting originates in the brain and therefore betrays characteristics of the writer's mental makeup, even when done with a writing implement held in the other hand, the mouth, or the toes. They believed that the components of writing, such as pressure, speed, interruptions, variations in emphasis, the length and angle of upstrokes and downstrokes, and the upward or downward slope of writing on the paper, can be quantitatively measured and used to form a **psychological profile** of the writer.

In the context of modern **forensic science**, experts sharply distinguish graphology from true handwriting analysis. Graphology, scientists attest, is a pseudoscience, a fun but not scientifically valid parlor game, like palm reading, although many corporations take it seriously enough to hire graphology experts to profile job candidates. While graphology is not regarded as forensic **evidence**, it is still often used in combination with other techniques to profile criminals to aid authorities in their investigations. In the 1940s and 1950s, for example, graphology may have helped authorities track down George Metesky, the "Mad Bomber" of New York City. During the investigation of the **murder** of JonBenet Ramsey, a six-year-old girl found dead in the basement of her Boulder, Colorado, home in 1996, various experts closely examined the three-page, handwritten ransom note found in the home, attempting to provide a psychological profile of the note's writer and even to identify the killer. In 2002, graphologists had some success **profiling** the "D.C. sniper" who terrorized the Washington, D.C., area, but skeptics argue that the authorities resorted to graphology out of desperation in trying to break the case.

More commonly, forensic scientists use handwriting analysis for two more limited and defined purposes. One is to authenticate documents such as records, diaries, wills, and signatures. In 1983, for example, a German publisher claimed to have in its possession a collection of sixty-two notebooks that were the handwritten diaries of Nazi dictator Adolf Hitler. Handwriting analysts compared the writing in the diaries with known samples of Hitler's handwriting and concluded that the diaries were authentic. Later analysis of the paper and ink, though, showed that Hitler could not have written them, and investigation revealed that they were the work of a clever forger who was able to imitate Hitler's handwriting (so successfully that one of the known samples used by the handwriting experts was itself a forgery by the same person). A similar case involved the 1991 claim by a man from Liverpool, England, that he had in his possession a sixty-three-page diary and that its author, one James Mayrick, was the infamous Jack the Ripper, who brutally murdered five London prostitutes in 1888. While analysis of the paper and ink showed that the diary was not written with modern materials, handwriting analysts concluded that it was a fake, noting that most of the writing was done in just a few sittings and that some of the flourishes in the handwriting were added later, likely in an effort to make the document look more authentic.

The second purpose for which handwriting analysis is used is to link a specimen of handwriting with a crime suspect by comparing the suspect's handwriting with, for example, the handwriting on a ransom note or other communication linked to a crime. The purpose is not to profile the writer but to determine if the same hand produced a document known to have been written by the suspect, called an exemplar or standard, and the document in question. One of the first noteworthy cases in which handwriting analysis of this type was used was the 1932 kidnapping and murder of Charles Lindbergh, Jr., the infant son of aviation hero Charles Lindbergh. During the investigation, Lindbergh received fourteen notes from the kidnapper. Handwriting analysis later linked these notes to Bruno Richard Hauptmann, who was convicted and executed for the crime.

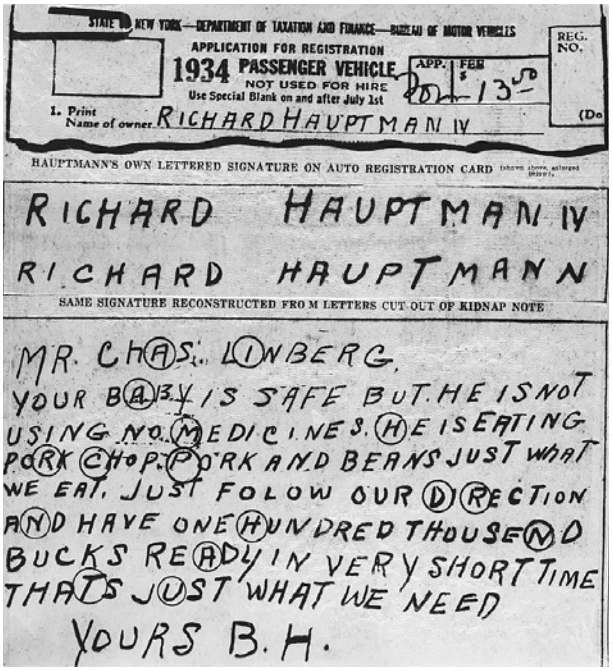
Handwriting analysts try to maintain a strict protocol with criminal suspects. They do not show the suspect the questioned document. They do not tell the suspect how to spell certain words or how to use punctuation. The suspect is to use writing materials similar to those of the questioned document. The dictated text should in some respects match the content of the questioned document so that the spelling and handwriting of certain words and phrases can be compared. The text the suspect is to write out should be dictated at least three times. And a witness should observe the procedure.

In either type of case—whether authenticating documents or investigating criminal suspects—handwriting analysts begin from the premise that while most people learn to write using a certain system, such as the Palmer or Zaner-Blosser system, they develop idiosyncrasies in the way they form letters and words. These idiosyncrasies become fixed and remain constant over time, even when the person is attempting to disguise his or her writing.

For comparison, analysts generally focus on four categories of factors that define a person's writing. The first is form: the shape of letters, their proportion, slant, lines, angles, retracing, connection, and curves. One writer, for example, might begin a *t* at the top and make a single straight line down, while another may begin at the bottom and form a loop. Similarly, a writer may form the vertical line of a *d* with an upstroke, then retrace downward to finish the letter, while another writer may form a loop rather than retracing. One person's capital *A* might be round and fat, another's thin and angular. One person's cross on a *t* may slope up, another's may be horizontal, and yet another's may slope downward. The second category is line quality, which results from the pressure exerted and the type of writing instrument and includes the continuity and flow of the writing. Thus, pauses can be discerned, and these pauses tend to take place in predictable patterns. The third category is arrangement, which includes spacing, alignment, formatting, and punctuation. Document examiners also look at a final category, content, which includes spelling, phrasing, grammar, sentence formation, and the like.

The central question is whether handwriting analysis is a valid forensic technique. The **Hitler Diaries** showed that even trained document examiners can be fooled, but for three decades it was regarded as valid and reliable evidence in court under the so-called *Frye* standard, which said that judges had to accept any form of expert testimony, including that of handwriting analysts, based on techniques generally accepted by scientists. The existence of such groups as the American Society of Questioned Document Examiners suggest that a community of scientists generally accepted the premises and techniques of handwriting analysis. Further, the U.S. Secret Service and the German law enforcement agency, the Bundeskriminalamt, maintain that their computer databases, the Forensic Information System for Handwriting (FISH), prove that among a large sample of writers, no two share the same combination of handwriting characteristics.

Since 1993, though, the admissibility of handwriting analysis has come under intense scrutiny. That year, the U.S. Supreme Court, in *Daubert v. Merrell Dow Pharmaceuticals*, created the stricter *Daubert* standard, which gives federal judges under the **Federal Rules of Evidence** more discretion in admitting or excluding scientific testimony. Specifically, it requires judges to determine whether a theory or technique has been tested, whether it has been submitted to peer review, whether standards exist for applying the technique, and what its error rate is.



Handwritten evidence in the case against Bruno Richard Hauptmann in 1934, who was convicted of kidnapping and murdering the infant son of the aviator Charles Lindbergh and writer Anne Morrow Lindbergh.

Under this stricter standard, virtually any forensic technique, including handwriting analysis and even such venerable tools as **fingerprint** comparison, could be questioned and excluded.

One federal ruling dealt a severe blow to the admissibility of handwriting analysis. In *United States v. Saelee* (2001), a federal court ruled that handwriting analysis had never been adequately tested, raising "serious questions about the reliability of methods currently in use" (162 F.Supp.2d 1097 [D.Alaska 2001]). The court went on to say that "the technique of comparing known writings with **questioned documents** appears to be entirely subjective and entirely lacking in controlling standards." In later cases, however, such as *United States v. Prime* (220 F.Supp.2d 1203 [W.D. Wash., 2002]), the courts examined the issue and ruled that such testimony was admissible under the *Daubert* standard.

SEE ALSO Criminal profiling; Document forgery; Expert witnesses; Federal Rules of Evidence; *Frye* standard; Hitler Diaries; Howard Hughes' will; Lindbergh kidnapping and murder; Pseudoscience and forensics; Questioned documents.

Handwriting forgery

Handwriting forgery is the process used by criminals to fraudulently make, alter, or write a person's signature—so that in most circumstances it appears identical with the genuine signature—with the intent of profiting from the innocent party. Authentic signatures are included on such papers as checks, employment records, legal agreements, licenses, titles, wills, and any other type of personal or business transaction or agreement. Even slight handwriting alternations are considered as much a crime as the complete fabrication of a signature when the intent it to deceive. However, the consequences of being convicted of handwriting forgery are usually much less than many other major crimes in the United States, with the specific punishment generally being in the form of a **misdemeanor** and set by various state and federal statutes. As a result of these minor consequences and because most people are uninformed of the various tactics used by such skilled criminals, the illegal activity of handwriting forgery is growing at a higher rate than most other crimes.

There are several ways in which forgers commit handwriting forgery. The process of tracing is used when a real signature is possessed by a forger such as in a bank check. The signature is often placed under a pane of glass positioned over a light source while a blank paper is laid on top. The forger then traces the signature's outline onto the blank page, usually first with a pencil and later with a pen. This method will not produce a precise duplication of the original, but will be seen as acceptable for many uses of the forger. Sometimes forgers use freehand simulations, which involve copying a genuine signature until the forger can simulate its general style and characteristics without difficulty. In both cases, tracing and freehand, the forger is unable to exactly reproduce the various impressions and downward pressures used by the original writer.

Expert handwriting forgers, however, can more easily forge vulnerable signatures, such as those without complex characters. Absence of writing control, excessive use of variations, and weakly shaped character forms also contribute to vulnerable handwritings, making them easier to be forged by criminals. For all of these vulnerabilities, the forger will typically use personal checks as the preferred means of handwriting forgery.

The act of handwriting forgery annually takes many millions of dollars in cash and property from victims, primarily in the form of fraudulent checks, credit card purchases, invoices, identification papers, and passports. Within the field of **forensic science**, investigative experts use scientific **handwriting analysis** to examine the legitimacy of signatures and legal identifications. The latest of handwriting forgery detection methods used by forensic scientists involves a computer-generated hologram of a signature in order to analyze its tiny variations. Using the scientific techniques of image processing and virtual reality, the digital image makes it quite easy to analyze the differences between the forger's writings and those of the original writer.

SEE ALSO Document forgery; Identity theft; Impression evidence; Ink analysis; Misdemeanor.

Hanging (signs of)

Hanging is a form of strangulation where a noose is pulled tight around the neck by the person's own body weight. The noose compresses the airways, cutting off the supply of oxygen to the lungs. It also compresses the carotid arteries, which carry **blood** to the brain. Both mechanisms cause asphyxia, in which body and brain are deprived of oxygen. However, asphyxia is not always the cause of death in hanging. In some cases, the pressure on the neck causes vagal inhibition, a reflex that leads to cardiac arrest. The forensic pathologist has to try to distinguish between hanging and other forms of strangulation and between suicidal, homicidal, and accidental hangings.

Most adult hangings are suicides. In children, hanging may occur by accident if they get themselves tangled up in clothes or a harness. Homicidal hanging is very rare and the generally the victim needs to be unconscious or intoxicated for such an act to occur. The ligature, that is, the material used to make the noose and suspend the victim, usually consists of whatever is at hand. Ropes, belts, and electric flex are among the most common ligatures in hangings. Clothing, washing lines, and even dog leads are sometimes used. The victim may use a fixed knot or a slip knot, the latter being particularly efficient at compressing the airways and blood vessels because it tightens so quickly under gravity.

Some hangings take place from a high point of suspension, where the body swings freely under gravity with the feet off the ground. However, hanging can also occur with the person kneeling, sitting, or half lying, from a relatively low point of suspension such as a doorknob or bedpost. The weight of the chest and arms is enough to provide fatal pressure on the neck; suspension of the whole body is not necessary. A tree is the most common suspension point in hangings occurring out of doors, but bridges or climbing frames have also been used. Indoors, there is a large range of suspension points including doors, banisters, rafters, and loft hatches, or practically any raised object. The circumstances of the hanging influence the signs on the body and the actual cause of death.

Suicide by hanging in prison is a particular problem. Obvious ligatures such as ropes or flex are clearly not made available. However, desperate people will fashion ropes out of bedclothes or their own clothes. Two of Britain's most notorious killers took their own lives by hanging in prison. Fred West hanged himself with a ligature made of strips of clothing in 1995, seemingly to avoid trial. In 2004, the serial killer Dr. Harold Shipman used bedclothes to hang himself from the window bars of his cell in Wakefield Prison.

An **autopsy** of a hanged body will often reveal neck markings. The nature of these depends on the type of noose. Few or no marks may be found with a noose made of a soft material like bed sheets. A rope or cord noose will, however, leave a deep furrow, often with accompanying abrasions and contusions. Hanging from a high suspension point leaves diagonal marks on the neck like an inverted V, which do not run around the full circumference of the neck. The point where the noose meets the vertical part of the rope is pulled up and away from the body and does not leave a mark on the neck. This can be used to distinguish a hanging from a manual strangulation. However, in a hanging from a low suspension point, the marks on the neck tend to be horizontal rather than diagonal and may look more characteristic of a manual strangulation.

High hangings are more likely to cause death by vagal inhibition, owing to the sudden pressure on the neck. The victim tends to be pale in such cases. A low hanging is more likely to lead to asphyxia and there may be some facial congestion and a purple protruding tongue. Asphyxia in hanging is usually related to the compression of the carotid arteries, rather than blockage of the airways. Petechial hemorrhages, caused by blood leaking from capillaries in the eyes owing to the pressure on the neck, are typical of many strangulations, but not often found in a hanging. Their absence can therefore help distinguish a hanging from other strangulations. The body may also show **lividity** due to pooling of blood in the legs, forearms, and hands.

In judicial execution by hanging, the body usually drops several feet, which causes disruption of the cervical vertebrae, which are the spinal bones in the neck. The cause of death, if the execution if correctly carried out, is disruption of the spine rather than asphyxia. Fractures of the cervical vertebrae are not often seen in suicidal, homicidal, or accidental hangings, unless the body has dropped through some distance.

In cases of suspected hanging, the pathologist will also carry out a **toxicological analysis** of the body. Drugs or alcohol sometimes play a role in hanging. It is not an easy form of homicide and a perpetrator may try to "knock out" or subdue the victim before applying the noose. In cases of suicide, the victim may drug himself or herself in an attempt to summon up the courage to carry out the act.

SEE ALSO Asphyxiation (signs of); Knots and ligatures.

Robert D. Hare

AMERICAN
FORENSIC PSYCHOLOGIST

Robert Hare has spent more than thirty years studying the concept of psychopathy, its assessment, its nature, its implications, and its amenability to treatment (or the lack thereof). Hare is the creator and developer of the Hare Psychopathy Checklist and the Hare Psychopathy Checklist-Revised, a reliable and valid assessment tool for determining the diagnostic presence of psychopathy, as well as risk for violence.

After completion of his master's degree in **psychology** in the early 1960s, Robert Hare realized that he needed to work for a while before commencing doctoral studies. Although he had no specific **training**, expertise, or interest in forensics, he accepted a position as the only prison psychologist at a men's maximum-security penitentiary near Vancouver, British Columbia (the British Columbia Penitentiary). His inexperience was immediately apparent to the inmates, and they commenced taking advantage of him by requesting favors, pushing boundaries, and manipulating him to the point of violation of prison rules. His interactions with a particular type of inmate (the psychopath), one who is endlessly manipulative, superficially charming, disrespectful of boundaries, a constant liar, and utterly unwilling to live within the standard rules and confines of society was, ultimately, one of the catalysts leading Hare to the study of psychopathy.

Hare's doctoral dissertation in psychology was concerned with the effects of punishment on human behavior. This led him to study the factors contributing to resistance to the effects of punishment, which, in turn, led Hare to research on psychopathy. He began publishing his empirical research on psychopathy in 1965, and published his first book, *Psychopathy: Theory and Research*, in 1970. This publication created the framework for Hare's future research in psychopathy.

Early in his work, Hare realized that a concept had to be quantifiable in order to be researched. He then set about creating an instrument with which to study the presence or absence of psychopathy in the criminal population. In 1980, Hare published his first 22-item psychopathy research scale. During this time period, the diagnostic criteria for antisocial personality disorder were being refined, and the psychiatric community paid little attention to Hare's work. By 1985, Hare had refined the assessment scale, pared it down to 20 items, and named it the *Psychopathy Checklist-Revised* (PCL-R). The PCL-R was to be completed during an in-person semi-structured interview, and used clinical chart data for corroborative information. Each checklist item was rated on a scale from zero (trait not present) to two (trait definitely present), making 40 the maximum possible score. The cutoff score for a diagnosis of psychopathy was 30. In 1991, Hare formally published the PCL-R, after having had validity and reliability data gathered as a result of the scale's use by his peers.

In addition to his groundbreaking research on the concept of psychopathy, and his development of the PCL-R, Hare has published books, articles, and book chapters on the subject of psychopathic criminal behavior. He belongs to the International Fellowship for Criminal Investigative Analysis, and is the recipient of numerous honors and awards, such as **FBI** citations, the Silver Medal of the Queen Sophia Center in Spain, the Canadian Psychological Association's Award for Distinguished Applications of Psychology, the American Academy of Forensic Psychology's award for "Distinguished Contributions to Psychology and Law," and the American Psychiatric Association's Isaac Ray Award for "Outstanding Contributions to Forensic Psychiatry and Psychiatric Jurisprudence." Robert Hare has made important and lasting contributions to the field and evolution of **forensic science**.

SEE ALSO Polygraphs; Profiling; Ritual killings; Training.

Robert (Roy) R. Hazelwood

AMERICAN
FORENSIC CONSULTANT

Former Federal Bureau of Investigation (**FBI**) agent Robert (Roy) Hazelwood retired from the FBI after serving for 22 years. When the Behavioral Sciences Unit (BSU) was created at Quantico, Virginia, Hazelwood was among the first criminal and behavioral profilers at the facility. He was a supervisory special agent with the Behavioral Science Unit at the FBI Academy, and his area of expertise was sexual crimes, particularly crimes involving sexual sadism. During his tenure with the FBI, Hazelwood taught courses at the FBI Training Academy, the University of Virginia, the University of Pennsylvania, the **United States Military Police** Criminal Investigation Division (CID), and the Southern Police Institute. He is a board-certified forensic examiner, an affiliate professor of administrative justice at George Mason University, vice president of the Academy Group, Inc. (a **forensic science** consulting firm comprised of former FBI and FBI BSU members), and an expert consultant, public speaker, lecturer, presenter, and published author of articles and books on forensic science (more than 40 journal and popular press articles, and co-author of five books). Numerous citations, certificates, and awards have been bestowed upon Roy Hazelwood by colleges and universities, law enforcement agencies, and criminal justice associations nationwide.

Prior to his career with the FBI, Hazelwood rose to the rank of major in the United States Army Military Police Corps, earned a master of science degree from NOVA University, and studied forensic **medicine** at the Armed Forces Institute of Pathology (AFIP).

Early in his career with the FBI's BSU, Hazelwood became interested in autoerotic fatalities, which led him to retrospectively study and amass data on more than 150 such cases. Another area of research interest he pursued involved a large-scale survey of the attitudes and beliefs held by law enforcement personnel (particularly police officers) concerning rape. In conjunction with scientists Janet Warren and **Park Dietz**, Hazelwood interviewed men convicted for sexually sadistic crimes; he personally interviewed perpetrators responsible for more than 800 rapes. They also extensively studied the wives and girlfriends of convicted sexual sadists. More recently, Hazelwood has conducted research in the area of juvenile sex offenders with scientists at the University of Virginia.

As vice president of The Academy Group, Inc. (AGI), Hazelwood continues his work in forensic science by acting as an expert consultant across North America, Latin America, and Europe in the areas of child abduction and molestation, rape, equivocal death, autoerotic fatalities, homicide, and sexual sadism. As an expert witness, he has testified in municipal, county, state, and federal courts, as well as before both houses of Congress and a presidential committee.

SEE ALSO Choking, signs of; Contact crimes; Criminal profiling; Hanging (signs of); Missing children.

Hemoglobin

As a component of **blood**, hemoglobin can be an important facet of a forensic investigation, especially to help detect the illegal practice known as "blood doping" in sports, and in helping to identify if a blood sample was from someone with a blood abnormality such as sickle cell disease.

Hemoglobin is a protein formed of two subunits (alpha and beta) that is found in red blood cells. The protein functions to pick up oxygen and distribute it throughout the body.

Both the alpha and beta subunits need to be present for the acquisition of oxygen, as does an iron molecule. Indeed, it is the presence of the iron that gives red blood cells the distinctive color that inspired their name.

The presence of iron enables hemoglobin to alternatively bind oxygen and carbon dioxide. As blood is pumped through the myriad of tiny channels that permeate the lung, oxygen can diffuse across the membrane of the channel to the red blood cell-containing fluid within the channels. There, the binding of oxygen to the iron-containing hemoglobin occurs. The oxygenated red blood cells pass out of the lungs and circulate throughout the body, transporting the oxygen along with them to cells.

Once oxygen has been released from hemoglobin, the vacated binding site is able to bind carbon dioxide and other waste products of cellular metabolism. This process is vital to maintain a body in a proper equilibrium. If otherwise allowed to accumulate, these products would reach toxic concentrations. The hemoglobin bound carbon dioxide is transported back to the lungs, where it is released from the red blood cells and expired. Completing the cycle, the once-aging vacant iron site can bind another molecule of oxygen.

The alpha and beta subunits of hemoglobin are encoded by separate genes. Normally, an individual has four alpha-encoding genes and two beta-encoding genes. Despite the different number of genes, protein production is coordinated so that precisely equal amounts of the subunits are made during red blood cell manufacture. The subunits are incorporated into the developing blood cells, where they remain throughout the days-to-weeks lifespan of the cells.

In the majority of people, both hemoglobin itself and the genes encoding the subunits are invariant. This aspect would seemingly rule out the routine use of hemoglobin as a tool to identify someone in a forensic investigation. However, in people with sickle cell disease (in which the abnormally-shaped red blood cell cannot easily pass through all blood vessels, producing an oxygen shortage) and thalassemia (a group of related maladies, in which hemoglobin production is low) the mutated hemoglobin **gene** that is the root of the malady can be detected in now-routine molecular biological test procedures such as gene **sequencing** (where the order of the bases that make up a gene is determined).

If a blood sample recovered from the investigation scene contains a mutated hemoglobin gene, the discovery of the same mutation in a blood sample of a suspect, for example, can be powerful, although not unequivocal, **evidence** tying the suspect to the crime scene.

In addition to the well-known hemoglobin disorders that underlie sickle cell anemia and thalassemia, there are several hundred other forms of abnormal hemoglobin. These forms, which usually do not cause harm to a person, can be detected using specialized molecular examination techniques, and so can be useful forensically.

In the case of a bloodstain at a crime or accident scene, determination of the amount of hemoglobin can be useful in indicating the approximate age of a person as well as their sex. Hemoglobin content can be determined in a less sophisticated fashion than hemoglobin disorders. Blood cells are broken apart in automated blood analyzers to free the hemoglobin. Upon exposure to a cyanide-containing compound, free hemoglobin binds the cyanide. The resulting compound (cyanmethemoglobin) specifically absorbs light at a wavelength of 540 nanometers, permitting the amount of hemoglobin to be determined. Normal ranges for hemoglobin (expressed as grams per deciliter; a deciliter being 100 milliliters) are 17–22 for newborns, 11–13 for children, 14–18 for adult males and 12–16 for adult females, as a few examples. While not by itself definitive, hemoglobin content determinations of a blood sample can be another useful piece of forensic evidence.

When hemoglobin levels in blood or the red blood cells are low, as in the aforementioned cases of sickle cell anemia and thalassemia, an individual is described as being anemic. Anemia can also arise from loss of blood in a traumatic injury or internal blood loss, a nutritional deficiency, or compromised bone marrow. Thus, hemoglobin analysis can provide clues concerning the health of a victim or suspect.

Higher than normal levels of hemoglobin can be encountered in people who routinely live or work at high altitude, due to the increased production of red blood cells to maximize the blood's oxygen carrying capacity. Athletes who have artificially increased this capacity through blood doping by infusing their own previously collected red blood cells, or injecting the drug erythropoetin, which triggers the body to increase its red blood cell supply, can be found out in this way.

SEE ALSO Blood.

Hemorrhagic fevers and diseases

Hemorrhagic diseases are caused by infection with viruses or bacteria. As the name implies, a hallmark of a hemorrhagic disease is copious bleeding. The onset of a hemorrhagic fever or disease can lead to relatively mild symptoms that clear up within a short time.

Hemorrhagic diseases occur naturally, and are fortunately rare. However, the ferocity and lethality of their symptoms as well as the speed at which they render a person extremely ill has been exploited in weaponry.

This weaponization has made the use of **forensic science** in the detection of the use of the agents of hemorrhagic fevers and diseases very important. A recent example is the tremendous effort of United Nations inspectors to unearth **evidence** of biological weapons before the United States began the war in Iraq in 2003.

The viruses that cause hemorrhagic diseases are members of four groups. These are the arenaviruses, filoviruses, bunyaviruses, and the flaviviruses. Arenaviruses are the cause of Argentine hemorrhagic fever, Bolivian hemorrhagic fever, Sabia-associated hemorrhagic fever, Lassa fever, Lymphocytic choriomeningitis, and Venezuelan hemorrhagic fever. The Bunyavirus group causes Crimean-Congo hemorrhagic fever, Rift Valley fever, and Hantavirus pulmonary syndrome. Filoviruses are the cause of Ebola hemorrhagic fever and Marburg hemorrhagic fever. Lastly, the Flaviviruses cause tick-borne encephalitis, yellow fever, Dengue hemorrhagic fever, Kyasanur Forest disease, and Omsk hemorrhagic fever.

Virtually all the hemorrhagic diseases of microbiological origin that arise with any frequency are caused by viruses. The various viral diseases are also known as viral hemorrhagic fevers. Bacterial infections that lead to hemorrhagic fever are rare, though one example is a bacterium known as scrub typhus.

Few of the known viral hemorrhagic diseases occur naturally in the United States. Accordingly, a primary risk factor for viral hemorrhagic diseases is travel to areas where the virus is indigenous (e.g., portions of Africa, Asia, the Middle East, and South America).

Forensic investigations of hemorrhagic fevers and diseases are not routine operations because of the tremendous health risk posed by the infectious agents. Work must only be conducted in high containment (BSL-4) laboratories. As of 2005, there are four such labs in the U.S.; two in the Washington, D.C. area, one at the **Centers for Disease Control and Prevention (CDC)** in Atlanta, and the other in San Antonio.

All personnel who work with these highly infectious viruses must wear protective clothing (e.g., double-gloves, biohazard suits, shoe coverings, face shields, respirators, etc.) and must often work in negative pressure rooms.

While the viruses in the groups display differences in structure and severity of the symptoms they can cause, there are some features that are shared by all the viruses. For instance, all the hemorrhagic viruses contain ribonucleic acid as their genetic material. The nucleic acid is contained within a so-called envelope that is typically made of lipid. Additionally, all the viruses require a host in which to live. The animal or insect that serves as the host is also called the natural reservoir of the particular virus. This natural reservoir does not include humans. Infection of humans occurs only incidentally upon contact with the natural reservoir.

Hemorrhagic diseases can result in symptoms that can progress from mild to catastrophic in only hours. As a result, an outbreak of hemorrhagic disease tends to be self-limiting in a short time. In some cases, this is because the high death rate of those who are infected literally leaves the virus with no host to infect. Often the outbreak fades away as quickly as it appeared.

Hemorrhagic fever-related illnesses appear in a geographical area where the natural reservoir and human are both present. If the contact between the two species is close enough, then the disease causing microorganism may be able to pass from the species that is the natural reservoir to the human.

Although little is still clear about the state of the microbes in their natural hosts, it is reasonably clear now that the viruses do not damage these hosts as much as they do a human who acquires the microorganisms. Clarifying the reasons for the resistance of the natural host to the infections would be helpful in finding an effective treatment for human hemorrhagic diseases.

The speed at which hemorrhagic fevers appear and end in human populations, combined with their frequent occurrence in relatively isolated areas of the globe has made detailed study difficult. Even though some of the diseases, such as Argentine hemorrhagic fever, have been known for almost 50 years, knowledge of the molecular basis of the disease is lacking. For example, while it is apparent that some hemorrhagic viruses can be transmitted through the air as aerosols, the pathway of infection once the microorganism has been inhaled is still largely unknown.

The transmission of hemorrhagic viruses from the animal reservoir to humans makes the viruses the quintessential zoonotic disease. For some of the viruses the host has been determined. Hosts include the cotton rat, deer mouse, house mouse, arthropod ticks, and mosquitoes. However, for other viruses, such as the Ebola and Marburg viruses, the natural host still remains undetermined. Outbreaks with the Ebola and Marburg viruses have involved transfer of the virus to human via primates. Whether the primate is the natural host or acquired the virus as the result of contact with the true natural host is not clear.

Another fairly common feature of hemorrhagic diseases is that once humans are infected with the agent of the disease, human-to-human transmission can occur. Often this transmission can be via body **fluids** that accidentally contact a person who is offering care to the afflicted person.

Hemorrhagic diseases typically begin with a fever, a feeling of tiredness, aching of muscles. These symptoms may not progress further, and recovery may occur within a short time. However, damage that is more serious can occur, which is characterized by copious bleeding, often from orifices such as the mouth, eyes, and ears. More seriously, internal bleeding also occurs, as organs are attacked by the infection. Death can result, usually not from loss of **blood**, but from nervous system failure, coma, or seizures.

SEE ALSO Ebola virus; Pathogens; Variola virus.

Edward Richard Henry

7/26/1850–2/19/1931
BRITISH
FINGERPRINT EXPERT

Over the course of his career, Sir Edward Richard Henry made significant advancements in the use of fingerprints as a tool to **forensic science**. He is responsible for developing the **fingerprint identification** system that is used throughout Europe and North America. In conjunction with his research, Henry published *Classification and Uses of Finger Prints*. As the head of Scotland Yard, he also led the transition from **anthropometry** to fingerprint identification.

Henry was born in London in 1850 and attended St. Edmund's College. He earned a degree from University College, London, in 1869, and a few years later began studying law at the Society of the Middle Temple. In 1873, Henry passed the examinations to join the civil service in India. It was in India where Henry first became involved in matters related to criminal identification and fingerprinting. He first worked in Allahabad, where he was an assistant magistrate collector, presiding over tax courts. Later, Henry was appointed as inspector general of the Bengal police.

While working as inspector general, Henry began to study how fingerprinting was and could be used as a way to identify criminals. He discussed the matter frequently with fellow English scientist Sir **Francis Galton** (1822–1911), and reviewed research conducted by William Herschel (1738–1822) and **Henry Faulds** (1843–1930). In 1896, Henry instituted the use of fingerprint impressions on criminal record forms in Bengal. Later that year, he developed a fingerprint classification system that allowed fingerprints to be filed, searched, and traced against thousands of others. Within a year, Henry's system was being used throughout British India. Within ten years, the system was being used by authorities throughout Europe and North America. Following the development of his system, Henry wrote and published a book detailing the subject, *Classification and Uses of Finger Prints*.

Henry returned to England in 1901, and became the assistant commissioner of Scotland Yard, overseeing the criminal investigation department. Later that year, under Henry's tutelage, Scotland Yard established its own fingerprint bureau. In 1903, Henry was appointed commissioner of Scotland Yard, a position he held for fifteen years. He was knighted in 1906.

SEE ALSO Fingerprint analysis (famous cases); Ridge characteristics.

William James Herschel

1833–1918
BRITISH
MAGISTRATE

William James Herschel is considered one of the first Europeans to recognize the value of fingerprints for **identification** purposes. He began using fingerprints and handprints, instead of signatures, in his work as a magistrate in colonial India in the 1850s and 1860s. He later collaborated with scientist **Francis Galton**, whose work led to establishing the first **fingerprint** classification system, implemented by Scotland Yard in 1901.

Herschel had always been fascinated by fingerprints. As a young man, he collected the fingerprints of his family members and friends as mementos, noticing that each impression was unique to each person, and that the patterns didn't change with age. In 1858, when he went to work in Jungipoor, India, as chief magistrate, Herschel found himself looking for a way to seal a contract with a local businessman. He asked for the man's handprint, and this unique method of signature secured Herschel's deal. Subsequently, Herschel began using handprints, and then fingerprints, on pensions, deeds, and jail warrants as a way to prevent fraud in a society where illiteracy was high.

At approximately the same time, Scottish physician and missionary **Henry Faulds** was studying the use of fingerprints in Japan. He wrote an article outlining his idea of using fingerprints to assist in criminal investigations for the scientific journal *Nature* in 1880. Herschel read the article and wrote a response to Faulds' piece in *Nature's* next issue. In it Herschel asserted that he had been collecting fingerprints since the 1860s, and was therefore the true inventor of this method.

In 1892, the debate caught the attention of Francis Galton, a British scientist and cousin of

Charles Darwin. Galton published *Finger Prints*, a work that established the uniqueness of fingerprints and suggested creating a classification system for them. Galton also publicly sided with Herschel, and thus Galton and Herschel became widely known as the two main innovators in fingerprint collection. Years later, Faulds' contributions were also recognized by the scientific community.

As one of the forefathers of fingerprint identification, Herschel's story and research has been well-documented in numerous books and journal articles, including the 2003 *Imprint of the Raj* by Chandak Sengoopta.

SEE ALSO Evidence; Fingerprint.

Hesitation wounds

Hesitation, or tentative, wounds are defined either as: any cut or wound that is self-inflicted after a decision is made not to commit suicide, or any tentative cut or wound that is made before the final cut that causes death. Such wounds are usually superficial, sharp, forced skin cuts found on the body of victims. These less severe cutting marks are often caused by attempts to build up courage before attempting the final, fatal wound. Non-fatal, shallow hesitation wounds can also accompany the deeper, sometimes fatal incisions. Although hesitation cuts are not always present in cases of suicide, they are typical of suicidal injuries. However, the presence of hesitation marks alongside or near to the final fatal mark usually indicates a forensic diagnosis of suicide over other possible causes of death.

Hesitation wounds are generally straight-line marks at the elbows, neck/throat, and wrists, although in a few cases they occur in the general area of the upper middle part of the abdomen (near the heart). Wounds made by people attempting suicide are typically made at an angle related to the hand that holds the weapon. The angle of such hesitation wounds is usually in a downward flowing direction because of the natural motion of the arm as it sweeps across the body. Hesitation wounds are often made under clothing, with particular parts of the clothing being parted to expose the target area of the body, a common feature seen by forensic experts examining suicidal wounds. Instruments used to inflict hesitation wounds are generally those found around the living quarters of the person attempting suicide. Such instruments include kitchen knives, single-edge and double-edge knifes, pocket knives, hatchets, razor blades, screwdrivers, and other sharp objects. People who have previously attempted suicide, but have not succeeded in their endeavor, will often carry visible scars from hesitation wounds.

Although usually used in association with attempted suicides, hesitation wounds are sometimes made in order to provide an alibi (a claim to have been elsewhere when a crime was committed) or to be seen as a victim (when in actuality the person was an active participant in the crime).

SEE ALSO Knife wounds; Suicide investigation.

Ludwig Hirszfeld

8/5/1884–3/7/1954
POLISH
SEROLOGIST

Ludwig Hirszfeld (also known as Ludwik Hirshfeld) is considered among one the most influential serologists and immunologists of the twentieth century. Along with the German physician Emil Freiherr von Dungern (born 1867), Hirszfeld discovered the inheritance of ABO **blood** types; these two scientists were responsible for naming the blood groups as such. Prior to Hirszfeld and von Dungern's work, the groups had been known as I, II, III and IV. Hirszfeld proposed the a and b designations for isoagglutinen (an **antibody** produced by one individual that causes agglutination of red blood cells in others of the same species. Agglutination is the clumping together of red blood cells, usually in response to a particular antibody.) In forensics, blood grouping and typing are critical for ascertaining whether bloodstains on weapons, tools, clothing, or elsewhere at a crime scene could have come from a particular victim or suspect; for matching fragmented human remains; and for assistance in resolving questioned paternity.

Another forensics contribution of Hirszfeld's was his establishment of serological paternity exclusion. This testing was the precursor to the modern-day use of **DNA** matching to establish criminal paternity—that is, establishing paternity in cases of unlawful sexual contact (particularly in the case of unlawful sexual contact with a minor). Serological blood testing can determine that an individual is not a biological parent of the offspring in question, hence the term paternity exclusion.

With R. Klinger, Ludwig Hirszfeld developed a serodiagnostic reaction test for syphilis, although this did not replace the Wasserman test for syphilis developed in 1906.

Ludwig Hirszfeld was born in Lodz, Poland, and studied **medicine** in Germany. After graduation from medical school he became a junior research assistant at the Heidelberg Institute for Experimental Cancer Research. There, his department chair was von Dungern, with whom he collaborated on studies of blood group heritability. In 1911, he accepted an assistantship at the Hygiene Institute of the University of Zurich; he was made an academic lecturer in 1914. The beginning of World War I led to epidemic outbreaks of typhus and bacillary dysentery in Serbia. Hirszfeld joined the Serbian Army as a serological and bacteriological advisor. While with the Serbian Army, Hirszfeld discovered the bacillus *Salmonella paratyphi C*, which has since been renamed *Salmonella hirszfeldi.* After the war ended, he and his wife (also a physician) returned to Warsaw, Poland, where he created a Polish **serum** institute; shortly thereafter, he was elected deputy director and scientific head of the State Hygiene Institute in Warsaw and became a professor there in 1924. In 1931, he was made a full professor at the University of Warsaw, and was asked to serve on numerous international boards.

After the occupation of Poland by the German Army, Hirszfeld was dismissed from his positions. He continued to do scientific work from his home until 1941, when he and his family were forced to move to the Warsaw ghetto. There, he was instrumental in organizing vaccination (against typhus and typhoid) and anti-epidemic campaigns. In 1943, he and his family fled the ghetto and remained underground until part of Poland was liberated in 1944. In 1944, Hirszfeld collaborated in the creation of the University of Lublin. In 1945, he became director of the Institute for Medical Microbiology at Wroclaw and dean of the medical faculty. He continued to teach at the institute, now affiliated with the Polish Academy of Sciences and named for him, until his death in 1954. Among the many honors bestowed on Ludwig Hirszfeld were honorary doctorates from the Universities of Prague (1950) and Zurich (1951); during his career, he wrote and published nearly 400 scholarly works in Polish, German, French, and English.

SEE ALSO Blood; Blood, presumptive test; Paternity evidence; Serology.

Hitler Diaries

In April 1983 Gruner and Jahr, the parent company of the West German publisher of the popular magazine *Stern*, announced that it had purchased for $2.3 million an astonishing set of documents: sixty-two notebooks that purported to be the handwritten diaries of Adolf Hitler, as well as an unpublished third volume of *Mein Kampf* (My Struggle), Hitler's autobiographical manifesto written while he was incarcerated in Landsberg prison in the 1920s. *Stern* began to serialize the diaries, which covered the period 1935–45, and sold publication rights to *Newsweek* in the United States and to the *London Times*.

The story surrounding the documents supposed that they had been on a plane carrying the Führer's personal archives out of Berlin when it was shot down in April 1945 near the village of Börnersdorf, in what would later become East Germany. The documents, which escaped destruction because they were housed in a metal box, were recovered by local farmers, who hid them until they were smuggled out of the country and came into the hands of a document collector and World War II enthusiast named Konrad Kujau.

The diaries sent shock waves throughout the world and touched off a historical controversy, for they portrayed a Hitler who was very different from the man who haunted the history books. In particular, they suggested that Hitler had no involvement in the 1938 riot against the Jews called *Kristallnacht* (Night of Broken Glass), that he knew nothing of the "final solution," or plans to exterminate Europe's Jewish population, and that his goal was simply to resettle western Europe's Jews in eastern Europe. If the diaries were authentic, they were the most significant historical find in decades, and the history of the Nazi regime of the 1930s and 1940s would have to be entirely rewritten.

Stern had initially been skeptical and reluctant to purchase the documents. In time, skepticism and reluctance turned into an almost fevered excitement about this apparent historical discovery. *Stern's* eventual willingness to accept the authenticity of the documents rested on two foundations. First were the memoirs of Lieutenant General Hans Baur, Hitler's chief SS pilot, who confirmed that a plane flown by one Major Friedrich Gundlfinger was indeed ferrying Hitler's private papers out of the country the month when his plane was shot down. Second, *Stern* sought confirmation from other sources. It submitted the papers to three handwriting experts: Dr. **Max Frei-Sulzer**, a former head of the police **forensic science** department in Zurich, Switzerland; American document verification expert Ordway Hilton; and a third expert in the employ of the German police. Comparing the writing in the diaries with known samples of Hitler's handwriting retrieved from Germany's Federal Archives, these experts concluded that both the diaries and the samples were written by the same hand, that of Adolf Hitler. Backing up their claims were prominent historians such as Britain's Hugh Trevor-Roper, although other historians noted historical inconsistencies in the diaries and denounced them as hoaxes.

The controversy prompted the German Federal Archives to conduct its own independent tests, focusing not on the handwriting, but on the physical documents themselves. On May 6, 1983, the archives held a press conference and announced that the diaries were forgeries.

The forensics **evidence** used to reach this conclusion was based on examination of the ink and paper, as well as seals affixed to the documents. Modern ink has different varieties of chemical composition, or "fingerprints," that fall into four groupings: (1) inks in which gallic acid is used to hold iron salts in suspension; (2) those in which gum arabic is used to hold carbon particles in suspension; (3) those that contain synthetic dyes, as well as a range of polymers and acids; (4) those that contain various solvents and additives such as chloride to hold synthetic dyes or pigments.

Ink samples, like any substance, can be tested using **chromatography**, a process by which the ingredients in the substance are held in a solution, then separated as they flow over a medium such as paper or silica gel that absorbs compounds at different rates. The bands created are then examined through micro-spectro photometry, a process of identifying substances from the light transmitted from the minute samples of them. In the case of ink, the results are then compared with a database of three thousand different inks maintained by the U.S. Federal Bureau of Investigation. The ink from the Hitler Diaries was subjected to these tests.

The chloride that was identified in the Hitler Diaries ink proved that the documents could have been written only in the previous year. Further, the paper, which had been "aged" by beating on it with a hammer and staining it with tea leaves, was examined under ultraviolet light. This examination showed that the paper contained an additive that had not been used in the papermaking process until 1954. The threads used to affix the seals to the documents, too, were suspect because they contained materials that were not available until after World War II. The **physical evidence** was conclusive: The documents were an elaborate forgery.

How could such a hoax be perpetrated on millions of people? At the center of the hoax was a sometime artist named Konrad Kujau (1938–2000), who was born into a middle-class family in Löbau, Germany. His father was an enthusiastic Hitler supporter, and the younger Kujau, who showed early promise as an artist, expressed his admiration for his father's hero by drawing sketches of the Führer. Kujau's early years are shrouded in some mystery; he worked in a number of short-lived jobs, and he later claimed to have studied at the Dresden Academy of Art. He surfaced near Stuttgart, West Germany, in 1957, where he had numerous brushes with the law and spent time in jail.

In the 1960s, Kujau decided to put his artistic skill to work as a forger, and he earned pocket change forging and selling the autographs of famous people. (In a bizarre footnote, it turned out that at least one of the documents the handwriting experts relied on was itself a Kujau forgery.) By the 1970s, Kujau was buying and selling Nazi memorabilia. He soon realized that he could enhance the value of the items in his collection by forging the signatures of prominent Nazi officials, as well as bogus documentation for them. Collectors snapped up the helmets, uniforms, flags, medals, and letters he sold in this way. Especially popular with collectors were paintings Kujau sold as Hitler's, but that were his own forgeries.

In the late 1970s, Kujau's criminal career took a more elaborate direction when he produced a handwritten manuscript purporting to be the third volume of Hitler's two-volume *Mein Kampf* (even though Hitler was known to have written the first two volumes with a typewriter). He went on to forge additional documents, including poems he sold to collectors by claiming they were from the pen of Hitler himself. Finally, he began producing the Hitler Diaries, which became a source of fascination among his gullible, but wealthy, clients.

The *Stern* saga began in 1979, when a journalist who worked for the magazine, Gerd Heidemann, himself a Hitler enthusiast, went to the home of one Fritz Stiefel to see his collection of Nazi memorabilia, including not just paintings and letters, but also a volume of Hitler's diary, supposedly one of six volumes extant. Heidemann smelled a major news story, but he knew that his editors would have interest only if he did further background work. He traveled to Börnersdorf, where he learned about the mysterious airplane crash and the metal box

A former reporter of West Germany's *Stern* magazine, Gerd Heidemann was convicted by a court of selling fake Hitler diaries to a West German magazine and sentenced to four years imprisonment in 1985. © REUTERS/CORBIS

containing papers that was retrieved from the wreckage. There Heidemann learned that there were not six but twenty-seven volumes of the diary, all in the hands of one Konrad Fischer, an alias Kujau commonly used. Based on his findings, Heidemann pitched the story to his editors, who agreed to pay two million German marks for the twenty-seven volumes. Kujau feared that selling the notebooks would lead to his exposure, but the money was just too much to refuse, so he began work on the diaries in earnest. Over a two-year period, Kujau wrote the diaries out in longhand Gothic script, sealing each notebook with special seals and black ribbon. For content, he relied on newspaper stories, medical documents, and reference books, including a book of Hitler's speeches.

After the documents were exposed as forgeries, Kujau fled, but he was arrested at the German border and tried in Hamburg in August of 1984. Kujau confessed to the forgeries, and during the trial he made no attempt to hide his guilt. Heidemann was tried as an accomplice, although he protested that he had also been duped. The pair was found guilty and sentenced to four and a half years in prison. The judge criticized *Stern*, stating the magazine "acted with such naïveté and negligence that it was virtually an accomplice in the fraud." After serving about three years of his sentence, Kujau was released. In the years that followed he created and sold art reproductions, ran unsuccessfully for public office, and was arrested in 1999 for forging his own driver's license. Kujau died in 2000. It has never been determined what happened to the total of five million marks *Stern* allegedly paid out for the Hitler Diaries.

SEE ALSO Chromatography; Handwriting analysis; Ink analysis; Micro-spectrophotometry.

Holocaust investigation

During World War II (1939–1945), an estimated total of 60 million people, including military personnel, paramilitary personnel, and civilians, had perished, whether in battle, by air raids or shelling of urban areas, village sieges, or in concentration camps. The term Holocaust refers to those ethnic populations who were persecuted and exterminated by the German Nazis in forced labor camps, death marches, inside ghettos, and rural areas. The International Military Tribunal in Nuremberg, Germany, conducted the investigation and trials of such crimes in the aftermath of World War II. In spite of strict secrecy kept by the Nazi authorities on their genocidal activities, thanks to several anti-Nazi paramilitary groups organized by civilians in the German-occupied territories, collectively known as the Resistance, testimonies of such atrocities were gradually gathered by the Allied Forces. Citizens from France, Italy, Austria, Poland, Norway, Denmark, and other countries formed a network of underground activity, supplying the Allies with intelligence, and smuggling targeted ethnic persons, such as Jews, Gypsies (Roma people), prisoners of war, and political dissidents from Germany and the occupied territories to the United Kingdom, southern France, and the Americas. In the face of the alarming amount of atrocities reported, the governments of the Allied Forces decided in early 1942 to thoroughly investigate and punish those responsible for such crimes. On December 17, 1942, the United States, the United Kingdom, and the Soviet Union signed a joint declaration acknowledging the mass murder of European Jews.

The Soviet Union issued the Moscow Declaration, on October 30, 1943, "Concerning responsibility of Hitlerites for committed atrocities" and the United Kingdom established, on August 8, 1945, the London Agreement, "Concerning prosecution and punishment of major war criminals of European Axis" (Axis meaning the Alliance of Nazi-Germany with Mussolini, then Dictator of Italy, and the Japanese Empire). Those two documents were combined into a body of laws to regulate the International Military Tribunal (IMT), created by the Allies (the United States, the United Kingdom, and the Soviet Union) in August of 1945. The IMT received jurisdiction to investigate and prosecute individual responsibilities concerning the following offenses: 1) crimes against peace, or "planning, preparation, initiation, or waging of wars of aggression, or war in violation of international treaties, agreements or assurances, or participation in a common plan or conspiracy for the accomplishment of any of the foregoing"; 2) war crimes, or "violations of the laws or customs of war ... shall include, but not be limited to, murder, ill-treatment or deportation to slave labor or for any purpose of civilian population of or in occupied territory, murder or ill-treatment of prisoners of war or persons on the seas, killing of hostages, plunder of public or private property, wanton destruction of cities, towns, or villages, or devastation not justified by military necessity"; and 3) crimes against humanity, or "murder, extermination, enslavement, deportation, and other inhumane acts committed against any civilian population, before or during the war ... or persecution on political, racial or religious grounds in execution of or in connection with any crime within the jurisdiction of the Tribunal, whether or not in violation of domestic law of the country where perpetrated."

From October 18, 1945, until October 1, 1946, twenty-two Nazi officers were prosecuted on one or more of such charges. Under IMT law, American military tribunals had also tried another 12 high-ranking German Officials at Nuremberg. However, the vast majority of post-war trials concerned lower-rank officials, such as concentration camps commandants, guards, leaders of mobile killing units (Einsatzgruppen), police officers, and Nazi physicians who carried out gruesome medical experiments on both political dissidents and other prisoners (Jewish and Gypsy women, men, and children) in the concentration camps. These criminals were prosecuted in different courts and locations of the Allied-occupied territories, such as Soviet-occupied zones of Germany and Austria, British and American courts, and Italy. Additionally, other countries also tried those who committed crimes in their respective territories during Nazi occupation and those who collaborated with Nazi authorities. Poland, for instance, sentenced to death Rudolf Hess, the commandant of Auschwitz extermination camp, in 1947. In post-war decades, Israeli intelligence continued to investigate and hunt Nazi criminals who had fled to other countries under fake identities, such as Adolf Eichmann, who was finally tried in Jerusalem in 1961.

In spite of testimonial **evidence** and intelligence on Nazi crimes against humanity gathered by the Allies and the Red Cross during the war, nothing prepared the world for the horrors that were disclosed when troops finally reached the concentration camps. In addition to the on-site photographs, movies, **physical evidence**, and reports by officers of the liberation forces, as well as the individual testimonies of those who survived the Holocaust or the Nazi medical experiments, a great amount of Nazi documentation and material evidence was found in prisons, in the secret police archives, and local police administrative files, which the Nazis did not succeeded in destroying before the Allied invasion.

From the Nazi documentation, such as decrees issued by Hitler to the Gestapo (German secret police organization), ministry memos, and doctrinaire Nazi material, it became clear to Holocaust investigators and prosecutors that concentration camps had served initially as a tool of 1) political terror against Germans, Austrians, Poles, and other political dissidents; 2) as a means of exploiting slave labor; and 3), as places for mass extermination of Jews, Roma people (Gypsies), and others (Serbs, Russians, and Albanians). Soon after Adolf Hitler was nominated as Chancellor of the Third Reich, the Nazi party issued a presidential emergency decree, in February 28, 1933, establishing a so-called "protective custody" that gave the Gestapo unlimited power to arrest people without judicial proceedings.

The Nazi rationale behind ethnic persecution and extermination was twofold. First, according, to the head of the SS, Heinrich Himmler, in a speech to the SS Major Generals at Posen in 1943, the mass extermination of Jews was necessary, although it was a very difficult task, because Jews, due to their religion, were against the Nazi war efforts, acting "in every town as secret saboteurs, agitators and trouble-mongers"; and second, because of the Nazi racial theory about the existence of a pure, "superior" race, the Aryans (Europeans descended from the Saxons), which should be protected from miscegenation with non-Aryan "inferior" races, which were gradually polluting and degrading the Aryan race. Therefore, Jews in particular, and all persons having at least one Jewish grandparent, should be eliminated.

The Roma people, like the Jews, were for centuries victims of discrimination by Europeans in general, due to their traditional customs and nomadic behavior. Nazi killing mobile units were sent to assassinate tens of thousands of Roma in the occupied eastern territories, such as Poland, Hungary, Serbia, and Albania, as well as in the western territories of countries such as France and Italy. Like the Jews, the Roma were also imprisoned in concentration camps, forced to work in factories and mines, tortured, shot, hung, or gassed in the death chambers. An estimated 1 million Roma are thought to have died under Nazi oppression, approximately half of the existing prewar population.

Nazi documents on the number and location of concentration camps all over Europe, such as one signed by the SS General Pohl, compared quantities of prisoners between 1939 and 1942, as follows: "At the beginning of war (Dachau, 1939 = 4,000 prisoners, today, 8,000; Sachsenhausen, 1939 = 6,500, today, 10,000; Buchenwald, 1939 = 5,300, today, 9,000; Mauthausen, 1939 = 1,500, today, 5,500; Flossenburg, 1939 = 1,600, today, 4,700; Ravensbureck, 1939 = 2,500, today 7,500." The report continues, showing a list of new camps built between 1940 and 1942: Auschwitz (Poland), Neuengamme (Germany), Gusen (Austria), Natzweiler (France), Gross-Rosen (Germany), Lublin (Poland), Niederhagen (Germany), Stutthof (near Danzig), Arbeitsdorf (Germany). The War Crimes Branch of the Third U.S. Army (Judge Advocate Section), reported that "Concentration Camp Flossenburg was founded in 1938 as a camp for political prisoners ... and it was not until April 1940 that the first transport of prisoners was received. ... Flossenburg was the mother camp and under its direct control and jurisdiction were 47 satellite camps or outer-commandos for male prisoners and 27 camps for female workers ..." The SS police (Gestapo) established a program of "extermination through work" in these camps, alternating with torture, starvation, and mass execution in gas chambers and incineration in furnaces. A secret motion picture made by the Gestapo of these mass executions was presented as evidence in the IMT court. According to surviving witnesses, when bored, the camp guards also amused themselves by randomly shooting or hanging prisoners.

Physical forensic evidence presented at IMT included an exhibit of three tattooed parchments, identified as human skin by Lieutenant George C. Demas, U.S.N.R., of the United States Chief of Counsel for the Prosecution of Axis Criminality. The evidence was presented in support of testimonial by a former prisoner at the Buchenwald camp, as follows: "In 1939, all prisoners with tattooing on them were ordered to report to the dispensary ... but after the tattooed prisoners had been examined, the ones with the best and most artistic specimens were kept in the dispensary, and then killed by injections administered by Karl Beigs, a criminal prisoner. The bodies were then turned over to the **pathology** department, where the desired pieces of tattooed skin were detached from the bodies and treated. The finished products were turned over to SS Standartenfuehrer Koch's wife, who had them fashioned into lampshades and other ornamental household articles. ..."

The IMT and other investigation committees could never make an accurate estimate of the real numbers of the Holocaust victims. Although Nazis in general kept detailed records, and some concentration camp death lists have been retrieved, it is likely

A section of tattooed human skin preserved as ornament, found at Buchenwald. It was submitted as evidence by American prosecution at the Nuremberg War Crimes Trial of 21 Nazi leaders. © CORBIS

that they only represent the tip of the iceberg. However, due to the huge scale of concentration camps operations and facilities, it was evident they were designed as death factories for mass extermination. Mass graves were also found by the Allied troops in several locations, with hundreds of corpses inside many of them. From some interim reports to Himmler, issued by German officers, it is known that, only from Hungary, "Up to June 27, 1944, 475,000 Jews were deported" to concentration camps in Germany. One report also informs Himmler that between January 11 and 31, 1943, a total of 45,000 Jews were deported from Poland, Berlin, and occupied Dutch territories to Auschwitz: "... the figure of 45,000 includes the invalids (old Jews and children). By the use of a practical standard, the screening of the arriving Jews in Auschwitz should yield at least 10,000 to 15,000 people fit for work. ..." Those "unfit for work" were killed in the gas chambers. Auschwitz and the other camps were constantly receiving prisoners and discarding the unfit for work, and renewing their work forces as the fit quickly became unfit through disease, murder, or starvation.

Long after the confusion of war, work is underway to preserve sites where forensic evidence of the Holocaust might still be found. Most extermination sites were cleaned or deliberately bombed and machinery dismantled by the retreating Germans to attempt to hide the full extent of and motive behind concentration camp atrocities, but some relatively undisturbed sites still remain. In the Birkenau camp in Poland, parts of walls from the gas chamber and crematorium still stand. Preservation groups are consulting forensic scientists for methods to protect traces of chemicals or human remains that are still in the area.

SEE ALSO Hitler Diaries; War crimes trials; War forensics.

Holocaust, property identification

After Nazi leader Adolf Hitler (1889–1945) rose to power in Germany in 1933, the Holocaust and, ultimately, World War II began. During this era, the Nazis stole art, other cultural property, and money from Jews and other groups. Hitler took art theft seriously; he sent an advance team into The Netherlands to identify important collections before invading. Many of these stolen works are of major importance and great monetary value. Some were given to Nazi functionaries and others were sold at auction, while many more were stored. After the war ended in 1945, the Allies found more than 2,000 repositories of artworks in Germany and Austria. Efforts at returning property began soon after and continue to this day. Many works of art in museums around the world still need to be restored to their rightful owners or their successors. **Art identification** experts are helping many initiatives, both national and international, in this work. Similarly, investigations are ongoing into sums of money deposited in bank accounts that may belong to Holocaust survivors and their families.

The International Council of Museums (ICOM) and the United Nations Educational Scientific and Cultural Organization (UNESCO) have been involved in this restoration on behalf of museums around the world. They have encouraged many new initiatives; for instance, in 1998, museums in The Netherlands began an inventory to check the history and **identification** of all items received between 1940 and 1948. There are also a number of databases listing works of art of dubious origin or works known to be stolen. Such databases may help those in the difficult search for stolen items—which could be anywhere in the world, either in a private collection or in a museum—particularly if expert advice is available.

For example, the Museum Provenance List is a compilation of museums that have listed works of art of doubtful origin in their collections. The Art Loss Register is the world's largest private international database of lost and stolen art with a special section for items looted during World War II. Their dedicated team of art specialists check the thousands of missing art works on their database against those offered at art auctions and art dealer fairs; they also check museum collections. As of 2005, they have so far identified 21 missing paintings, including works by Claude Monet, Pierre Bonnard, and Alfred Sisley. Sometimes the detective work involves tracing the rightful owners of a looted painting, rather than locating the work itself. In 2002, the Register, with the help of a museum in the Czech Republic and a journalist in the United States, finally tracked down the descendants of the owner of André Derain's *Head of a Young Woman*. The painting had been stolen in 1941.

The Commission for Looted Art in Europe helps families, communities, and institutions with the identification and recovery of looted cultural property and works on some 100 cases at any one time. In one example, the commission was approached by the Glanville family for help in recovering a triptych called *Three Stages of Life* by German artist Count Leopold von Kalckreuth. The artwork had been looted from their home in Vienna in 1938. The work was quickly located in the Neue Pinakothek in Munich. Ten weeks later, the German museum agreed to return it to its rightful owners, who had relocated to London.

Many Jewish families also tried to hide cash from the Nazis by opening up accounts in neutral Switzerland and in Palestine (later, in part, to become the modern state of Israel). The banks involved have made some restitution; for instance, Swiss banks finally made payments of 1.25 billion U.S. dollars to Holocaust survivors and Jewish organizations in 2000, after many years of dispute.

The Nazis were also responsible for one of the biggest thefts ever perpetrated by a government. As they invaded European countries in the late 1930s and early 1940s, they looted central banks for gold to finance their war machine. That gold was then sold to Switzerland and other neutral countries. The Nazis also stole gold, coins, and jewelry from Jews and other victims of their persecution.

One of the more sinister ways the Nazis obtained gold was by removing the fillings from the teeth of their victims in concentration camps. The company that supplied the cyanide for the mass gas exterminations told the Nazis that they could melt down and reprocess the gold fillings into bars. Some of this gold ended up in the German and Swiss banks, but it is difficult for experts to determine, even with the most advanced modern forensic techniques, how much of it comes from concentration camp victims. The matter is under discussion again as of 2005, with the possibility that further reparation may be made to Holocaust survivors.

SEE ALSO Art identification.

Homogeneous enzyme immunoassay (EMIT)

Forensic **medicine** and hospital laboratories utilize several different types of biochemical assays (tests) for drug detection in body **fluids** and tissues, including liquid chromatography-mass spectrometry, high-performance liquid **chromatography**, and immunochemical techniques, among others. Immunochemical techniques identify chemicals in urine, **blood** plasma, or tissues through the reactions between body antigens and antibodies in the presence of a foreign protein or chemical.

Cells present fragments of intracellular proteins to T cell lymphocytes (a type of white blood cell) that scan tissues in search of foreign **pathogens** such as viruses, bacteria, or **toxins**. When a foreign protein (or toxin) is detected by T cells, an immune response is triggered and antibodies are produced by B-lymphocytes and sent to bind to these alien proteins. Antibodies are proteins that enhance **antigen** recognition by other cells of the **immune system**. Enzyme-Multiplied Immunoassay Technique (EMIT) was introduced in 1972 for the rapid detection of hormones and drug metabolites in human fluids.

Antibodies against abused drugs are synthesized in laboratories to make them recognizable as foreign entities by a B-lymphocyte (type of white blood cell). Drug molecules are attached to a high molecular weight protein to form an antigen conjugate. These antigen conjugates are then injected into a host animal, whose immune system will produce drug-specific antibodies. The resulting antibodies may be of two types, either monoclonal or polyclonal antibodies. Monoclonal antibodies are families of identical proteins that only bind to a specific site of an antigen molecule, whereas polyclonal antibodies are not identical and bind to more than one antigen site. Once the desired blood levels of **antibody** are obtained, antibodies are recovered from the animal blood and purified.

EMIT detects even small quantities of drugs and drug metabolites (drug-derived molecules) in biological fluids, such as blood and urine. EMIT assays can be run in two different ways: Competitive EMIT and Non-competitive EMIT. Competitive EMIT contains drug antigens which will compete for the same antigen sites with the drug under investigation that is present in the body fluid sample. In a non-competitive EMIT assay, the drug under investigation reacts with a labeled antibody protein to form a colored substance. The following drugs are detected by EMIT: cocaine and metabolites, cannabinoides, opiates, **amphetamines**, phentanyl, methadone, **barbiturates**, benzodiazepines, phenylciclidine, and propoxyphene.

SEE ALSO Amphetamines; Antibody; Antigen; Barbiturates; Commercial kits; DEA (Drug Enforcement Administration); Illicit drugs; Immune system; Narcotic; Toxicological analysis; Toxicology.

J. Edgar Hoover

AMERICAN
GOVERNMENT OFFICIAL

For more than forty-five years, J. Edgar Hoover served as the director of the **United States Federal Bureau of Investigation** (**FBI**). Under Hoover's leadership, the bureau gained responsibility and importance within the U.S. government. A proponent of forensic investigation techniques, Hoover established the FBI's national **fingerprint** depository and crime laboratory. Hoover is also known for his aggressive anti-Communist and anti-radical actions and illegally investigating suspected individuals with wiretaps and surveillance.

Born in Washington, D.C., Hoover was active in the cadet corps and debate team in high school. He attended George Washington University, earning bachelor and master's degrees in law in 1916. In 1917, he joined the U.S. Department of Justice, working in the General Intelligence Division. When his division was moved to the FBI (at that time known as the Bureau of Investigation) in 1921, Hoover became the assistant director there.

Hoover became the director of the FBI in 1924, a position he would hold until his death in 1972. At the time, the FBI had been undergoing much criticism for a number of scandals under the previous administration. With Hoover in charge, the bureau rid itself of unqualified special agents, and implemented a new hiring process that selected only high-quality candidates. Hoover also ordered the creation of a crime laboratory, one that would provide forensic analysis on investigations across the country. In addition, he made the bureau's new fingerprint collection a national resource. The FBI thus became well known across the country, in particular because of its high-profile pursuit of gangsters like John Dillinger, Pretty Boy Floyd, and Baby Face Nelson. Hoover was honored for his contributions to the field of **forensic science** in 1959, when he was given the John A. Dondero Award from the **International Association for Identification**.

Over the course of his career, Hoover also became known for his relentless pursuit of Communists and other politically radical groups. He publicly attacked such figures as Martin Luther King, Jr., Robert Kennedy, and Ramsey Clark, and, in the privacy of the bureau, arranged such illegal investigative measures as wiretapping, surveillance, and the use of informers. Knowledge of some of these activities didn't become public until after Hoover's death in 1972.

SEE ALSO Bugs (microphones) and bug detectors; Careers in forensic science; FBI Crime Laboratory.

Howard Hughes' will

Howard Hughes, Jr. (1905–1976), an aviator, film producer, and manufacturer, died a multibillionaire. Unmarried and childless, Hughes left no clear heir. He had spent his final years as a mentally ill recluse and no one knew his intentions for his fortune. The fierce battle over the Hughes estate became a public spectacle involving dueling handwriting experts and neuropathology. The fight illustrates the difficulty of disproving hoaxes in the days before advanced forensic testing.

Hughes was born in Houston, Texas, to a mining engineer who devised an oil-drill bit that revolutionized the American oil industry. The family became wealthy, but the early death of his parents had a profound effect on Hughes. Always withdrawn, he became a hypochondriac fearful of germs. He ended his education in 1924 to enter the world of business. Not content with inheriting 75% of his father's tool company fortune, Hughes bought out the other 25% previously dispersed among relatives. The agreements with his relatives were bitterly arrived at and caused a permanent rift. After hiring executives to run his business, Hughes moved to Los Angeles and became a film producer. In 1933, he founded the Hughes Aircraft Company and it grew into one of the most profitable aircraft production companies in the world. Obsessive-compulsive by nature, Hughes became ever more eccentric as the years passed. Additionally, after sustaining serious injuries in an airplane crash, he became addicted to the painkiller codeine.

Hughes eventually refused to see people other than his closest business executives. Living behind closed curtains, he became best known to the public for his uncut hair and long fingernails. In November 1970, Hughes moved to the Bahamas to avoid taxes. He never returned to the United States. The last six years of his life were those of an itinerant exile, moving from one luxurious hotel to another. In his last years, Hughes refused medical treatment and did not eat properly. He became an emaciated wreck, weighing only ninety-four pounds at the time of his death. He denied his aides the right to tend him, until he finally lapsed into unconsciousness. They then flew him in an air ambulance to Houston, but he was dead of kidney failure by the time the plane landed, on April 5, 1976.

Hughes' death set off a stampede for his fortune. The assets of Summa Corporation, under which all of his businesses were governed, were valued at more than $2 billion. Probate was opened in Houston, Las Vegas, and Los Angeles. No one was certain if Hughes had left a will. George Francom, a personal aide, later testified that Hughes once mentioned he had drawn up a handwritten will. But when Francom asked about its whereabouts, the ever-suspicious Hughes refused to tell him where it was.

Summa conducted a worldwide search, but failed to turn up a signed document. The search did, however, yield an unsigned carbon copy of a 1954 will, written at the time Hughes set up the Howard Hughes Medical Institute in Florida. Stating his concern about germs and disease, Hughes declared that he wanted the institute to inherit most of his wealth and accomplish something good in his name.

The Summa representatives presented this 1954 carbon copy to a probate court as the best available **evidence** of Hughes' intentions. They argued that although a written will could not be found, Hughes' real and declared intent was to leave his whole fortune to the medical institute. Summa vice president Frank William Gay, attorney Chester Davis, and Hughes' former administrative assistant, Nadine Henley, wanted to continue to run the Hughes empire. Under their plan, as trustees of the medical institute, they would remain in command. They hoped to block the legal offensive of Hughes' former aide Noah Dietrich, with whom Hughes split in 1956, and who entered the fray with a new will.

The Mormon will, dated March 19, 1968, appeared days after Hughes' death as a public relations executive of The Church of Jesus Christ of Latter-Day Saints (Mormons) sorted through the mail on his desk one afternoon. A tattered yellow envelope, bearing a partly illegible Las Vegas postmark, was addressed to Spencer W. Kimball, president of the Mormon Church. Inside the first envelope was a smaller one that bore instructions written in a large scrawl. Kimball was directed to deliver the enclosed will to legal authorities in Clark County, Nevada. It was signed Howard R. Hughes.

The Mormons immediately doubted the legitimacy of the document. The three-page document, on lined legal paper identical to the type Hughes regularly used for memos to his staff, lacked the signatures of witnesses. Not wishing to appear foolish, Mormon Church leaders submitted the will to a Utah handwriting expert, Leslie King, who had studied Hughes' handwriting in an earlier court case. After a quick examination, she declared that Hughes possibly wrote the will. The Mormons then went to Las Vegas, the seat of Clark County, to file the testament.

The Mormon will gave one-fourth of the Hughes estate to the Hughes Medical Institute; divided one-eighth between the University of Texas, the University of Nevada, and the University of California; gave one-sixteenth to the Church of Jesus Christ of Latter-Day Saints; sent one-sixteenth to establish a home for orphaned children; gave one-sixteenth to go to the Boy Scouts of America; split one-sixteenth among Hughes' ex-wives, Jean Peters of Los Angeles and Ella Rice of Houston; gave one-sixteenth to cousin William R. Lummis (spelled Lommis in the will) and gave the last one-sixteenth to Melvin Du Mar (spelling incorrect) of Gabbs, Nevada. Dummar stated that he picked up the hitchhiking Hughes in 1968, loaned him a quarter, and never had any further connection with the old man after dropping him off.

The remainder of the estate went to the key men in Hughes' company. Dietrich was named executor of the estate despite the fact that he had not spoken with Hughes since 1956. Executors receive a portion of an estate for their services, giving Dietrich a financial interest in the case.

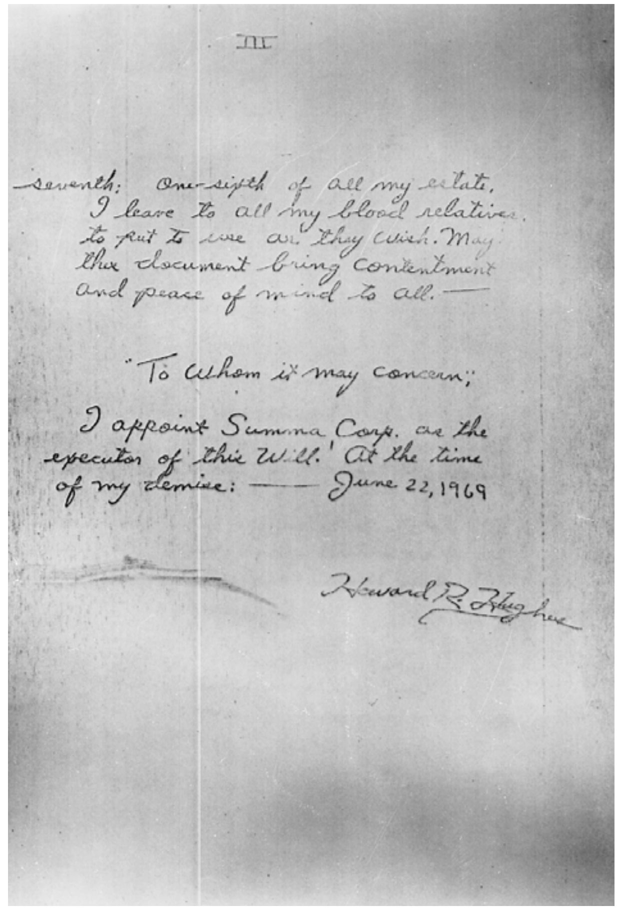
The will immediately became suspect because of the numerous spelling errors that filled its pages as well as suspect references. Hughes paid painstaking attention to detail throughout his life and never made vague statements. Dummar was suspected of forging the Mormon will, because no one could understand why Hughes would leave him one hundred and fifty million dollars or why the reclusive and germ-phobic billionaire would hitchhike. Dummar later admitted that his story was false. Lastly, lawyers who worked for Hughes found it inconceivable that he would have relied on a handwritten last testament. He had a deep fear that his handwriting could be forged and even tried to keep his signature secret.

In 1976 the technology did not exist for accurate forensic examination of the Mormon will. Ten handwriting experts, included well-known Bernard Bern, declared the document to be in Hughes' handwriting. One stated that the writing was typical of Hughes' consistent inconsistencies.

Hughes had three maternal second cousins who would become his heirs under Texas law if there was no will. Handwriting expert Spencer Otis, one of the most-respected analysts in the United States, examined the Mormon will and declared it to be a forgery. Hughes' relatives on his maternal side combined with his relatives from the paternal side to fight Summa. The heirs, who numbered twenty-three in all, were led by William Lummis. They wanted the estate to be divided according to a formula that would give nearly one-quarter to Lummis' mother and distribute the rest among the other heirs.

Meanwhile, a neuropathologist examined a portion of Hughes' brain that had been preserved in a jar on a shelf in Houston's Methodist Hospital. The scientist searched for evidence of disease or damage that could have impaired Hughes' judgment. Such a finding would throw into question anything that Hughes signed or said during his later years, but the neuropathologist found nothing significant.

By the end of 1976, the legal battle over the Hughes estate involved at least two hundred lawyers who pored over records in half a dozen states to find clues as to Hughes' intentions for his empire. They found a key to a safe-deposit box among Hughes' belongings in his old Hollywood office in Hollywood and a 1938 registered letter to the First National Bank in Houston saying he was enclosing a will. Neither discovery produced results.



III

seventh: One-sixth of all my estate, I leave to all my blood relatives to put to use as they wish. May this document bring contentment and peace of mind to all. —

"To whom it may concern;

I appoint Summa Corp. as the executor of this Will.' At the time of my demise: — June 22, 1969

Howard R. Hughes

The last page of a purported handwritten will of the late billionare Howard Hughes, found to be a forgery by investigators. © BETTMANN/CORBIS

In June 1978, after a seven-month trial, a jury decided by unanimous verdict that Hughes did not author the Mormon will. In the absence of another valid will, the court awarded the Hughes estate to the billionaire's surviving relatives. Lummis, as the court-appointed executor, agreed to administer the estate. By this time, the value of the Hughes' estate had dropped into the millions, with much of the fortune going to attorney's fees.

SEE ALSO Document forgery; Handwriting analysis; Questioned documents.

Human migration patterns

One of the most heated debates in **anthropology** and **archaeology** involves the evolution of man and the subsequent migration of the species that led to humans populating the world. Scientists question whether humans evolved in Africa or somewhere else and if the human species did evolve in Africa, scientists have asked when they began migrating to other places. In addition, anthropologists wonder whether humans, as they began their migration, simply replaced pre-human species in a given location or interbred with them.

Traditionally, scientists trying to answer these types of questions have traveled throughout the world searching for the oldest human remains and artifacts in a given location. Then, using scientific dating techniques, such as carbon dating, they estimate when humans might have first lived in a location. This type of work is obviously painstaking and requires great amounts of experience. It is highly dependent on environmental factors that may or may not have preserved human remains in a condition that allows for proper dating. It also assumes that the materials found are actually the oldest.

Beginning in the 1990s anthropologists and archaeologists began using techniques similar to those used in **forensic science** to solve some of the questions relating to human migration patterns. Instead of collecting bones and artifacts, scientists began collecting **DNA** from people all over the world. The DNA contains information that can be used to determine when populations from different parts of the world arrived at their current locations.

The DNA found in human cells is an extremely long molecule that is made up of a sequence of four different nucleotides. Over time, small changes, called mutations, occur in the order of the nucleotides in this sequence. If a molecular biologist detects a particular mutation in the DNA of a population somewhere in the world and then detects the same mutation in another group, and this mutation is not found in any other populations, it can be assumed that the two groups are closely related. That is, they probably were at one time a single group and then one group migrated to a new location. By searching for mutations and mapping them to the locations of populations of people throughout the world, anthropologists can build a picture of human migration patterns. In addition, because the rate of mutations in DNA can be estimated, scientists can also estimate when the various waves of migrations took place.

Two major types of molecular analyses have been used to probe questions concerning human migration patterns. A large study of the Y chromosome, which is passed from father to son, shows that all humans share a common ancestor who lived in Africa about 60,000 years ago. Another study focused on mitochondrial DNA (mtDNA). Mitochondria, which are organelles that power the cell, contain DNA that is passed from mother to daughter. The mtDNA study agrees with the Y chromosome study in placing the origin of the human species in Africa, however it demonstrates that migrations began much earlier, around 150,000 years ago. Archaeological evidence suggests that a wave of migrations out of Africa and into the Middle East began around 90,000 years ago.

Evidence from studies of the DNA in the Y chromosome show that a second wave of migrations out of Africa began around 45,000 years ago. These people moved to the Middle East, India, and China. During a brief warming period between Ice Ages, humans migrated farther east, to Central Asia, 40,000 years ago and then a group of them reached Europe about 35,000 years ago. Somewhere around 20,000 years ago, a group from Central Asia migrated north toward Siberia and the Arctic Circle. At the end of an ice age around 15,000 years ago, a group from the Arctic Circle migrated across the Bering Strait and populated North America. While these patterns of migration generally agree with archeological data, the dates tend to be much more recent than fossils and artifacts suggest.

Similar to traditional archaeologists, researchers working with mtDNA believe migrations out of Africa occurred earlier than Y chromosome data suggest. However, **mitochondrial DNA analysis** indicates that a single wave of migration, rather than two major waves, left Africa about 80,000 years ago and moved through the Middle East and toward India and Asia. This research then indicates that humans populated Australia 60,000 years ago, and artifacts found there corroborate these findings. The mitochondrial DNA data also indicates that people reached Europe about 50,000 years ago. This means that they cohabitated with Neanderthals for about 10,000 years, but that there was no interbreeding between the two groups of hominids. Finally, about 25,000 to 20,000 years ago, mtDNA data indicates that people from Siberia crossed over a land bridge to populate North America. Tools dating to 16,000 years old have been found in current-day Pennsylvania in North America.

Although there are discrepancies between the results from the two molecular techniques and that of archaeological data, most scientists agree that as more disciplines become involved in answering the questions, new and better insight will arise. In particular, the types of investigations that allow forensic scientists to identify differences between individuals contribute greatly to the understanding of differences between populations throughout the world.

SEE ALSO Anthropology; DNA sequences, unique; Genetic code.

Hypothermia

An important facet of a forensic investigation into a death is the determination of the **cause of death**. In cases where outward signs of physical trauma (i.e., gunshot or stab wounds) are absent, a forensic investigator may be presented with more subtle indicators of death.

One example is hypothermia; the intentional or accidental reduction of core body temperature to below 95°F (35°C) which, in severe instances, is fatal. Humans are endothermic (warm-blooded) creatures, whose core body temperature is physiologically regulated at approximately 98.6°F (37°C), even in fluctuating environmental temperatures. An abnormal rise in this core temperature can cause heat stroke, with an abnormal decrease representing hypothermia.

Intentional hypothermia is used in **medicine** in both regional and total-body cooling. The body's metabolic rate (the rate at which cells provide energy for the body's vital functioning) decreases 8% with each 1.8°F (1°C) reduction in core body temperature, thus requiring reduced amounts of oxygen. Total-body hypothermia lowers the body temperature and slows the metabolic rate, protecting organs from reduced oxygen supply during the interruption of blood flow necessary in certain surgical procedures. In some procedures, like heart repair and organ transplantation, individual organs are preserved by intentional hypothermia of the organ involved. In open-heart surgery, blood supply to the chilled heart can be totally interrupted while the surgeon repairs the damaged organ. Organ and tissue destruction using extreme hypothermia −212 to −374°F (−100 to −190°C) is utilized in retinal and glaucoma surgery and to destroy pre-cancerous cells in some body tissue. This is called cryosurgery.

In contrast to these beneficial uses of intentional hypothermia, accidental hypothermia (i.e., falling into icy water, or exposure to cold weather without appropriate protective clothing) is potentially fatal and is of forensic interest.

Hypothermia is classified into four states. In mild cases, 95–89.6°F (35–32°C), symptoms include feeling cold, shivering (which helps raise body temperature), increased heart rate, and a desire to urinate, and some loss of coordination. Moderate hypothermia, 87.8–78.8°F (31–26°C) causes a decrease or inhibition of shivering, along with weakness, sleepiness, confusion, slurred speech, and lack of coordination. Deep hypothermia, 77–68°F (25–20°C) is extremely dangerous, as the body can no longer produce heat. Sufferers may behave irrationally, become comatose, lose the ability to see, and often cannot follow commands. In profound cases, 66–57°F (19–14°C), the sufferer will become rigid and may even appear dead, with dilated pupils, extremely low blood pressure, and barely perceptible heartbeat and breathing. This state usually requires complete, professional cardiopulmonary resuscitation for survival.

Normally, the body's core temperature represents a homeostatic balance between heat generation due to metabolic processes, and the loss of heat through conduction, convection, evaporation, and respiration, and radiation.

Conduction occurs when direct contact is made between the body and a cold object, and heat passes from the body to that object. Convection is when cold air or water makes contact with the body, becomes warm, and moves away to be replaced by another volume of cold air or water. The cooler the air or water, and the faster it moves, the faster the core body temperature drops.

Evaporation through perspiration and respiration provides almost 30% of the body's natural cooling mechanism. Because cold air contains little water and readily evaporates perspiration; and because physical exertion produces sweating, even in extreme cold, heat loss through evaporation takes place even at very low temperatures. When heat loss involves both evaporation and convection, for instance when someone is outdoors in wet clothes, body temperature can quickly plummet to dangerously low levels.

SEE ALSO Death, cause of; Death, mechanism of.

Hypoxia

Hypoxia is a condition in which cells of the body are deprived of oxygen. Despite the varying reasons for hypoxia, depending on the location within the body, the consequence is the same: tissues cannot survive for long without oxygen. Prolonged oxygen deprivation proves fatal to cells. When the brain is involved, the consequence for a person is coma and death.

Cells acquire energy from oxygen and glucose. Most cells can survive for a short period using an anaerobic (lacking oxygen) metabolic process. But brain cells cannot. The damage to brain cells when hypoxia occurs is immediate. Blood carries a limited amount of reserve oxygen and brain cell death can occur within minutes of falling below normal oxygen levels.

There are several types of hypoxia. One of the more common is hypoxic hypoxia; the reduction of the amount of oxygen passing into the blood because of a reduced oxygen exchange (i.e., reduced lung capacity) or high altitudes. Reduction in lung capacity may be a result of lung damage, disease, or removal of portions of the lungs. Smokers are particularly susceptible to hypoxic hypoxia. People who change altitudes can adjust to the lower oxygen pressure as the blood produces more red blood cells carrying additional **hemoglobin** (the oxygen-carrying molecule in red blood cells).

Hypemic hypoxia occurs when the number of hemoglobin molecules or red blood cells is reduced. Either condition causes a reduction in the oxygen carrying capacity of the blood. Hypemic hypoxia can result from hemorrhage or anemia. It can also be induced by drugs, chemicals, or an increase in carbon monoxide (a condition experienced by smokers).

Stagnant hypoxia occurs as a result of poor blood circulation. Blood flow is reduced by prolonged sitting in one position, cold temperatures, or being exposed to g forces (the inertial force produced by acceleration or gravity). People who fly in aircraft frequently, sit in a chair for hours, or are sedentary may experience this type of hypoxia. It is important for the elderly or those whose movement is restricted to be sure they get enough oxygen to avoid this type of hypoxia.

Histotic hypoxia is the inability of the tissues to use oxygen. When organ tissues are involved, they appear blue in color and are called cyanotic. The blue color associated with cyanosis, especially noted around the lips, is due to the build-up of high levels of deoxygenated hemoglobin in capillaries. Drinking alcoholic beverages, poisoning by cyanide or carbon monoxide, and certain narcotics can impair gaseous exchange in the tissues, and lead to hypoxia. Prolonged hypoxia can lead to tissue damage or death.

SEE ALSO Death, cause of; Death, mechanism of.

Identification

Identification means verifying that something or someone is a particular object or person. To a large extent, the field of forensics revolves around this task because, in many cases, laws revolve around the identity of objects or people. The United States legal system includes laws covering topics from voter identification to **identity theft** to eyewitness identification. Identity must be established before death certificates can be issued and before life insurance policies are redeemed. Forensic scientists may be called upon to identify the origin of objects found at the scene of a crime such as bullets, hairs, or documents. Their work often requires the identification of a person from **trace evidence** such as fingerprints, **blood**, or even teeth marks. Forensic scientists maintain a variety of skills and technologies, which aid them in identification.

Each human being has unique characteristics, both physical and social, and these characteristics are what allow for the identification of humans. The study of these characteristics is called **biometrics**. Biometric techniques attempt to quantify the unique characteristics of a person by measuring them in some way.

The most obvious biometric technique is identification by appearance. This includes a person's height, weight, skin color, hair color, and eye color. Other visible physical markings such as scars, facial hair, and wearing glasses can also be used for identification. Of course, most of these physical characteristics may be altered over time: weight can be gained and lost; hair can be colored; even eye color can change by wearing contacts. Such changes can make features of the appearance deceptive when attempting to identify a person.

Humans have a variety of different physical features that are not obviously apparent that make them unique from one another. These include **DNA**, the shape of the teeth, hand and fingerprints, and features of the eyes. DNA is an extremely long molecule found in the nucleus of all human cells, including the cells at the root of hairs, and in skin tissue, **semen**, and blood. DNA is made up of a sequence of four different nucleotides and particular regions of this sequence can vary in unique ways from person to person. These variations can be determined using different biochemical analyses, often called DNA typing or **DNA profiling**, and are used for identification. Forensic dentistry (**odontology**) is the study of the various features of teeth that allow for the identification of a person from his or her teeth. Usually identification is based on comparing teeth or bite marks to dental records from an earlier time. Often these comparisons look for the presence of dental treatments and reconstructions. In addition, DNA can be extracted from teeth. Each person's hand and fingerprints are unique, even those of identical twins who have identical DNA. The exact patterning of the ridges, sweat pores, and pores of oil glands has been used for identification in criminal cases since the end of the nineteenth century. Retinal scans rely on the pattern of blood vessels in the back of the human eye, which have a unique pattern in each person. Although somewhat costly, this form of identification is one of the most accurate available.

A third group of biometric features revolve around behaviors that are unique to an individual. These can be social behaviors such as how a person walks or moves, a person's speech patterns and voice inflection, and handicaps that may be apparent. Such features can be documented on video or audiotape and analyzed for identification. Other behaviors used in biometrics include signature analysis, keystroke dynamics, and digitally analyzed voice characteristics.

Finally, physical identifiers can be imposed on people. Examples include branding and tattooing, although these types of identification can be associated with socially repressive systems, such as slavery and racial subjugation. Other forms of imposed physical identification include wearing of jewelry with identifying information such as dog tags, ID bracelets, anklets, and badges. Some of these may even be equipped with radio transponders that not only identify a person, but also his or her location. Microchips have been developed that can be implanted under the skin of valuable breeds of animals so that they cannot be lost and under the skin of endangered species so that information about their migration patterns can be learned. As this technology develops, the application may be applied to the identification of humans in certain circumstances.

The forensic identification of objects spans a broad array of techniques and technology depending on the object in question and the reason for the identification. When fires occur, forensic scientists may be called upon to identify charred remains. In the case of **automobile accidents**, **tire tracks**, car parts, and even shards of **glass** may require identification. Incidents involving guns depend on **ballistics** experts to identify the bullet as well as the firearm responsible for discharging it. Recovered materials from thefts and forgeries often require the identification of valuables such as artwork, manuscripts, and jewels. Crimes involving breaking and entering require the identification of the tools used to force entry. The examples of investigation related to criminal activity and requiring identification are extensive.

SEE ALSO Biometric eye scans; Biometrics; DNA fingerprint; DNA sequences, unique; Fingerprint; Fracture matching; Hair analysis; Handwriting analysis; Odontology.

Identification of Beslan victims in Russia

The Republic of Chechnya in southwest Russia has been seeking its independence from the rest of the Russian Republic. During Russian Premier Joseph Stalin's reign from 1929–1953, he had many Chechens deported to distant regions, such as Siberia. Since that time, the Chechens have sought their independence from Russia. However, it was the proclamation of war on Chechnya launched by the Russian military in 1994, after failed attempts to oust the Chechen president, that launched the long and bitter fighting that has since ensued between the Republic of Chechnya and Russia. Armed conflicts and allegations of crimes against humanity by the Russians against the Chechens have resulted in terrorist attacks from the Chechen rebels. The escalating violence generated a devastating seizure and attack on a Russian school by Chechen terrorists, resulting in over 300 deaths. More than 100 of the victims required forensic **DNA identification**. Forensic analysis of the Chechen hostage takers also produced **evidence** that they were under the influence of narcotics at the time of the attack.

September 1, 2004, was the first day of school after summer break for the children of Beslan school number 1 in the North Ossetia region of Russia, which borders the Republic of Chechnya. However, shortly after arrival at the school, over 1,200 students, teachers, and parents were taken hostage by Chechen terrorists. The hostage takers demanded that Russian troops leave nearby Chechnya and continued to hold the hostages in the school gymnasium for three days. The world watched on television as parents and relatives of the hostages gathered outside the school. Conflicting reports on the number of hostages added to the confusion.

The culmination of the takeover was a series of explosions and gun battles between the Chechen militants and the Russian police. A massive fire broke out in the gymnasium, where the majority of the hostages were confined. Many were shot trying to escape as waiting relatives outside looked on in horror. When the violence was over, a total of 336 people had been killed, including 156 children and 31 of the Chechen rebels. Many of the bodies in the gymnasium were severely burned, charred, and unrecognizable.

Over 350 wounded were taken to nearby hospitals and the victims who had perished were transferred to the Vladikavkaz morgue. In the confusion, hundreds of people were missing. Desperate friends and family members clutched photographs and searched the hospitals hoping to find their relatives among the injured. They also went to the morgue hoping not to find their loved ones among the dead victims.

Initially, bodies of victims were identified physically, by their clothing, birthmarks or characteristics recognized by friends and family members. Because so many of the bodies were severely burned, the investigators turned to DNA analysis for identification of many of the victims. It was a difficult task, as the badly burned state of the corpses required multiple extractions and **PCR** amplification assays to obtain DNA that was able to produce a profile. Relatives of missing persons provided **blood** samples, which were also used to generate DNA profiles. Samples of both relatives and victims were taken to Moscow for analysis. Comparison of the profiles of the victims to that of the relatives provided definitive identification of all of the unidentified victims with the exception of one child. The DNA profile from the last child victim identified did not match the DNA profile of the parents, requiring many buried bodies to be exhumed and re-examined. Finally, all victims were correctly identified, enabling the families to bury and mourn their loved ones.

Forensic techniques were used in another means to investigate the tragedy at the Beslan school. Among the dead were 31 of the Chechen terrorists who had held the hostages in the gymnasium. Blood was taken from the Chechens and sent to Moscow for forensic analysis. Russian law enforcement officials reported that most of the militants were under the influence of drugs at the time that the school was seized. High levels of both heroin and morphine were found in many of the attackers' blood. Those without evidence of narcotics in their system showed signs of abuse of other drugs.

The forensic tests of the militants also indicated that some of them had been in withdrawal, and had not received drugs for several days. Such a state is often consistent with aggressive and abnormal behavior. The lack of drugs could account for some of the attackers' brutality. The suspicion that the hostage takers were probably long-time drug abusers is consistent with the suggestion that many leaders of groups that plan terror attacks coerce their followers into taking narcotics. Individuals in a drug-induced state may be more amenable to carrying out the grim tasks associated with many terrorist attacks.

Forensic analysis was paramount during the investigation of the tragedy at Beslan school number 1. Without these modern forensic techniques, the investigation would have required much more time, requiring those affected by the tragedy to wait for answers rather than begin the healing process.

Investigators gather IDs and personal belongings found in the debris of a school in Beslan, Russia, after a hostage seizure by Chechen separatists in 2004 ended in a bloodbath with at least 335 people killed, half of them children. © DENIS MARININ/REUTERS/CORBIS

SEE ALSO CODIS: Combined DNA Index System; DNA; DNA profiling; European Network of Forensic Science Institutes; PCR (polymerase chain reaction); STR (short tandem repeat) analysis; Toxicological analysis; Toxicology.

Identification of Christopher Columbus' remains

DNA analysis could be used to solve an **identification** puzzle going back more than 500 years. The remains of Christopher Columbus are said to lie in Seville Cathedral, in Spain. However, bones buried in Santo Domingo Cathedral in the Dominican Republic

A scientist points to the box allegedly containing the remains of explorer Christopher Columbus, in Seville, Spain, 2003.

are also said to belong to the famous explorer. In 2005, Spanish researchers are hoping to extract enough DNA from both sets of bones to allow an identification to be made.

Columbus died in 1506 in Valladolid, Spain, and was buried in a monastery there. His remains were later moved to Seville. However, he had always expressed a wish to be buried in the Americas. In 1537, the widow of his son Diego was allowed to take the bones of both her husband and his father to the Dominican Republic for burial in the cathedral of Santo Domingo. There they remained until 1795, when Spain lost control of the country. The bones believed to belong to Columbus were dug up and moved so they would not fall into the hands of foreigners. The remains finally arrived in Seville, via Cuba, in 1898.

These are the bones buried in Seville Cathedral next to those of Hernando Colon, Columbus' son. However, in 1877, workers digging in Santo Domingo Cathedral uncovered a box containing 13 large bone fragments and 28 smaller ones and inscribed with Columbus' name. It looked as if the Spanish had dug up the wrong bones in 1795.

Extraction of DNA from the bones in Santo Domingo and Seville and comparison with Hernando Colon's DNA could identify which set of remains is the genuine one. Preliminary DNA testing in 2004 used mitochondrial DNA, which is passed down from the mother, rather than nuclear DNA, which was unavailable in the samples, and showed that the remains attributed to Columbus in Spain contain DNA that is similar to that of his brother Diego, who was also buried near Seville. Spanish researchers also traveled to Santo Domingo to carry out a preliminary assessment. They will study the condition of the remains and hope to take a sample of DNA for analysis. DNA can remain intact for hundreds of years, so there is a good chance that the analysis and identification can be confirmed.

SEE ALSO DNA fingerprint; Exhumation.

Identification of the son of Louis XVI and Marie-Antoinette

For more than two centuries, one of the most mysterious questions in history concerned the fate of the son of Marie-Antoinette and Louis XVI of France. Known as the "Lost Dauphin," official records claimed that ten-year-old Louis Charles, the heir to the throne of France, died in prison in 1795. Rumors, however, suggested that the child had escaped and the body found in prison was that of a double. In 2000 forensic techniques were applied to **DNA** from the remains of the heart of the purported Louis Charles as well as to locks of hair from Marie-Antoinette, her two sisters, and samples of DNA from two of the sisters' living relatives. These analyses confirmed that the heart was from a child with maternal relations to Marie-Antoinette.

During the French Revolution at the end of the eighteenth century, Louis XVI and his wife, Marie-Antoinette, were unseated from the throne. Louis XVI was killed at the guillotine and his wife and son were imprisoned in the Temple prison in Paris. Eventually, Marie-Antoinette, too, was beheaded and the son, named Louis Charles, was left in prison for two more years. He was treated poorly, left alone in a windowless room most of the time, and at the time of his death on June 8, 1795, his body was covered in scabies and tumors.

Official records show that Louis Charles died of tuberculosis, but many historians did not accept the official reports. Popular rumor supported the idea that the boy was taken from the jail cell and that another boy was left in his place. Others believed that members of the French Revolution had murdered him. Eventually, the idea that Louis Charles had escaped and was still alive found favor with the public. In 1814, the monarchy was restored to France and at this point many people came forward, claiming to be the lost dauphin.

Although he never claimed it himself, John James Audubon, the naturalist, was rumored to have been the escaped Louis Charles. He was born the same year as Louis Charles and lived in Paris as a child. He was adopted around the same time that Louis Charles was said to have escaped from prison. However, it was later shown that Audubon was born in Haiti, the illegitimate son of a French father. One Louis Charles impersonator was a man from Wisconsin named Eleazar Williams. Native American Mohawks kidnapped Williams at the age of seven. He went on to become an Episcopal minister in Green Bay and claimed to be the lost dauphin. He never presented **evidence** to prove his claim, and was eventually shown to have Mohawk genetic traits, proving that he could not have been descended from the French monarchy. A German clockmaker named Karl Wilhelm Naundorff also claimed to be Louis Charles. He convinced Louis Charles' childhood caretaker that his memories coincided with memories she had of the Louis Charles' youth. Naundorff moved to the Netherlands and there he convinced the government that he deserved the royal name of Burbon, which his descendents still use. In 1950, one of Naundorff's bones was exhumed and compared to DNA from Marie Antoinette. The DNA did not match, discrediting Naundorff's claim.

At the time of Louis Charles' death, a physician named Philippe-Jean Pelletan performed an **autopsy** on the boy who had died in the prison. As was custom for royalty, the doctor removed the heart so that it would not be buried with the body. The doctor then hid it in a handkerchief, brought it home and put it in a jar of alcohol where he kept it as a curiosity. Later, one of Pelletan's students was intrigued by the heart and stole it for himself. On his deathbed, the student admitted his theft to his wife, who returned the heart to Pelletan. Pelletan's wife then sent the heart to the Archbishop of Paris. In 1830, the palace where the heart was stored in a crystal urn was sacked and the urn was smashed. Pelletan's son, however, went to the palace and retrieved it from where it lay in a pile of glass. The heart was then sent to the arm of the Bourbon family that was in Spain. Later, the heart returned to Paris once again and was placed in a crystal vase in the royal crypt at the Saint Denis Basilica.

The heart of Louis XVII is displayed in a Paris church. DNA studies proved that Louis XVII, son of French King Louis XVI and Queen Marie-Antoinette (who were put to death during the French Revolution), did not escape as rumored, but died while imprisoned.

In April 2000, the Duc de Bauffremont requested that samples from the heart be removed for genetic testing. Two samples were taken: one from the aorta and one from the heart muscle. The samples were then split, and half was sent to the Center for Human Genetics of Leuven in Belgium. The other part was sent to the laboratory of Professor Ernst Brinkman in Münster, Germany.

The study focused on DNA from the mitochondria, the organelle responsible for providing energy to the cell. Each cell contains many mitochondria, and thus many copies of mitochondrial DNA. In contrast, each cell only contains one nucleus, and therefore only one copy of nuclear DNA. In addition, mitochondrial DNA is shorter and more likely to have survived intact over the centuries. Mitochondrial DNA originates from the egg, so the study could only determine the maternal relationships. The part of the mitochondrial DNA used in the study is called the D-loop, or displacement loop. It contains two regions that have considerable variability between people called HVR 1 and HVR 2. These two regions have been studied in a variety of cases involving very old tissue, including Neanderthal skeletons.

Mitochondrial DNA data from Marie-Antionette's family had already been collected from the Naundorff study in the Netherlands. These sequences were from hair from Marie-Antoinette and her two sisters, Johanna Gabriela and Mada-Josepha, and two living relatives, the Queen of Romania and her brother, Andre. The Center for Human Genetics found that the mitochondrial DNA from the heart of the putative Louis Charles varied from a standard in five nucleotide locations and these variations are identical to the variations found in the mitochondrial DNA sequences of Marie-Antoinette and all of her relatives. The laboratory in Germany found the same variations at four of the locations, but could not retrieve data from the fifth location because the DNA was degraded. The conclusion of both laboratories was that the boy who died in prison in 1795 was related to Marie-Antoinette and most likely was Louis Charles.

In June 2004 the heart of Charles Louis was removed from the crystal vase and buried alongside the bodies of Louis XVI and Marie-Antoinette and a funeral was held for the boy who would have been King Louis XVII of France.

SEE ALSO DNA fingerprint; DNA recognition instruments; DNA typing systems; Genetic code; Mitochondrial DNA analysis.

Identification of tsunami victims, Southeast Asia

On December 26, 2004, a tremendous earthquake measuring 9.0 on the Richter scale occurred under the sea near Southeast Asia. When the Australian and Eurasian tectonic plates under the Indian Ocean moved, a huge tidal wave was created that traveled thousands of kilometers across the ocean, causing a tsunami that devastated islands and coastal areas across the region. While the region is rebuilding after the physical destruction, teams of forensic scientists have taken on the immense task of identifying the victims of this tragedy.

The Southeast Asian tsunami is one of the largest natural disasters of modern times. The series of waves that emanated from the sub-oceanic earthquake off the shore of Sumatra claimed over 200,000 lives, as of February 2005, and the death toll continues to rise. In addition, thousands of people are still missing. Indonesia was the hardest hit and suffered the largest death toll. Also affected were regions of Sri Lanka, Southeast India and its Andaman and Nicobar Islands, Malaysia, Thailand, Bangladesh, Burma, and the Maldives. The devastation of the tsunami was far reaching; The Seychelle Islands as well as Tanzania, Kenya, and Somalia on the African mainland also suffered losses of life in the tragedy. In addition, because there are many tourist resorts in this region, the dead and missing include people from countries all over the world.

When the destruction was over, pictures of the missing were displayed at **identification** centers and family members gathered near the morgues, identification centers, and hospitals. Relatives of vacationers traveled to the region and assisted aid workers and the International Red Cross in their search for additional victims and wounded.

Identification of the tsunami victims is the largest forensic undertaking since the World Trade Center disaster of September 11, 2001. Over three years later, **DNA** profiles from the World Trade Center are still being analyzed, suggesting that the tsunami identification project will also continue for years.

After the tsunami, dead bodies lay strewn over beaches and required collection. Due to the force of the waves, dismembered body parts were also retrieved. Forensic specialists from all over the world rushed to Southeast Asia to assist with the task of identifying the victims, who were brought to makeshift morgues. Initially, physical identification was performed before the more complex task of using DNA. Corpses were photographed and compared to pictures displayed by friends and relatives. Physical characteristics such as hair or eye color, tattoos, and clothing were used initially to identify individuals. Dental x rays and fingerprints also proved useful. All of this information was recorded for each victim in makeshift, then organized, databases.

Once physical means of identification were exhausted, DNA samples were taken from the corpses for analysis. Identification of such a vast number of victims by forensic DNA analysis is a daunting task. Even though forensic companies and government agencies across the world are assisting with the process, the number of samples is overwhelming. Difficult samples of bone and skin often require multiple DNA extractions and analyses. Many of the dead were submerged in water then exposed to sun and heat while awaiting collection. High temperatures often degrade DNA, making it more difficult to analyze and requiring multiple attempts at extraction and amplification.

Each of the organizations assisting with identification and forensic analysis utilize their own

An American plastic surgeon prepares to repair facial injuries on tsunami victims in Thailand in order to help relatives recognize and identify the dead. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

protocols and methods. This also causes complications when trying to compare victim data from several different organizations. In a meeting shortly after the tsunami, **Interpol** (a global police information organization) requested that a standardized means of forensic analysis be used by the involved scientific teams. Furthermore, DNA profiles and other information are entered into a computer database to make identification faster and easier amongst the various worldwide sites where DNA analysis is taking place. Thus, standardized methods such as those of Interpol and the European Network for Forensic Science Institutes (ENFSI) are extremely useful during a crisis such as the tsunami.

Forensic scientists are also extracting DNA from personal effects, such as razors, toothbrushes, and hairbrushes, of the missing. DNA profiles generated from these samples will be used for a reference database. This database is then compared to the DNA profiles of those from victims in hopes of finding matches. In addition, relatives of the missing have given **blood** samples for DNA profiles. These can then be compared to the database of victim profiles to identify the victims based on the similarity of their DNA sequence to that of their parents, children, or siblings. In some cases, whole families were killed, requiring DNA profiles from more distant relatives to be used. While most identifications need about 10 DNA markers in the profile, up to 50 markers must be compared in these situations.

Automation of many of the steps of the DNA analysis is speeding up the identification process. Unidentified victims are buried in temporary graves and have been labeled with electronic chips that carry the information associated with the body that was obtained by forensic scientists. The use of forensic techniques has been instrumental in identifying

Forensic teams try to identify the bodies of victims of the December 26, 2004, tsunami at a makeshift morgue at Yan Yao temple in Takuapa in southern Thailand. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

the victims of the Southeast Asian tsunami, however, it will be years until the project is complete.

SEE ALSO CODIS: Combined DNA Index System; DNA; DNA databanks; DNA fingerprint; DNA profiling; European Network of Forensic Science Institutes; Interpol; Odontology; September 11, 2001, terrorist attacks (forensic investigations of); Standardization of regulations; STR (short tandem repeat) analysis.

Identification of war victims in Croatia and Bosnia

Forensic analyses are used for many types of investigations, including those of wartime crimes against humanity, such as occurred in Bosnia and Croatia during the 1990s. A combination of forensic techniques, including forensic **DNA** analysis, forensic dental analysis, **ballistics** analysis, and others, were used to identify the victims of violence in these newly independent countries.

At the end of World War II, the communist country of Yugoslavia was formed and was comprised of multiple ethnic groups that were continually at odds. However, after the fall of the Soviet Union and communism in Eastern Europe, violence erupted in regions of now former Yugoslavia. Various regions declared independence in 1992, and others attempted to expand by invading neighboring territories. The diverse ethnic backgrounds of the former Yugoslav states added to the conflict and wars broke out amongst the different ethnic and religious groups. During several bloody years, more than 100,000 people were killed, a vast majority being civilians. Access to the region by the international press was limited, but reports from those who were present as well as Croatians and Bosnians alike, suggested that ethnic cleansing was rampant and mass executions were commonplace. Similar atrocities were committed in the Kosovo region of the former Yugoslavia, where ethnic Albanians and Serbians were both allegedly the victims of ethnic cleansing.

Many of the dead were buried in mass graves and survivors were forced to flee to neighboring regions for safety. When aid workers and forensic teams were allowed access to the war-torn regions of Bosnia-Herzegovina, Croatia, Serbia, and Kosovo, many of the mass graves were exhumed to identify the dead and determine the **cause of death**. As of March 2005, the **identification** of victims is ongoing. Most of the bodies were decomposed to mere skeletal remains when the teams arrived. However, this still allows for a significant amount of information to be gained about the individuals. Initial means of forensic identification include detailed examination of the clothing and belongings on and around the skeletons. Height is estimated and sex determined if possible. Unique skeletal features are then noted and x rays obtained. Then, dental records are used to compare the dead to the dental records of missing people.

Although some individuals may be identified using unique skeletal features, most cannot and require DNA analyses to be performed using DNA isolated from the teeth or bones of the skeletons. Multiple laboratories are currently performing DNA analysis corpses removed from mass graves. In general, commercially available molecular kits are used along with **PCR** techniques to amplify unique **gene** sequences, or STR (short tandem repeat) loci. In some cases mitochondrial DNA (genetic material in the mitochondria, organelles that generate energy from the cell and are inherited from the mother), is being used. The sequences obtained by these analyses are then entered into a computer and compared to a database. This database contains sequences of DNA determined from **blood** samples of relatives of missing persons. Comparison of the sequences and DNA profiles enables scientists to determine whether or not the skeleton in the mass grave was a relative of someone registered in the database. In addition to mass graves, thousands of bodies remain in refrigerators and morgues waiting to be examined and profiled.

In 1996, the International Commission on Missing Persons (ICMP) was created and given the responsibility of helping remaining family members find their missing relatives. The ICMP assists all victims in the former Yugoslavia, regardless of religion or ethnic background. Organized into four major areas: the forensics program, family association development, the political program, and the DNA program, the ICMP has the goal of **training** scientists and technicians around the region to set up a network of laboratories for victim identification and to help rebuild the war-torn communities.

Investigators have encountered many complications examining mass graves in countries that were once Yugoslavia. Because of the implication of war crimes against humanity, some of the mass graves have been disturbed by perpetrators. Bodies were often moved, mutilated, or other actions taken to attempt to disguise the cause of death. At The Hague, the International Criminal Tribunal for the former Yugoslavia (ICTY) is responsible for bringing criminal charges against those allegedly involved in the war crimes and ethnic cleansing. Forensic investigators are discovering **evidence** that some murdered individuals were killed execution-style or tortured. Physical forensic examination of the bodies is key to the ongoing trials, as evidence such as bullet holes in the **skull** and blindfolds may indicate execution-style shooting.

It is expected that the **war crimes trials** of individuals responsible for atrocities in Croatia, Bosnia-Herzegovina, Serbia, and Kosovo will continue for years. This is also the case with the identification of victims in mass graves found across the region.

SEE ALSO DNA; DNA databanks; DNA fingerprint; DNA mixtures, forensic interpretation of mass graves; DNA profiling; Odontology; STR (short tandem repeat) analysis; War crimes trials; War forensics.

Identity theft

A forensic investigation can involve tracing the whereabouts of a person or their finances (a facet of **forensic accounting**). Someone who is eluding capture can adopt a new identity or assume the identity of someone else. The mechanisms of identity theft must be familiar to a forensic scientist.

Identity theft is the most popular—and most profitable—form of consumer fraud, and is among the fastest growing crimes in America. It encompasses all types of crime in which someone illegally obtains and fraudulently uses another person's confidential information, most often for financial gain. A person's Social Security number is valuable to an identity thief. Armed with the Social Security number, a criminal can open a bank account or credit card account, apply for a loan, and remove funds from varying financial accounts. In some cases, criminals have assumed the victim's identity altogether, incurring debt in the victim's name and committing crimes that become a part of the victim's criminal record.

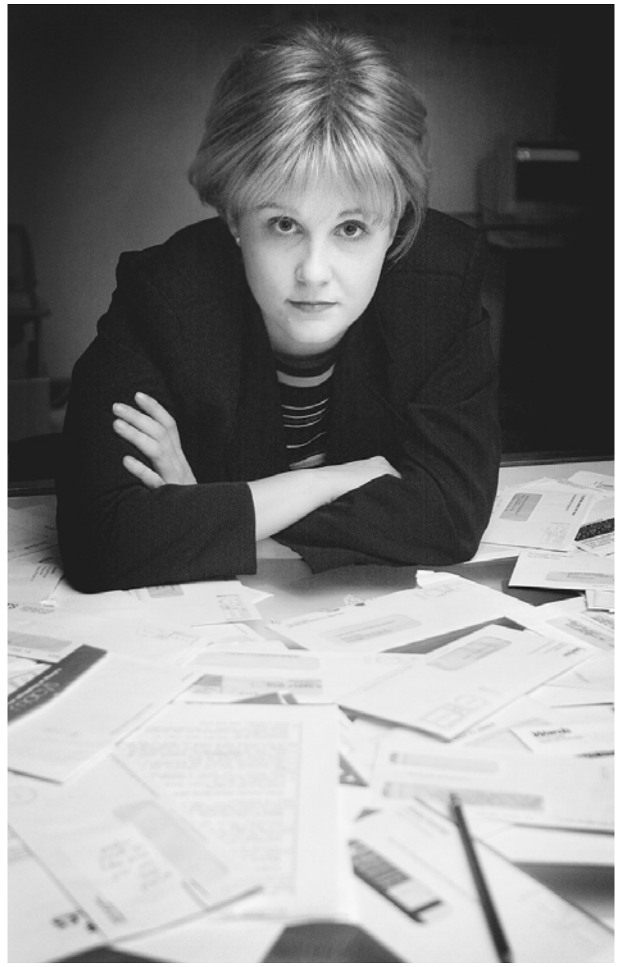
The rate of identity theft or identity fraud so escalated in the late 1990s that the Social Security Administration declared it a national crisis.

Advanced computer and telecommunication technologies have armed thieves with new ways to obtain large amounts of personal data from afar. Hackers can spy on e-mail and Internet users, silently stealing passwords or banking information.

Old-fashioned methods also remain effective. "Dumpster diving" thieves sort through garbage for telltale signs of identity such as cleared checks, bank statements, even junk mail, such as "preapproved" credit cards. A "shoulder surfing" criminal spies on someone as they type in a pin number or password at an automatic teller machine (ATM). "Skimming" occurs when a cashier receives a credit card for a purchase, then surreptitiously swipes the card through a portable device that records the card information.

The threat to privacy has prompted a number of new laws governing fraud. In 1998, Congress passed the Identity Theft and Assumption Deterrence Act. The legislation created a new offense of identity theft, making it a separate crime against the person whose identity was stolen. Prior to this legislation, identity theft was considered a crime only against the company the victim defrauded. Under the federal identity theft act, any person "knowingly transferring or using, without lawful authority, a means of **identification** of another person with the intent to commit, or to aid or abet, any unlawful activity that constitutes a violation of Federal law, or that constitutes a **felony** under any applicable State or local law" will be charged with a crime. Violators face a maximum term of 15 years in prison, a fine, and criminal forfeiture of any personal property used or intended to be used to commit the offense.

Identity thieves are often charged with other violations, including credit card fraud, computer fraud, and mail fraud. These felonies can carry substantial penalties and up to 30 years imprisonment. The Federal Bureau of Investigation (**FBI**), the United States Secret Service, and the United States Postal Inspection Service help prosecute identity theft cases. Many states have also enacted legislation regarding identity theft. Arizona led the way with a specific identity theft statute passed in 1996. As the crime's serious threat became evident, more states followed suit. In 1999, 22 states passed identity theft legislation. According to a U.S. General Accounting Office (GAO) report published in 2002, identity theft can be a felony offense in 45 of the 49 states that have laws to address the problem. Two years after the passage of the federal identity theft act, the justice department testified that it had used the statute in 92 cases, according to a GAO report.



Associated Press reporter Nedra Pickler displays the unauthorized credit card bills charged to her name in 2002, after she became the victim of identity theft, a growing crime. In a matter of a week, thieves charged $30,000 worth of merchandise on credit cards obtained using her identity. AP WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

The Identity Theft and Assumption Deterrence Act requires the Federal Trade Commission (FTC) to "log and acknowledge the receipt of complaints by individuals who certify that they have a reasonable belief" that someone stole their identity. The act enabled the creation of the Identity Theft Data Clearinghouse, a federal database for tracking complaints. Consumers call a toll-free hotline (1-877-ID-THEFT) to enter their complaint, and have the option to do so anonymously. When established in 1999, the FTC logged about 260 calls per week. By 2002, the hotline was receiving more than 3,000 contacts a week.

Identity fraud complaints and related information are shared electronically between the FTC and other law enforcement agencies nationwide via the Consumer Sentinel Network, a secure, encrypted

Web site. The network was initially set up in 1997 as a way of tracking telemarketing scams. As of March 2005, more than 1,000 law enforcement agencies in the United States, Canada, and Australia had enrolled in the FTC's Consumer Sentinel Network collaboration. Accessing the Network allows police to analyze identity theft cases and determine if there is a larger pattern of crime. At this time, comprehensive results involving the number of cases prosecuted under the federal identity theft act and state statutes are not available.

SEE ALSO Codes and ciphers; Computer forensics; Computer hackers; Document forgery; Technology and forensic science.

Illicit drugs

Some chemical substances are dangerous to health due to their addictive nature, impact on the central nervous system metabolism, life-threatening side effects, and associate behavioral and mood changes. Drugs classified by the U.S. Drug Enforcement Administration (**DEA**) under Schedule I are considered illicit drugs when sold to or consumed by the public, except for some chemical derivatives with restricted and controlled medical applications. These are also known as psychoactive drugs of abuse, due to their effects in mood, sensory perception, and behavior. Substances of the following classes are considered illicit drugs: opiates, hallucinogens, depressants, and stimulants under Schedule I (tightly regulated use and supply), as well as the controlled substances under Schedules II, III, IV, and V, when used or sold without medical prescription. Among the most common illicit drugs in use are:

- cannabinoids (such as marijuana and hashish oil)
- hallucinogens (LSD, mescaline, peyote, MDMA)
- dissociative anesthetics (PCP, ketamine, dextromethorphan)
- stimulants (**amphetamines**, methamphetamine, cocaine)
- depressants (GHB, rohypnol, **barbiturates**, benzodiazepines)
- narcotics (opium, heroin, methadone, codeine)
- inhalants (nitrous compounds, glues, solvents, ether).

Drugs of abuse affect the brain structures that regulate feelings of reward, personal empowerment, and pleasure, which constitute an important component of their addictive properties, along with developed tolerance.

The initial effects of cannabinoids, such as relaxation, euphoria, and diminished concentration, are similar to alcohol. The active chemical of cannabinoids (the alkaloid THC or tetrahydrocannabiol) apparently interferes with nerve cells access to glucose (an essential source of energy for brain metabolism and function), inducing an aftermath sensation of acute hunger. Addiction is followed by increased tolerance, which leads to more frequent consumption and/or to increased doses. The speed of signal transfer between nerve cells (synapses) is reduced with long-term use, as a consequence of the loss of neurons (nerve cells) and components of nerve cells. Poor memory, learning difficulties, and a general apathy are the results of prolonged, frequent use of cannabinoids. Respiratory complications are also common, because cannabinoids are usually inhaled through smoking. High levels of THC in the brain may induce toxic psychosis and hallucinations, especially when the leaves are consumed in foods or infusions. In food or drinks, marijuana effects take about one hour to begin and last for approximately four hours. Flashbacks sometimes occur in some individuals in the three days following a high-dose intake.

Hallucinogens such as LSD, MDMA, mescaline, psilocybin, psilocin, and muscimol are drugs that interfere with neuronal pathways that process sensory information, and also affect the metabolism and levels of chemical messengers known as **neurotransmitters**, such as serotonin and dopamine. Hallucinogenic plants such as psilocybin, and peyote cactus, along with psilocin mushrooms have been taken by tribal medicine men in search of "visions" for centuries. Hallucinations are altered states of sensory perception that lead to all kinds of pleasant or unpleasant sensory experiences. They affect several functional brain structures that control emotions, behavior, body temperature, cardiac rate, blood pressure, sensory-motor coordination, and breathing. LSD (lysergic acid diethylamide) is a strong hallucinogen with unpredictable effects that may last for approximately 12 hours and create frequent occurrences of flashbacks in the following two days. However, it is not an addictive drug and most users stop using it over time. LSD induces tolerance in frequent users, however, leading to ingesting increased amounts of the drug. The results could include long-lasting mood disorders, psychotic episodes, severe depression, and suicide. These adverse effects may persist for years after the individual has stopped LSD consumption, suggestive of some forms of brain damage.

Mescaline is extracted from the peyote cactus, and also induces hallucinations along with physiologic changes similar to those caused by LSD. Effects last between 8 and 12 hours and its metabolites are detectable in urine for two or three days after use. Hallucinogenic mushrooms such as *Psilocybe cubensis* and *Amanita muscaria*, are highly toxic for liver and kidney cells. They induce drowsiness alternating with psychomotor agitation, distorted auditory and visual sensory perceptions, and lack of concentration, as well as nausea, paranoia, and chronic mental disorders.

MDMA, or ecstasy, is both a hallucinogen and a stimulant drug that dramatically increases the levels of serotonin in the brain, causing a sensation of immense joy, amplification of tactile sensations, altered body temperature, and increased sexual drive. MDMA interference with the metabolism of the neurotransmitter serotonin results in nerve cell toxicity that may cause brain damage. Cases of coma and death are also reported in association with MDMA. Frequent use of ecstasy has also indirectly influenced the spread of sexually transmitted diseases including HIV because of its ability to decrease sexual inhibitions and its frequent use in nightclubs.

Dissociative anesthetic drugs were first developed as pharmaceutical products for sedation or for general anesthesia. Dextromethorphan is a sedative of certain autonomous brain functions. Ketamine and PCP (or phencyclidine) are drugs for general anesthesia that present side effects of auditory and visual distortion, and sensations of "floating" above the environment or above oneself (out-of-body sensation). These two substances block glutamate pain receptors in the brain. The neurotransmitter glutamate is responsible for signaling pain sensation, and is also involved in memory formation, the learning process, and mood modulation. PCP inhibits dopamine, serotonin, and norepinephrine reuptake from cell receptors. These neurotransmitters control the modulation of feelings of reward, joy, euphoria, and physical energy. Phencyclidine is also a dissociative drug of potential abuse that induces dissociative anesthesia, a state in which the patient is conscious without feeling pain. In surgical centers, physicians carefully monitor the vital signals of a patient under PCP, ketamine, or other CNS depressant anesthetics, due to their dangerous and sometimes unpredictable side effects on blood pressure, elevation of body temperature, and heartbeat. When these drugs are illegally taken, users frequently end up in emergency rooms with convulsions, coma, hyperthermia (high core body temperature), or cardiac arrest. Addicts also undergo mood disorders, such as violent behavior, hallucination, panic episodes, paranoia, disorientation, memory loss, depression, and suicidal tendencies.

Depressant drugs, such as flunitrazepam (e.g., rohypnol) and gamma-hydroxibutyrate (or GHB) are frequently mixed with alcoholic beverages, a combination that is sometimes lethal. Rohypnol, often called the "date rape" drug, belongs to the family of benzodiazepines, drugs introduced in medical practice to control anxiety and nervousness. Because rohypnol markedly depresses the central nervous system (CNS), slows motor reflexes, causes disorientation and temporary amnesia, it is used by some who mix the drug in their victim's drink. As the drug is tasteless, odorless, and colorless, sexual assailants use it in nightclubs and parties, without the knowledge of their targets. GHB is now an illegal anabolic drug that was largely used by body builders between 1980 and 1992, when its use became forbidden in the United States. It has a sedative and euphoric effect, may induce coma, convulsions, breathing difficulties and vomiting, especially when mixed with alcohol or cannabinoids.

Stimulants affect the brain reward centers, inducing sensations of euphoria, boldness, and aggressiveness because they accelerate basal metabolism, cardiac rate, and increase blood pressure and sensory motor response. They also cause dizziness, insomnia, behavioral and emotional disorders, sexual inhibition, and lack of concentration. Cocaine is a strong stimulant and highly addictive drug that is trafficked in two chemical forms, hydrochloride salt (powdered cocaine), and freebase form (or crack). Powdered cocaine is inhaled into the nasal passages or diluted in water and intravenously injected, whereas crack is smoked. Cocaine and crack affect the dopamine pathways by attaching to the molecule that transports dopamine to cellular receptors, preventing dopamine reuptake from receptors. Therefore, it prolongs the effects of dopamine in the brain. Both forms of cocaine induce tolerance, leading to increased doses and more frequent consumption. Irritability, mood swings, restlessness, auditory hallucination, and violent behavior develop and tend to worsen through long-term cocaine abuse. Cardiac arrest or coma is a common cause of death when these and other stimulants are mixed with other drugs or alcohol, or taken in high doses.

Johann Muehlegg of Spain celebrates winning the gold medal in the men's 50-kilometer cross-country ski event at the Winter Olympics in 2002. Muehlegg was later stripped of his medal after testing positive in a drug test. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

Narcotics are chemical derivatives from opium, such as codeine, morphine, and heroin, with very effective analgesic activity in relieving intense pain. However, because of their highly addictive properties and some dangerous adverse effects, a total of 23 opium derivatives are classified under Schedule I. Morphine is the most powerful analgesic found in natural opium, but both natural and synthetic opioid compounds are effective intense-pain inhibitors. Morphine causes analgesia without inducing loss of consciousness, along with a sense of wellbeing. Normal doses of morphine and other opioids depress the brain centers that regulate breathing by diminishing their sensitivity. With doses progressively higher, respiratory depression occurs, thus leading to death from acute overdose, a common result of opioid abuse. Other effects of chronic use of opioids are low blood pressure (hypotension), vomiting, constipation, and depression. Repeated use induces tolerance to the respiratory centers as well as decreased analgesia and euphoria, leading to dependency of higher doses and more frequent use, which increases the risk of accidental overdose.

Inhalants are chemical vapors derived from substances and solvents used in glues, wax, and domestic household products, as well as nitrous compounds and ether. They usually either depress the CNS or block oxygen access to the brain. Inhalants are often the first drugs that children experiment with. A study by the National Institute on Drug Abuse (NIDA) of 2003, named "Monitoring the Future," has shown that 12.7% of 10th graders and 11.2% of 12th graders had used inhalants at least once.

SEE ALSO Amphetamines; DEA (Drug Enforcement Administration); Hypothermia; Hypoxia; Narcotic; Nervous system overview; Psychotropic drugs; Toxicological analysis.

Imaging

High-tech diagnostic imaging techniques that have allowed physicians to explore bodily structures and functions with a minimum of invasion to the patient have been exploited for other uses. Forensic investigations have been one of the beneficiaries.

A forensic investigator may be faced with a body that displays no outward signs of trauma. Learning the **cause of death** may involve delving inside the body. Imaging techniques allow a detailed examination without the immediate need of a destructive **autopsy**.

The use of imaging techniques in forensics has followed the development of the techniques for other purposes. During the 1970s, advances in computer technologies, in particular the development of algorithms powerful enough to allow difficult equations to be solved quickly enough to be of real-time use in the clinical diagnostic setting and to eliminate "noise" from sensitive measurements, allowed the development of accurate, accessible, and relatively inexpensive (when compared to surgical explorations) non-invasive technologies. Although relying on different physical principles (i.e., electromagnetism vs. sound waves), all of the high-tech methods relied on computers to construct visual images from a set of indirect measurements. The development of high-tech diagnostic tools was the direct result of the clinical application of developments in physics and mathematics. These technological advances allowed the creation of a number of tools that made diagnosis more accurate, less invasive, and more economical.

The use of non-invasive imaging traces it roots to the tremendous advances in the understanding of electromagnetism during the nineteenth century. By 1900, physicist Wilhelm Konrad Roentgen's (1845–1923) discovery of high-energy electromagnetic radiation in the form of x rays were used in medical diagnosis.

The development of powerful high-tech diagnostic tools in the later half of the 20th century was initially the result of fundamental advances in the study of the reactions that take place in excited atomic nuclei. Applications of what were termed nuclear spectroscopic principles became directly linked to the development of non-invasive diagnostic tools used by physicians.

In particular, Nuclear Magnetic Resonance (NMR) was one such form of **nuclear spectroscopy** that eventually found widespread use in the clinical laboratory and medical imaging. NMR is based on the observation that a proton in a magnetic field has two quantized spin states. Accordingly, NMR allowed the determination of the structure of organic molecules and, although there are complications due to interactions between atoms, in simple terms NMR allowed physicians to see pictures representing the larger structures of molecules and compounds (i.e., bones, tissues, and organs) obtained as a result of measuring differences between the expected and actual numbers of photons absorbed by a target tissue.

Groups of nuclei brought into resonance, that is, nuclei absorbing and emitting photons of similar electromagnetic radiation (e.g., radio waves) make subtle yet distinguishable changes when the resonance is forced to change by altering the energy of impacting photons. The speed and extent of the resonance changes permits a non-destructive (because of the use of low energy photons) determination of anatomical structures. This form of NMR is used by physicians as the physical and chemical basis of a powerful diagnostic technique termed Magnetic Resonance Imaging (MRI).

MRI scanners rely on the principles of atomic nuclear-spin resonance. Using strong magnetic fields and radio waves, MRI collects and correlates deflections caused by atoms into images of amazing detail. The resolution of the MRI scanner is so high that they can be used to observe the individual plaques in multiple sclerosis.

Principles of SONAR technology (originally developed for military use) found clinical diagnostic application with the 1960s development of ultrasound. A sonic production device termed a transducer was placed against the skin of a patient to produce high frequency sound waves that were able to penetrate the skin and reflect off internal target structures. Modern ultrasound techniques using monitors allow physicians real-time diagnostic capabilities. By the 1980s, ultrasound examinations became commonplace in the examination of fetal development.

The advent of other imaging to supplant x rays provided for less potentially damaging forms of diagnosis. High photon energies found in x rays are ionizing and are thus capable of destroying chemical and molecular bonds in cells. In contrast, ultrasound relies not on electromagnetic radiation but rather on pressure waves that are non-ionizing.

Microscopes using ultrasound can be utilized to study cell structures without subjecting them to lethal staining procedures that can also impede diagnosis through the production of artifacts (extraneous bits of highlighted material). Ultrasonic microscopes differentiate structures based on underlying differences in **pathology**. Ultrasonic imaging devices are also among the least expensive of the latest high-tech innovations in diagnostic imaging.

During the early 1970s, enhanced digital capabilities spurred the development of Computed Tomography (derived from the Greek *Tomos*, meaning slice) imaging, also called CT, Computed Axial Tomography or CAT scans, invented by English physician Godfrey Hounsfield. CT scans use advanced computer-based mathematical algorithms to combine different readings or views of a patient into a coherent picture usable for diagnosis. Hounsfield's innovative use of high energy electromagnetic beams, a sensitive detector mounted on a rotating frame, and digital computing to create detailed images earned him the Nobel Prize. As with x rays, CT scan technology progressed to allow the use of less energetic beams and vastly decreased exposure times. CT scans increased the scope and safety of imaging procedures that allowed physicians to view the arrangement and functioning of the body's internal structures on a small scale.

American chemist Peter Alfred Wolf's (1923–1998) work with positron emission tomography (PET) led to the clinical diagnostic use of the PET scan, allowing physicians to measure cell activity in organs. PET scans use rings of detectors that surround the patient to track the movements and concentrations of radioactive tracers. The detectors measure gamma radiation produced when positrons emitted by tracers are annihilated during collisions with electrons. PET scans have attracted the interest of psychiatrists for their potential to study the underlying metabolic changes associated with mental diseases such as schizophrenia and depression. During the 1990s, PET scans found clinical usage in the diagnosis and characterizations of certain cancers and heart disease, as well as clinical studies of the brain.

MRI and PET scans, both examples of functional imaging (in addition to detailing structures they provide a view of dynamic functions), are the subject of increased research and clinical application. MRI and PET scans are used to measure reactions of the brain when challenged with sensory input (e.g., hearing, sight, smell), activities associated with processing information (e.g., learning functions), physiological reactions to addiction, metabolic processes associated with osteoporosis and atherosclerosis, and to shed light on pathological conditions such as Parkinson's and Alzheimer's disease.

During the 1990s, the explosive development of information technologies and the Internet allowed imaging data to be shared globally, both in real-time and by mining databases.

SEE ALSO Alternate light source analysis; Biometric eye scans; Confocal microscopy; Polarized light microscopy; Scanning electron microscopy; Ultraviolet light analysis; Visible microspectrophotometry.

Immune system

A staple in forensic investigations is the use of antibodies to detect a target **antigen**. **Blood** typing and the detection of bacteria, or their elaborated **toxins**, rely on the recognition of antigens by their corresponding antibodies. The production of antibodies is one aspect of the immune system, the body's biological defense mechanism that protects against foreign invaders.

The true roots of the study of the immune system date from 1796, when English physician Edward Jenner discovered a method of **smallpox** vaccination. He noted that dairy workers who contracted cowpox from milking infected cows were thereafter resistant to smallpox. In 1796, Jenner injected a young boy with material from a milkmaid who had an active case of cowpox. After the boy recovered from his own resulting cowpox, Jenner inoculated him with smallpox; the boy was immune. After Jenner published the results of this and other cases in 1798, the practice of Jennerian vaccination spread rapidly.

Louis Pasteur established the cause of infectious diseases and the medical basis for immunization. Pasteur formulated the germ theory of disease, the concept that disease is caused by communicable microorganisms. In 1880, Pasteur discovered that aged cultures of fowl cholera bacteria lost their power to induce disease in chickens but still conferred immunity to the disease when injected. He went on to use attenuated (weakened) cultures of **anthrax** and rabies to vaccinate against those diseases. The American scientists Theobald Smith (1859–1934) and Daniel Salmon (1850–1914) showed in 1886 that bacteria killed by heat could also confer immunity.

In 1888, Pierre-Paul-Emile Roux (1853–1933) and Alexandre Yersin (1863–1943) showed that diphtheria bacillus produced a toxin that the body responded to by producing an antitoxin. Emil von Behring and Shibasaburo Kitasato found a similar toxin-antitoxin reaction in tetanus in 1890, and von Behring discovered that small doses of tetanus or diphtheria toxin produced immunity, which could be transferred from animal to animal via **serum**. He concluded that the immunity was conferred by substances in the blood, which he called antitoxins, or antibodies. In 1894, Richard Pfeiffer (1858–1945) found that antibodies killed cholera bacteria (bacterioloysis). Hans Buchner (1850–1902) in 1893 discovered another important blood substance called complement (Buchner's term was alexin), and Jules Bordet in 1898 found that it enabled the antibodies to combine with antigens (foreign substances) and destroy or eliminate them. It became clear that each **antibody** acted only against a specific antigen. **Karl Landsteiner** exploited this specific antigen-antibody reaction to distinguish the different blood groups.

In the 1880s Russian microbiologist Elie Metchnikoff discovered cell-based immunity: white blood cells (leucocytes), which Metchnikoff called phagocytes, ingested and destroyed foreign particles. Considerable controversy flourished between the proponents of cell-based and blood-based immunity until 1903, when Almroth Edward Wright brought them together by showing that certain blood substances were necessary for phagocytes to function as bacteria destroyers. A unifying theory of immunity was posited by Paul Ehrlich in the 1890s; his "side-chain" theory explained that antigens and antibodies combine chemically in fixed ways, like a key fits into a lock. Until now, immune responses were seen as purely beneficial. In 1902, however, Charles Richet and Paul Portier demonstrated extreme immune reactions in test animals that had become sensitive to antigens by previous exposure. This phenomenon of hypersensitivity, called anaphylaxis, showed that immune responses could cause the body to damage itself. Hypersensitivity to antigens also explained allergies, a term coined by Pirquet in 1906.

Much more was learned about antibodies in the mid-twentieth century, including the fact that they are proteins of the gamma globulin portion of plasma and are produced by plasma cells; their molecular structure was also determined. An important advance in immunochemistry came in 1935 when Michael Heidelberger and Edward Kendall (1886–1972) developed a method to detect and measure amounts of different antigens and antibodies in serum. Immunobiology also advanced. Frank Macfarlane Burnet suggested that animals did not produce antibodies to substances they had encountered very early in life; Peter Medawar proved this idea in 1953 through experiments on mouse embryos.

In 1957, Burnet put forth his clonal selection theory to explain the biology of immune responses. On meeting an antigen, an immunologically responsive cell (shown by C. S. Gowans [1923–] in the 1960s to be a lymphocyte) responds by multiplying and producing an identical set of plasma cells, which in turn manufacture the specific antibody for that antigen. Further cellular research has shown that there are two types of lymphocytes (nondescript lymph cells): B-lymphocytes, which secrete antibody, and T-lymphocytes, which regulate the B-lymphocytes and also either kill foreign substances directly (killer T cells) or stimulate macrophages to do so (helper T cells). Lymphocytes recognize antigens by characteristics on the surface of the antigen-carrying molecules. Researchers in the 1980s uncovered many more intricate biological and chemical details of the immune system components and the ways in which they interact.

SEE ALSO Antibody; Antigen; Homogeneous enzyme immunoassay (EMIT); Vaccines.

Impaired driving SEE Breathalyzer®

Impression evidence

When an item like a shoe or a tire comes into contact with a soft surface, it leaves behind a pattern showing some or all of its surface characteristics known as an impression. The collection and analysis of impression **evidence** found at the scene of a crime can often be very important to an investigation.

The major types of impression evidence are **shoeprints**, **tire tracks**, tool marks and the marks that are found on a fired bullet. Impressions can be found in a variety of surfaces including dust, carpet, mud, and, very significantly, **blood**. Collection of an impression is a specialized forensic task because, unlike a hair or bullet, an impression cannot just be packaged and taken back to the lab. Impression evidence is often fragile; a tire track may deteriorate or even be destroyed by rainfall, for example. There is a need for the forensic scientist to retain as much information as possible when collecting impression evidence.

Impressions may be found in either two or three dimensions. An object like the sole of a shoe will leave a two dimensional impression on a hard surface such as a tiled floor. The impression comes from static charge on the sole transferring particles from the sole to the surface. Sometimes wet deposits on a sole will adhere to such a surface. A three-dimensional impression is made when the surface over which the shoe passed was soft and the sole actually sank into it. The method used to collect the impression evidence depends largely on how the impression was made and on what kind of surface. The impression is photographed on-site and then a plaster cast may be made, or the impression may be dusted with **fingerprint** powder. Dyes can be used to bring up impressions in non-porous surfaces, such as linoleum, although these are absorbed by a porous surface like carpet. Impressions made in dust can be very fragile. Contact with a brush or spray would destroy them. However, electrostatic treatment allows the impression to be lifted onto a more stable surface for transport back to the lab. Many new methods are being developed for the collection and enhancement of impression evidence so that the maximum information can be extracted.

SEE ALSO Casting; Crime scene investigation.

Indicator, acid-base

The forensic examination of tissues or other material can involve chemical testing. These tests help reveal the presence of contaminating chemicals and can help determine the cause of the incident or the death. Some tests rely on a color change to indicate the presence of the target compound. Acid-base indicators are often utilized to show this reaction.

An acid-base indicator is often a complex organic dye that undergoes the color change when the pH (a measure of the amount of acidic or basic components) changes over specific values. Many plant pigments and other natural products are good indicators. Synthetic compounds like phenolphthalein and methyl red are also good acid-base indicators.

Paper that has been impregnated with indicator chemicals and allowed to dry is a common site in laboratories that do acid-base testing. This paper, which is typically cut into thin strips, is called pH paper. The use of different chemicals allows the strips to detect different ranges of pH.

The pH at which the color of an indicator changes is called the transition interval. Forensic chemists use appropriate indicators to signal the end of an acid-base neutralization reaction. Such a reaction is usually accomplished by titration—slowly adding a measured quantity of the base to a measured quantity of the acid (or vice versa). When the reaction is complete and there is no excess of acid or base, but only the reaction products, this is called the endpoint of the titration. The indicator must change color at the pH which corresponds to that endpoint.

The indicator changes color because of its own neutralization in the solution. Different indicators have different transition intervals, so the choice of indicator depends on matching the transition interval to the expected pH of the solution just as the reaction reaches the point of complete neutralization.

The two most common pH indicators are phenolphthalein and methyl red. Phenolphthalein changes from colorless to pink across a range of pH 8.2 to pH 10. Methyl red changes from red to yellow across a range of pH 4.4 to pH 6.2. Other indicators are available through most of the pH range, and can be used in the titration of a wide range of weak acids and bases.

SEE ALSO Chemical and biological detection technologies; Inorganic compounds; Toxicological analysis.

Infectious disease research SEE USAMRIID (United States Army Medical Research Institute of Infectious Diseases

Inferior SEE Anatomical nomenclature

Infrared detection devices

Infrared detection devices are sensors that detect radiation in the infrared portion of the **electromagnetic spectrum** ($\cong 10^{12}$ to 5×10^{14} Hz). Often, such devices form the information they gather into visible-light images for the benefit of human users; alternatively, they may communicate directly with an automatic system, such as the guidance system of a missile.

Because all objects above absolute zero emit radiation in the infrared part of the electromagnetic spectrum, infrared detection provides a means of "seeing in the dark"—that is, forming images when light in the visible portion of the spectrum ($\cong 4.3 \times 10^{14}$ to 7.5×10^{14} Hz) is scarce or absent. Because the warmer an object it is the more infrared radiation it emits, infrared imaging is also useful for the detection of outstanding heat sources that may be invisible or hard to detect even when there is ample visible light. Many devices used by police investigators, including forensic examiners, exploit some form of infrared detection technology.

Infrared—"below-red"—light consists of electromagnetic radiation that is too low in frequency (i.e., too long in wavelength) to be perceived by the human eye, yet is still too high in frequency to be classed as microwave radio. Infrared (IR) light that is just beyond the human visual limit ($\cong 1.0 \times 10^{14}$ to 4.0×10^{14} Hz) is termed near IR, while light farther from the visible spectrum is divided into middle IR, far IR, and extreme IR.

All objects above absolute zero glow in the far IR, so no source of illumination is needed to image scenes using such radiation; to image scenes in near IR, illumination from a light-emitting diode or filtered light bulb must be supplied. Near-IR imagers, however, are still cheaper than passive, far-IR imagers.

There are two basic designs for electronic IR imagers. The first is the scanner. In this design, light from a tiny portion of the scene to be imaged is focused by an optical and mechanical system on a small circuit element that is sensitive to photons in the desired IR frequency range. The intensity of the signal from the IR detector element is recorded, then the mechanico-optical system shifts its focus to a different fragment of the scene. The response of the IR detector element is again recorded, the view shifts again, and so forth, systematically covering the scene. Many scene-covering geometries have been employed by scanning imagers; the scanner may record horizontal or vertical lines (rasters), spiral outward from a central point, cover a series of radii, and so on.

The second basic type of IR imaging system is the “starer.” Such a system is said to “stare” because its optics do not move like a scanner’s, scanning the scene a little bit at a time; instead, they focus the image onto an extended focal plane. Located in this plane is a flat (planar) array of tiny sensors, each equivalent to the single IR sensor employed in a scanning system. By measuring the IR response of all the elements in the flat array simultaneously (or rapidly), the system can record an entire image at once. Image resolution in a staring scanner is limited by the number of elements in the array, whereas in a scanning system it is limited by the size of the scanning dot.

Hybrid designs, in which partial or entire scan-lines are sensed simultaneously by rows of sensors, have also been developed. Chemical films have also been developed for IR imaging, but these are rarely used today.

The earliest IR imagers, built in the 1940s, 1950s, and 1960s, were scanners. Starers were not technologically feasible until the early 1970s, when large-scale circuit integration made the manufacture of focal-plane arrays with good resolution feasible. As integrated-circuit technology has been refined, focal-plane arrays have become cheaper. Starers have many advantages, including greater reliability due to the absence of moving parts, quicker image acquisition, and freedom from internally-produced mechanical vibration.

The security of a building or area of land from intruders is often enhanced by **cameras** that image the perimeter of the secure area and can be monitored by personnel in a central office. At night, such systems must either be supplied with illumination or must be capable of IR imaging. Visible-light camera systems are cheaper and easier for human users to interpret; however, because excess illumination of an area by visible light (“light pollution”) is sometimes a concern, and because security forces may wish to keep an area under surveillance without making their presence known, IR systems are widely used for perimeter security and other surveillance tasks. Scrutiny of the recorded data from such surveillance cameras can be useful in piecing together the course of nighttime events in a forensic investigation.

Aerial IR imaging can track vehicles, show which vehicles in a parking lot have arrived most recently, distinguish heated buildings, and locate buried structures (e.g., clandestine chemical laboratories) emitting heat through vents. IR images can be used to determine precisely the **time of death** of a body less than 15 hours old or to detect **document forgery** by revealing subtle mechanical and chemical disturbances of the original paper and ink. The power consumption in a building can be estimated in real time by observing the IR radiation emitted by the power transformer on the pole outside; modifications to walls or automobiles are often obvious in IR images; and IR images can reveal such visually inconspicuous features of crime scenes as use of cleaning solvents to remove **blood**, drag-marks across carpets, fresh paint, and **explosives** residues.

SEE ALSO Analytical instrumentation.

Ink analysis

Ink analysis may be an important part of the investigation of **questioned documents**, including forged checks, wills, or altered records. Although all blue or black inks may look the same, there can be some important differences in their chemical composition. These can be revealed by laboratory analysis and the results can help assess whether there have been any additions or alterations to a document.

Analysis of documents under a microscope can be informative as a first step. The investigator may be able to see slight changes in ink color, not visible to the naked eye, that could be indicative of alterations, or there may be suggestions of obliteration and overwriting. The ink itself may be analyzed by non-destructive or destructive testing, depending on whether a sample needs to be taken from the document, a process that would alter it. It is preferable to try the non-destructive approach first, so that the document is left intact.

The main method of non-destructive ink analysis is **micro-spectrophotometry**. This involves scanning the ink with ultraviolet or infrared light to record its spectrum, that is, the wavelengths of light it absorbs. Some inks fluoresce, or emit light, on exposure to ultraviolet, while others disappear. Each ink should give a distinct pattern or spectrum on exposure to ultraviolet or visible light. Put simply, this is a way of discovering the true “color” of the ink. The spectrum of the ink on the document can therefore be compared with the spectra of standard inks. Other non-destructive or minimally destructive methods, such as Raman **spectroscopy**, can be used to supplement micro-spectrophotometry. It can be very informative to scan the document with infrared light because, at high frequencies, ink is invisible but pencil marks which may lie underneath will show up.

The main method of destructive testing of ink is known as **thin layer chromatography** (TLC). In reality, it is not very destructive to the document if done with care. However, a photographic record of the original document is taken before the procedure is started. A tiny sample of the inked paper is punched out using a thin, hollow needle; a hypodermic syringe is ideal. The investigator avoids places where the pen has changed direction or where ink lines meet. This avoids any interference with subsequent **handwriting analysis**. The sample is placed in a test tube with a solvent that dissolves the ink. Next, a tiny spot of the sample solution is placed onto a strip of paper, alongside spots from various reference ink samples. The paper is placed in a beaker containing a small amount of another solvent. It is positioned so that the paper dips into the solvent but the spots of sample remain dry. The solvent is drawn up the paper through capillary action and the sample spots move up with it. **Chromatography** means "writing with colors" and the chemical components of the ink, which are, of course, colored, travel with the solvent at a speed that depends upon their composition.

The end result with TLC is a pattern of colored spots, known as a chromatogram, for each ink. Different inks will have different chromatograms. If the sample ink has the same chromatogram as one of the reference inks, it suggests they are the same, and so **identification** can be made. The United States Secret Service has a reference ink database and the U.S. Treasury has a database of ink thin layer chromatograms which can be very informative.

Another technique called high performance liquid chromatography (hplc), which can be used as an alternative to tlc. Hplc involves injecting the ink sample onto a long thin metal column that is then washed over with a mixture of solvents, carrying the ink components one at a time to an electronic detector. Between them, non-destructive and destructive methods of analysis can identify more than 90% of ballpoint pen inks.

Just because a document appears to have been written throughout in the same ink does not mean it has not been altered or added to. The same ink fills many different writing implements. Pens, usually ballpoint pens, can be distinguished from one another by looking at the non-inked areas known as striae within a line of writing with a microscope. Striae arise from imperfections within the ball or ball housing of the writing pen.

However, it can be difficult to age an ink, unless it is known for sure that the ink did not exist when the document was said to have been prepared. From the 1990s, some ink manufacturers started to add a chemical tag to their products to indicate the year of manufacture. This enables chemical analysis to age the ink, but the tests to do this remain rather expensive.

SEE ALSO Document forgery; Questioned documents; Secret writing.

Inorganic compounds

There are two main classes of chemical compounds, organic and inorganic. **Organic compounds** are based on carbon (containing the element carbon as a structural backbone) and are found in living things. Inorganic compounds are those based on other elements. This distinction is a generalization. Some important inorganic compounds, like calcium carbonate, or lime, contain carbon. Carbon-based compounds need not come from living things; synthetic **fibers** like nylon and polyester are carbon based but not found in plants or animals. From the point of view of **forensic science**, both organic and inorganic compounds are found in items of **evidence**. The techniques used for determination of chemical composition of such evidence often depend upon whether the component compounds are organic (derived form living tissue or material) or inorganic.

Glass and paint are probably the most important types of evidence containing inorganic compounds. Glass is composed of silica, soda, lime and impurities that are usually mineral salts. The chemical composition of glass is often determined with the scanning electron microscope (SEM) in conjunction with energy dispersive x-ray analysis (EDX). The microscope ensures magnification of ten thousand times or more of the sample, using electrons rather than light. The item under the microscope will emit radiation that is characteristic of the elements of which it is made. The presence and proportions of these elements can be determined and then compared with reference types of glass. This allows not only the type of glass found at the crime scene to be identified, but also a comparison with glass fragments found on a suspect.

Paint is the other type of evidence that contains inorganic compounds, as pigments or extenders. The red, yellow, and white pigments of paint tend to be inorganic in nature. As with glass, XRD (x-ray diffraction) and EDX together are used to look at the inorganic content of a paint flake or smear. These are crossed against paint references or comparison samples. Atomic absorption **spectroscopy** is another technique that can be used to identify inorganic components of evidence. This relies on the emission of specific wavelengths of light when an inorganic element, such as a metal, is heated. Atomic absorption is used in a forensic context to determine the chemical nature of soil or mud samples found at the scene of a crime

SEE ALSO Glass; Organic compounds; Paint analysis.

Institutes

There are a growing number of **training** institutes and centers of professional excellence throughout the worldwide **forensic science** community.

In the United States, the American Society of Crime Laboratory Directors (ASCLD) is a nonprofit professional society whose mission it is to create and promote the highest standards of professional performance in forensic scientific analysis. This organization holds annual symposia and professional institutes designed to offer continuing education and training in forensic science, management, and leadership. In 1995, the ASCLD established the National Forensic Science Technology Center in order to create a centralized means of providing outstanding quality of education, systems support, and training for the forensic scientific community throughout the United States.

The United States Department of Justice's Bureau of Alcohol, Tobacco, Firearms and Explosives (**ATF**) Laboratory has a long and illustrious history of excellence in the worldwide forensic community in the areas of alcohol, tobacco, firearms, explosives, and **fire debris** analysis. A central facet of ATF's mission is to provide training to the worldwide forensic community, as well as to U.S. federal, state, and local investigators and examiners.

The **European Network of Forensic Science Institutes** (ENFSI) was created with the expressed intention of creating a world community of forensic scientists who would exchange ideas, and share knowledge as a universal group of experts, maintaining the highest standards of professional practice, without being bound by culture or location.

Interpol has a forensic section containing international working groups in areas such as **DNA**, fingerprints, and disaster victim **identification**. In addition, Interpol hosts an international forensic science symposium every three years, the stated purposes of which are to provide a professional forum for forensic managers, to present an overview of the scientific advances occurring during the previous three years, and to create an environment conducive to the open exchange of information among all Interpol member states.

In Australia, the National Institute of Forensic Science was established as a national common police service whose purposes are: to sponsor and support forensic scientific research; to hold institutes for the sharing, support, and exchange of forensic training, education, and information; and to maintain system-wide standards of forensic scientific quality assurance. In addition, the NIFS works at continual professional forensic science quality improvement, both locally and worldwide, as well as at the promotion of environmentally responsible use of resources.

The Forensic Science Division, located in Hong Kong, provides comprehensive forensic scientific services to the criminal justice system. It contains two sections: the Criminalistics and Quality Management Group and the Drugs, Toxicology, and Documents Group. The Criminalistics and Quality Management Group has eight operational sections: Biochemical Sciences A Section, Biochemical Sciences B Section, Chemical Sciences Section, DNA Database Section, Parentage Testing Section, Physical Sciences Section, and Scene of Crime and Quality Management Section.

India's Central Forensic Science Laboratory was designed to meet the forensic science needs of the Indian Central Bureau of Investigation, the Delhi Police, the government of India, and various Indian central government agencies. In addition to the analysis of forensic, scientific, and evidentiary materials, the CFSL conducts research and development in all areas of forensic science, and provides forensic science training to investigating officers and others involved in the forensic sciences, and conducts institutes and educational symposia for police, professional, and public organizations.

Japan's Training Institute of Forensic Science is tasked with providing organizational staff, police professionals, and criminal laboratory personnel with training, education, and strategic technology in the theory and practice of forensic science. In addition to the five core training courses offered (Basic, Advanced, Specialized Technique, Research, and Management Courses), the Training Institute of Forensic Science is committed to the international exchange of forensic science information and technologies through its international research and training course.

The Netherlands Forensic Institute is part of the Ministry of Justice, and is responsible for ongoing forensic scientific and technical research. It is organized into the following technical units: **pathology**; toxicology; DNA-technology; hair and **fibers**; firearms and ammunition; shotgun residue; explosives; **toolmarks**, footwear, and tire impressions; forensic engineering and material science; **fire investigation**; fingerprints; environmental analysis; **illicit drugs**; general chemistry (excluding fire-accelerants and paint); hand- and machine-writing; speech; **questioned documents**; traffic accidents; vehicle identification; and digital technology. The NFI is one of the founding members of the ENFSI, and it maintains extensive contact, collaborative partnerships and projects, and professional networks with other countries' forensic laboratories, research institutes, and universities. The NFI is expressly committed to worldwide cooperation in the solution and prevention of international crime.

In Poland, the Institute of Forensic Research conducts forensic science research, prepares for and provides expert opinions throughout the country's legal system, and is tasked with professional development, advancement, and promotion of the forensic sciences, particularly within the legal and justice systems. The Institute conducts ongoing research in the areas of toxicology; illicit drugs; **DNA profiling**; road accidents; forensic engineering; paint; **glass**; fibers and textiles; gunshot residues; toolmarks, footwear, and tire impressions; forensic **photography**; handwriting; questioned documents; fingerprints; forensic **psychology**; and audio-speech analysis.

Singapore's Forensic Science Division of the Department of Scientific Services, Institute of Science and Forensic Medicine, claims world-renowned status for its forensic science services. It is the sole provider of forensic science expertise and services to the Central Narcotics Bureau, to the police, and to the Singapore judiciary. In addition, it provides expert forensic, medical, and legal services to hospitals and other requesting government agencies. Since 1996, the Forensic Science Division has achieved and maintained the distinction of being ASCLD accredited in the areas of DNA, **serology**, controlled drugs, firearms/toolmarks, **trace evidence**, questioned documents, and toxicology. The ASCLD accreditation is considered symbolic both of the achievement of international recognition and of consistent maintenance of the highest standards of professional excellence.

The Istanbul University Institute of Forensic Sciences is the only academic institution in Turkey to offer graduate degrees in forensic science. The Institute is a member of ENFSI, and it provides expert forensic scientific support to Turkey's criminal justice system.

This is by no means an exhaustive list of the most comprehensive or internationally respected forensic institutes in the world today; it is intended as a representative sampling designed to pique the reader's interest and, perhaps, to spark a personal exploration of the worldwide forensic scientific community.

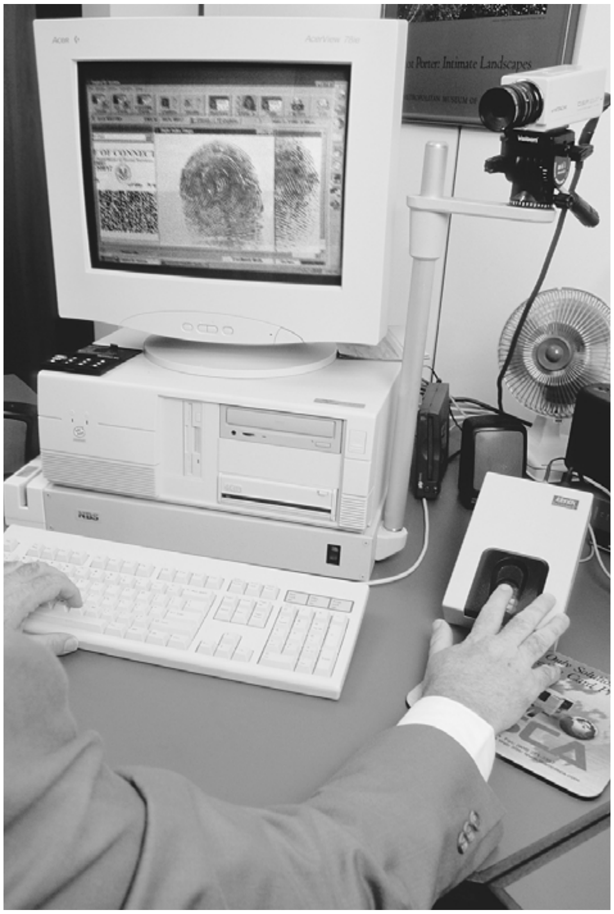
SEE ALSO American Academy of Forensic Sciences; FBI Crime Laboratory; Law Enforcement Training Center (FLETC), United States Federal; Technology and forensic science.

Integrated automated fingerprint identification system

An important part of a forensic investigation is the **identification** of the victim or suspect. One of the most useful identification tools is the **fingerprint** pattern. An individual's fingerprint pattern is a unique identifier. This identification power was recognized long ago. On-paper impressions of fingerprint patterns stored in file cabinets have been a standard feature of law enforcement. In the Internet age, such information can be shared with the wider community. Computer databases can be made accessible to virtually any law enforcement agency, and to other forensic investigations who have the necessary authorization to access the database.

The most important fingerprint database is known as the Integrated **Automated Fingerprint Identification System** (IAFIS). The database—the largest in the world—is a national repository of fingerprint and other information on criminal history, which is maintained by the Federal Bureau of Investigation (**FBI**) Criminal Justice Information Services Division.

A user accessing the database can print out or download specified images. As well, images can be uploaded to the database. Indeed, the fingerprint image patterns in the database are voluntarily submitted by local, state, and federal law enforcement agencies. Over 47 million fingerprint patterns currently reside in the database.



The project manager in biometrics for the state of Connecticut demonstrates integrated fingerprint identification software.

Many of the files in the database contain the digitized images of ten prints, the eight fingers and two thumbs, of an individual. Eight print patterns, which lack thumbprints, are also included.

The images can be downloaded directly to the database when submitted electronically. Fingerprints that are submitted by mail are converted to an electronic format.

Users can search the IAFIS database to compare a submitted fingerprint pattern with this tremendous number and geographically diverse repository of fingerprints. The submitted pattern is compared to those in the database. Any matching pattern is displayed, complete with the other information on the individual.

The IAFIS increases a forensic investigator's chance of identifying a subject or a deceased person. The electronic nature of the database facilitates rapid turnaround. Typically, in a non-criminal case, a response to a submission occurs within 24 hours. When a submission is concerned with a criminal or forensic investigation, the turnaround time occurs within two hours. Conceivably, a fingerprint pattern can be submitted and a response received within the same business day.

This rapid submission and turn-around capability has markedly accelerated forensic investigations. In the past, identifying a fingerprint from a national paper database took months. Indeed, it was this limitation that prompted the FBI to partner with law enforcement agencies in the 1990s to establish the electronic database. The IAFIS began operation in July of 1999.

SEE ALSO Automated Fingerprint Identification System (AFIS); Crime scene investigation; Digital imaging; Fingerprint; Fingerprint analysis (famous cases); Latent fingerprint.

Integrated Ballistics Identification System (IBIS)

When bullets and shell casings are shot from **firearms** they can leave unique marks, which when examined by forensic scientists can link a particular firearm to a specific crime. Before 1998, the U.S. Federal Bureau of Investigation (**FBI**) and the Bureau of Alcohol, Tobacco, Firearms and Explosives (**ATF**), both under the U.S. Department of Justice, developed independent **imaging** systems and databases to analyze and store ballistic images. The FBI system was called **Drugfire**, while the AFT system was named IBIS (Integrated Ballistics Identification System).

The Integrated Ballistics Identification System was purchased in 1993 by the ATF from its developer, Forensic Technology, Inc. (FTI) of Montreal, Canada. The project, which eventually turned into IBIS, was begun in 1990 in order to provide law enforcement professionals with the ability to use digital computer images of ballistic **evidence** and to assist crime laboratories with a growing number of firearm-related crimes.

The IBIS uses sophisticated electronic and optical technology to digitally compare evidence stored in the database. Initially, IBIS equipment photographs the surface of fired bullets and casings from crime scenes and laboratories. Upon entering a new image into the database, the system searches for a match by using advanced mathematical algorithms to correlate the new image against previously stored images. Using filters such as **caliber**, date of crime, date of entry, and rifling specifications, the correlations produce lists of possible matches. A forensic examiner then visually compares the matched images on a computer monitor. If a possible match is found, the images are compared with actual evidence by an examiner on a microscope for a final determination. Once an identification is confirmed in association with at least two different crimes, a unique identifier is assigned for future reference to that image.

Leaders of the FBI and ATF realized that their two systems (Drugfire and IBIS) were incompatible and agreed in the 1990s that both systems needed to transmit information between each other. In May 1997, the National Integrated Ballistics Information Network (NIBIN) board was created to develop a national imaging system. One year later, FBI and ATF officials agreed to pursue the joint development of one system, using only the IBIS, and created the National Integrated Ballistics Information Network. In December 1999, FBI and ATF leaders signed a memorandum that defined their individual roles: the FBI was granted responsibility for providing the communications network and the ATF was given responsibility for field operations. Forensic Technology was awarded the NIBIN Expansion Contract in 2002 for products and services relevant to IBIS. By the end of 2002, IBIS systems had been installed in 233 U.S. crime laboratories as part of the NIBIN and, as of the beginning of 2005, IBIS systems were used in over thirty countries by thirty-three local, provincial, state, and federal law enforcement agencies. The IBIS technology has allowed law enforcement officials to match over 32,000 pieces of evidence and has helped to open thousands of new investigative leads.

SEE ALSO ATF (United States Bureau of Alcohol, Tobacco, and Firearms); Ballistics; Computer forensics; Drugfire; FBI (United States Federal Bureau of Investigation).

Integument

The integumentary system includes the skin and the related structures that cover and protect the body. The human integumentary system is made up of the skin, which includes glands, hair, and nails. The skin protects the body, prevents water loss, regulates body temperature, and senses the external environment. Examination of the integument can also provide the forensic scientist with clues regarding the identity of a crime victim, the nature of the crime committed, and even the perpetrator of the crime.

The human integumentary system serves many protective functions for the body. Keratin, an insoluble protein in the outer layer of the skin, helps prevent water loss and dehydration. Keratin also prevents excessive water loss, keeps out microorganisms that could cause illness, and protects the underlying tissues from mechanical damage. Keratin is also the major protein found in nails and hair. Pigments in the skin called melanin absorb and reflect the sun's harmful ultraviolet radiation. The skin helps to regulate the body temperature. If heat builds up in the body, sweat glands in the skin produce more sweat that evaporates and cools the skin. In addition, when the body overheats, blood vessels in the skin expand and bring more blood to the surface, which allows body heat to be lost. Conversely, if the body is too cold the blood vessels in the skin contract, resulting in less blood at the body surface, and heat is conserved. In addition to temperature regulation, the skin serves as a minor excretory organ, because sweat removes small amounts of nitrogenous wastes produced by the body. The skin also functions as a sense organ as it contains millions of nerve endings that detect touch, heat, cold, pain and pressure. Finally, the skin produces vitamin D in the presence of sunlight, and renews and repairs damage to itself.

In an adult, the skin covers about 21.5 square feet (2 square meters), and weighs about 11 pounds (5 kilograms). Depending on location, the skin ranges from 0.02–0.16 inches (0.5–4.0 millimeters) thick. Its two principal parts are the outer layer, or epidermis, and a thicker inner layer, the dermis. A subcutaneous layer of fatty or adipose tissue is found below the dermis. Fibers from the dermis attach the skin to the subcutaneous layer, and the underlying tissues and organs also connect to the subcutaneous layer.

Ninety percent of the epidermis, including the outer layers, contains keratinocytes cells that produce keratin, a protein that helps waterproof and protect the skin. Melanocytes are pigment cells that produce melanin, a dark pigment that adds to skin color and absorbs ultraviolet light thereby shielding the genetic material in skin cells from damage. Merkel's cells disks are touch-sensitive cells found in the deepest layer of the epidermis of hairless skin.

In most areas of the body, the epidermis consists of four layers. On the soles of the feet and palms of the hands where there is a lot of friction, the epidermis has five layers. In addition, calluses, abnormal thickenings of the epidermis, occur on skin subject to constant friction. At the skin surface, the outer layer of the epidermis constantly sheds the dead cells containing keratin. The uppermost layer consists of about 25 rows of flat dead cells that contain keratin.

The dermis is made up of connective tissue that contains protein, collagen, and elastic fibers. It also contains blood and lymph vessels, sensory receptors, related nerves, and glands. The outer part of the dermis has fingerlike projections, called dermal papillae that indent the lower layer of the epidermis. Dermal papillae cause ridges in the epidermis above it, which in the fingers give rise to fingerprints. The ridge pattern of fingerprints is inherited, and is unique to each individual. The dermis is thick in the palms and soles, but very thin in other places, such as the eyelids. The blood vessels in the dermis contain a volume of blood. If a part of the body, such as a working muscle, needs more blood, blood vessels in the dermis constrict, causing blood to leave the skin and enter the circulation that leads to muscles and other body parts. Sweat glands whose ducts pass through the epidermis to the outside and open on the skin surface through pores are embedded in the deep layers of the dermis. Hair follicles and hair roots also originate in the dermis and the hair shafts extend from the hair root through the skin layers to the surface. Also in the dermis are sebaceous glands associated with hair follicles that produce an oily substance called sebum. Sebum softens the hair and prevents it from drying, but if sebum blocks up a sebaceous gland, a whitehead appears on the skin.

The skin is an important sense organ, and as such includes a number of nerves that are mainly in the dermis, with a few reaching the epidermis. Nerves carry impulses to and from muscles, sweat glands, and blood vessels, and receive messages from touch, temperature, and pain receptors. Some nerve endings are specialized such as sensory receptors that detect external stimuli. The nerve endings in the dermal papillae are known as Meissner's corpuscles, which detect light touch, such as a pat, or the feel of clothing on the skin. Pacinian corpuscles, located in the deeper dermis, are stimulated by stronger pressure on the skin. Receptors near hair roots detect displacement of the skin hairs by stimuli such as touch or wind. Bare nerve endings throughout the skin report information to the brain about temperature change (both heat and cold), texture, pressure, and trauma.

Some skin disorders result from overexposure to the ultraviolet (UV) rays in sunlight. At first, overexposure to sunlight results in injury known as sunburn. UV rays damage skin cells, blood vessels, and other dermal structures. Continual overexposure leads to leathery skin, wrinkles, and discoloration and can also lead to skin cancer.

SEE ALSO Crime scene reconstruction; DNA.

International Association for Identification

The roots of the International Association for Identification (IAI) extend back to 1915 when Harry H. Caldwell, an inspector with the Oakland (California) Police Department, identified the need to organize a criminal identification group. Consequently, twenty-two criminal identification operators formed the International Association for Criminal Identification in October 1915, with Caldwell as its presiding officer. Today, the IAI (web page http://www.theiai.org/) is the world's oldest and largest forensic organization, with over 5,000 members from the United States and numerous foreign countries. Through a network of products and services, the IAI is the primary organization engaged in the dissemination of information and support of **forensic science** professionals.

The word criminal was dropped from its name in 1918 because IAI bureaus were performing increasing amounts of non-criminal work. The newly named organization, International Association for Identification, was subsequently incorporated in Delaware on December 22, 1919. Throughout the twentieth century, the IAI grew in prominence as new state bureaus, divisions, committees, and other groups were formed. Indeed, the organization was recognized by the U.S. Federal Bureau of Investigation (**FBI**) and other government agencies as a valuable partner against crime; a status it maintains today.

Presently, the structure of the IAI, with headquarters in Mendota Heights, Minnesota (south of Minneapolis), consists of independent divisions and regions throughout the world. Two major IAI awards are presented each year: The John A. Dondero Memorial Award—established in 1958 and first awarded to FBI Director **J. Edgar Hoover** in 1959—recognizes people who make significant contributions to the field of identification; and the Good of the Association Award—first awarded in 1988—recognizes persons who make outstanding contributions to IAI goals, interests, and objectives.

The IAI runs six certification programs: Latent Print (the first program, established in 1977), Crime Scene; Forensic Art; Footwear and Tiretrack Analysis;

Bloodstain Pattern, and Forensic Photography/Imaging. A peer-reviewed IAI journal called the *Journal of Forensic Identification*, established in 1988, is an internationally recognized bimonthly journal that includes scientific articles on case reports, experiments, original investigations, reviews, tests, and other related subjects. The IAI also sponsors the Annual IAI International Educational Conference, which features educational presentations, field trips, general and advanced seminars, hands-on workshops, and vendor exhibits. Established in 1988, the Robert L. Johnson Foundation provides research and educational scholarships and grants to promote the advancement of professional forensic identification. A student membership category was created in 2000 so that full-time college students with majors in forensic science, law enforcement, and related fields could benefit from IAI information and **training**.

SEE ALSO Careers in forensic science; FBI (United States Federal Bureau of Investigation); Identification.

International laws and trials SEE Trials, international

Internet tracking and tracing

Forensic science, in particular the process of **forensic accounting**, where the routing of finances, property, and other material items are traced, relies upon trails of **evidence**. The information that resides on the Internet can be tracked and traced, and so can be valuable in forensics.

Tracing is a process that follows the Internet activity backwards, from the recipient to the user. As well, a user's Internet activity on web sites can also be tracked on the recipient site (i.e., what sites are visited and how often, the activity at a particular site). Sometimes this tracking and tracing ability is used to generate e-mail to the user, promoting a product that is related to the sites visited. User information, however, can also be gathered covertly.

Techniques of Internet tracking and tracing can also enable authorities to pursue and identify those responsible for malicious Internet activity. For example, on February 8, 2000, a number of key commercial Internet sites such as Yahoo, Ebay, and Amazon were jammed with incoming information and rendered inoperable. Through tracing and tracking techniques, law enforcement authorities established that the attacks had arisen from the computer of a 15-year-old boy in Montreal, Canada. The youth, whose Internet identity was "Mafiaboy," was arrested within months of the incidents.

Law enforcement use of Internet tracking is extensive. For example, the U.S. Federal Bureau of Investigation has a tracking program designated Carnivore. The program is capable of scanning thousands of e-mails to identify those that meet the search criteria.

Cookies are computer files that are stored on a user's computer during a visit to a web site. When the user electronically enters the web site, the host computer automatically loads the file(s) to the user's computer.

The cookie is a tracking device, which records the electronic movements made by the user at the site, as well as identifiers such as a username and password. Commercial web sites make use of cookies to allow a user to establish an account on the first visit to the site and so to avoid having to enter account information (i.e., address, credit card number, financial activity) on subsequent visits. User information can also be collected unbeknownst to the user, and subsequently used for whatever purpose the host intends.

Cookies are files, and so can be transferred from the host computer to another computer. This can occur legally (i.e., selling of a subscriber mailing list) or illegally (i.e., "hacking in" to a host computer and copying the file). Also, cookies can be acquired as part of a law enforcement investigation.

Stealing a cookie requires knowledge of the file name. Unfortunately, this information is not difficult to obtain. A survey conducted by a U.S. Internet security company in 2002 on 109,212 web sites that used cookies found that almost 55% of them used the same cookie name. Cookies may be disabled by the user, however, this calls for programming knowledge that many users do not have or do not wish to acquire.

A bug or a beacon is an image that can be installed on a web page or in an e-mail. Unlike cookies, bugs cannot be disabled. They can be prominent or surreptitious. As examples of the latter, graphics that are transparent to the user can be present, as can graphics that are only 1x1 pixels in size (corresponding to a dot on a computer monitor). When a user clicks onto the graphic in an attempt to view, or even to close the image, information is relayed to the host computer.

Information that can be gathered by bugs or beacons includes: the user's IP address (the Internet address of the computer) and e-mail address; the user computer's operating system (which can be used to target viruses to specific operating systems; the URL (Uniform Record Locator), or address, of the web page that the user was visiting when the bug or beacon was activated; and the browser that was used (i.e., Mozilla, Explorer).

Like cookies, the information provided by the bug or beacon can be useful to law enforcement officers and forensic investigators who are tracking down the source of an Internet intrusion.

E-mail transmissions have several features that make it possible to trace their passage from the sender to the recipient computers. For example, every e-mail contains a section of information that is dubbed the header. Information concerning the origin time, date, and location of the message is present, as is the Internet address (IP) of the sender's computer.

If an alias has been used to send the message, the IP number can be used to trace the true origin of the transmission. When the originating computer is that of a personally owned computer, this tracing can often lead directly to the sender. However, if the sending computer serves a large community—such as a university—through which malicious transmissions are often routed, then identifying the sender can remain daunting. Yet depending on the e-mail program in use, even a communal facility can have information concerning the account of the sender.

The information in the header also details the route that the message took from the sending computer to the recipient computer. This can be useful in unearthing the identity of the sender. For example, in the case of "Mafiaboy," examination of the transmissions led to a computer at the University of California at Santa Barbara that had been commandeered for the prank. Examination of the log files allowed authorities to trace the transmission path back to the sender's personal computer.

Chat rooms are electronic forums where users can visit and exchange views and opinions about a variety of issues. By piecing together the electronic transcripts of the chat room conversations, enforcement officers can track down the source of malicious activity.

Returning to the example of "Mafiaboy," enforcement officers were able to find transmissions at certain chat rooms where the upcoming malicious activity was described. The source of the transmissions was determined to be the youth's personal computer. Matching the times of the chat room transmissions to the malicious events provided strong evidence of the youth's involvement.

SEE ALSO Computer forensics; Computer hackers; Computer security and computer crime investigation.

Interpol

Interpol's main functions are to act as a global police communication system, to gather intelligence on activities of criminal international organizations and individuals, to provide its member states with several types of criminal databases and analytical services, and to give proactive support for police operations around the world.

The idea of founding an international police organization was initially conceived during the First International Criminal Police Congress, held in Monaco in 1914. Lawyers, magistrates, and police officers from 14 countries basically constituted the public present at the time. In that same year, World War I was initiated and the project was put aside until 1923 when the President of the Vienna Police, Dr. Johannes Schober, promoted the foundation of the International Criminal Police Commission (ICPC), which was the embryo of the modern Interpol. ICPC central office was located in Vienna, Austria, and when Germany annexed Austria to its territories in 1942, the Nazis moved the organization to Berlin. In protest, the vast majority of ICPC member-countries broke with the organization. Consequently, the ICPC was practically extinct at the end of World War II in 1945.

The reorganization of ICPC started in 1946, under Belgian initiative, and the name Interpol was created as a telegraphic address. The new headquarters were located in Paris, France, with new countries progressively seeking membership. The United Nations first recognized Interpol as a consultant agency in 1949. In 1971 the UN recognized it as an inter-governmental police organization, five years after the modernization process that created a new statutory regulation, administrative structure, and a new name, International Criminal Police Organization (ICPO-Interpol).

In the following decades, Interpol incorporated new technologies and organized its General Secretariat in Lyon, France, and the respective Interpol National Central Bureaus (INCBs) in each member-country. A communication system, X.400, was developed in 1990 for electronic exchange of information among the several INCBs around the world and the General Secretariat. Among other resources, an Automatic Search Facility (ASF data bank) was created in 1998 and in 2002, a web-based data system (I–24/7)

INTERPOL's database screen where all stolen artworks are catalogued, allowing cross-checking during inquiries. © DUNG VO TRUNG/ CORBIS SYGMA

was developed to optimize the access of INCBs to all available criminal records and new inputs.

The creation and consolidation of the European Union, as well as the new security challenges posed by terrorism and other transnational criminal activities such as international kidnapping and pedophilia, human traffic for labor, and narco-trafficking, make evident the strategic importance of Interpol. For instance, as an inter-governmental criminal police with law enforcement powers, Interpol is positioned to facilitate and coordinate the implementation of coordinated police operations simultaneously in several countries.

The administrative structure of Interpol consists of: 1) the General Assembly, composed of delegates appointed by each of its 182 member-countries; 2) the Executive Committee, whose members are elected by the General Assembly to represent the four Interpol regions (Africa, Asia, the Americas, and Europe) in Interpol affairs and decision-making; 3) the General Secretariat, along with the technical and administrative staff. Each member country maintains an Interpol National Central Bureau (INCB) that provides services to local law enforcement and institutions and functions as a liaison between the member state and the rest of the organization. The Interpol Executive Committee and the General Assembly have independent authority to appoint expert advisors.

SEE ALSO International Association for Identification.

Interpol, United States National Central Bureau

Forensic investigations at the local, state, and national level can be aided by the resources and data housed at international police institutions such as **Interpol**.

As the United States branch of Interpol, an international police organization, the United States National Central Bureau (USNCB) in Washington, D.C., serves as a communications clearinghouse for police seeking assistance in criminal investigations that cross international boundaries. Directed by the U.S. Attorney General and representing sixteen law enforcement agencies under the Department of Justice in conjunction with the Department of the Treasury, the USNCB focuses on fugitives, financial fraud, drug violations, terrorism, and violent crimes. It can refuse to respond to any of the 200,000 annual inquiries from other nations and, as required by Interpol bylaws, does not assist in the capture of people sought for political, racial, or ethnic reasons.

Although Interpol dates back to 1923, the USNCB did not come into existence until the 1960s because of a lukewarm American attitude toward the organization. Hesitant about the benefits of international police work, the Federal Bureau of Investigation (**FBI**) in the Department of Justice did not post wanted notices with Interpol until 1936. When **J. Edgar Hoover** (1895–1972), head of the FBI from 1924 to 1972, observed Interpol's success in apprehending criminals, his subsequent support of the police force prompted Congress to order the Attorney General to accept Interpol membership in 1938. Hoover became the permanent American representative to Interpol with only the FBI authorized to do business with the group. In 1950, Hoover pulled the FBI out of Interpol for reasons that remain unclear. The Treasury, however, continued to maintain informal contact with the organization and became the official U.S. representative in 1958. When the U.S. decided to establish the USNCB in 1962 as part of Attorney General Robert F. Kennedy's fight against organized crime, the history of American involvement dictated a sharing of power between the two agencies with Justice as the dominant partner.

The USNCB became operational in 1969, with a staff of three and an annual caseload of 300. Agents are complimented by computer specialists, analysts, translators, and administrative and clerical support personnel drawn largely from the ranks of the Department of Justice. The agents operate in divisions dedicated to specific investigative areas while the analysts review case information to identify patterns and links. The law enforcement agencies represented at the USNCB include the Bureau of Alcohol, Tobacco, and Firearms; the Drug Enforcement Administration (**DEA**); the Environmental Protection Agency; the FBI; the Financial Crimes Enforcement Network; the Fish and Wildlife Service; the Immigration and Naturalization Service (INS); Internal Revenue Service; U.S. Customs Service; the Department of Agriculture, the Department of Justice, Criminal Division; the Department of State; the U.S. Marshals Service; the U.S. Mint; the U.S. Postal Inspection Service; and the U.S. Secret Service. Additionally, each state, the District of Columbia, and New York City have established points of contact to receive international criminal reports from the USNCB.

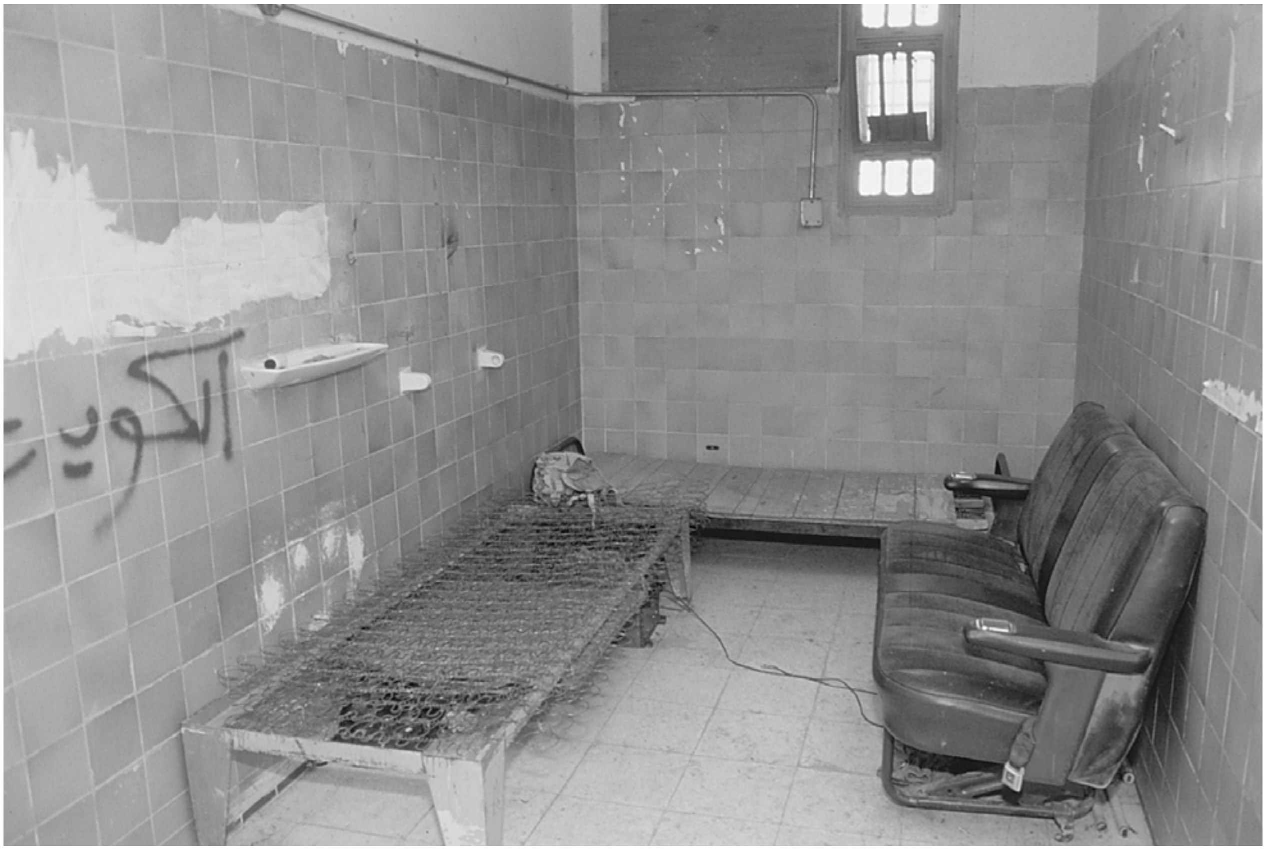
The USNCB operates by linking the Treasury Enforcement Computer System, the FBI's **National Crime Information Center**, INS files, and DEA records to Interpol. In 1990, the U.S. and Canadian governments established an Interpol Interface between the USNCB and the Canadian NCB in Ottawa. This link allows police to tap into law enforcement networks across the border to verify driver registrations and vehicle ownership.

SEE ALSO European Network of Forensic Science Institutes; FBI (United States Federal Bureau of Investigation).

Interrogation

The aim of a criminal interrogation is to obtain information from a suspect that the suspect does not want to divulge. Interrogation must be carried out in a manner that does not violate the suspect's civil rights or compromise the legal admissibility of the obtained information. There is often confusion between the concepts of interview and interrogation. The distinction is this: an interrogation occurs when one person asks all the questions and the other gives the answers; an interview is a conversation where both people ask and respond to questions. A thorough interview should always precede an interrogation, providing a foundation for the questioner to gather essential information about the subject's feelings, motivations, fears, and belief systems, which can then be used to direct an interrogation. Through the course of the interview, the subject is asked questions about him/herself, others involved in the event, and the crime itself. The interview process should be conducted in an informal and non-threatening manner; the goal is to obtain verbal and nonverbal information about the subject while building rapport and determining whether an interrogation is warranted.

A cardinal rule in interrogation is that there one best chance at obtaining a confession or the desired information, and it occurs the first time a subject is interrogated. There are several facets of interrogation that significantly increase the probability of successful outcome. The first involves laying adequate groundwork and thoroughly preparing for the interrogation.



Iraqi cell used for interrogation where investigators with the U.S.-led coalition in 1990 found evidence of Iraqi torture of its own citizens and of Kuwaiti victims. © JACQUES LANGEVIN/CORBIS SYGMA

The interrogation must occur in an appropriate environment, where there is relative comfort but total freedom from distractions and interruptions. All potential distractions, such as cell phones, radios, beepers, etc. must be silenced; there should be no windows, telephones, or clocks in the room. The interrogator should be free to fully observe the posture, body language, and nonverbal cues of the subject throughout the course of the session. By eliminating other stimuli, the interrogator can be certain that all reactions stem from the line of questioning and the issues presented. An important aspect of environmental preparation entails prior preparation for documenting the information obtained. It is critical not to stop the process of interrogation. No matter what the means of recording the interrogation, it is imperative to obtain an signed, written summary statement of fact which will be admissible in a court of law. The interrogator must be certain to allot sufficient time to complete the interrogation, in order to maximize the likelihood of successful outcome.

The interrogator must be thoroughly familiar with the case facts, particularly those concerning the crime's commission. The interrogator gains immeasurable credibility and stature if he or she can communicate knowledge of how the crime was committed to the subject. Similarly, it is essential for the interrogator to become familiar with the subject's belief system, feelings, and attitude about the crime and victim. Psychologically, the interrogator must understand the subject's conflicts, needs, and goals in order to best elicit truthful information.

Interrogation is more direct than interviewing; its only goal is to elicit a confession or admission of guilty knowledge. The interrogator presents the subject with facts and information, and does not solicit new information. It is therefore critical for the interrogator to have previously amassed case facts and information with which to persuade the subject to tell the truth. The more experienced the interrogator and the more thorough the advance preparation, the more convincing the arguments will be.

There are several universal defense mechanisms that, if properly recognized and utilized by the interrogator, will greatly increase the likelihood of obtaining information: minimization, projection, and rationalization. Properly exploiting these defense mechanisms allows the subject to maintain a semblance of dignity while still being held accountable by the interrogator for their actions. If the interrogator minimizes the gravity of the incident by referring to it as an accident or an unfortunate mistake, the subject may also internally minimize the perceived impact of the incident and feel less resistant to talking about it By suggesting that someone else (often the victim) might share in the blame for the incident, the interrogator uses projection to allow the subject to feel that the incident is excusable. When an interrogator suggests that he or she can understand the subject's perspective (rationalization), it conveys empathy and allows the subject to feel like a decent individual who was in a bad circumstance at the time of the incident. By using careful wording, the interrogator can simultaneously decrease the subject's feeling of shame about the event and increase feelings of hopefulness about the ultimate outcome. The interrogator must be extremely careful not to mislead the subject into a belief in legal leniency or to in any way suggest denying the subject due process. Either event could lead to legal inadmissibility of the confession.

The interrogator presents a set of themes and arguments over the course of the interrogation, as many times and in as many ways as necessary to obtain a confession. In order to ensure a successful outcome, the interrogator must continually confront (degree and manner of confrontation must be person- and situation-specific) the subject with facts and information about the case and gradually limit the subject's ability to deny participation therein. One way to do this is by repeatedly stating the subject's participation in the incident(s) and questioning only the justification or motive for the event. Once the subject begins to acknowledge responsibility or participation in the crime, the interrogator can offer the individual reasons to confess without loss of dignity, such as an opportunity to tell his or her side of the story, to obtain psychological help, or to play a positive role in the ultimate outcome of the case. Successful interrogation outcome depends on maintaining a balance of the environmental, situational, and personality factors at play, while utilizing every available psychological technique and without compromising the legal integrity of the process.

SEE ALSO Criminal profiling; Ethical issues; Polygraphs; Profiling; Psychological profile.

Investigation, crime scene SEE Crime scene investigation

Isoantibodies

Isoantibodies are antibodies (proteins that defend against foreign agents, such as bacteria) in **blood**.

Hemagglutination (clumping of red blood cells) reactions are used in the typing of blood. The presence or absence of antigens (a substance perceived as foreign to the body), designated A and B, located on the surface of red blood cells is determined by employing the use of specific antisera (antibodies). Since an individual possesses antibodies to the opposite **antigen**, when anti-A antiserum is mixed with type B red blood cells, no hemagglutination will occur. Similarly, persons of blood type A will have anti-B in their **serum**. Persons with type AB blood contain both A and B antigens on their red blood cells. Individuals with type O blood lack both A and B antigens, but they do have anti-A and anti-B in their serum.

ABO blood types are controlled by three alleles (versions of genes): IA and IB are co-dominant and both are dominant over the recessive i. The homozygous recessive condition (ii) results in type O blood. A person with blood type A may have either of the following genotypes: IAIA or IAi. The genotype IAIB results in type AB blood.

The Rh factor is a complex of over 30 different antigens on the surface of human red blood cells. The Rh factor that is routinely used in blood typing is the called the Rh, or D, antigen. The presence of the Rh factor is determined by a hemagglutination reaction between anti-Rh antiserum and red blood cells. Persons who have the Rh antigen are called Rh-positive. Rh-negative individuals do not naturally have anti-Rh in their sera.

Isoantibodies are present in human serum. An individual possesses isoantibodies to the opposite A or B isoantigen. For example, persons of blood type A will have serum containing isoantibodies to the B antigen. Rh-negative individuals do not normally have anti-Rh antibodies in their sera. When red blood cells with Rh antigen are introduced into Rh-negative individuals, anti-Rh-antibodies are produced.

In 1929, Kosaku Yosida established the existence of isoantibodies in body **fluids** other than blood (**saliva**, sinus secretions, etc.). By establishing the existence of serological isoantibodies in fluids other than blood, Yosida paved the way for far more sophistication in the forensic analysis of bodily fluids, along with the ability to use multiple means of **identification** of a single perpetrator of a crime.

SEE ALSO Antibody; Antigen; Secretor; Serology; Serum.

Isotopic analysis

Varieties of the same chemical element, but with different atomic weights, are called isotopes. Isotopic analysis (IA) is the analysis of the isotope composition of a sample. Samples in IA can contain almost anything: different objects of everyday life, pieces of rocks, pieces of wood, samples of tissue taken from a human body, chemical compounds, and so on. In general, IA is used for **identification** of a sample and for the determination of its age. Determining the age of an object can be important in a forensic examination, especially when examining human remains from cold cases, ancient sites, or mass graves. IA is based upon the use of mass spectrometers or radioactive radiation counters. A mass spectrometer is a device that determines the quantity and composition of different isotopes (of the same chemical element as well as various elements) in the sample.

The isotope composition of many objects is unique (relative to the composition itself as well as to the isotope concentrations), and because of this, isotopic analysis offers the possibility for identification of a sample. Isotopic analysis is also utilized in varying disciplines, including chemistry, **medicine**, biology, **geology**, archeology, and criminal forensics. Recently, isotopic analysis has seen use in the diagnosis of some diseases through analysis of air exhaled by the patient. Often, isotopic analysis permits the scientist to distinguish the genuine product from its imitation. For example, the technology is used to distinguish expensive types of wine and liquor from their imitations.

Isotopes can be both stable and radioactive. IA of radioactive isotopes permits scientists to determine the age of the investigated sample. Often the isotope ^{14}C is used for this purpose. This isotope itself is unstable and decays with time, and in the decay process, other stable isotopes are created. In nature, the concentration of ^{14}C is maintained because of cosmic radiation. While a tree lives, for example, the concentration of ^{14}C in its wood is equal to the ^{14}C concentration in the environment, because atoms of radioactive carbon penetrate the wood from the atmosphere with carbon dioxide (CO_2) molecules due to photosynthesis, and also through the tree root system. But when the tree dies, these exchange processes cease, and the ^{14}C concentration in the tree begins to decrease. The law of radioactive carbon concentration alteration in the sample is known, hence if its concentration is measured in the sample and compared with the concentration of the isotope in nature, the age of the tree itself can be determined (or more precisely, the time since the tree died). When the decay period of the radioisotope is considered, the age of the sample can be determined within an accuracy of several decades.

SEE ALSO Analytical instrumentation; Radiation damage to tissues.

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Jefferson, Thomas, paternity issue

Thomas Jefferson (1743–1836), the third president of the United States, has long been considered to have fathered children with Sally Hemings, one of his slaves. Slaveowners were notorious for taking sexual advantage of slaves and, if he did so, Jefferson would not have been unusual among the men of his time and place. A 1998 **DNA** test attempted to resolve the issue, but could not establish with certainty the paternity of Hemings' descendents.

Sally Hemings (1773–1835), one of Jefferson's slaves for most of her life and the probable sister of Jefferson's wife, gained notoriety when one of Jefferson's political opponents charged that she was also Jefferson's mistress. In 1787, Hemings accompanied Jefferson to Paris where he served as the U.S. minister to France. While in Paris, Hemings received a modest wage from Jefferson because the French did not permit slavery. Jefferson and Hemings returned to Virginia in 1789. Over the next two decades, Sally had six children, four of whom survived to adulthood. After Jefferson's death in 1826, his daughter Martha granted Hemings her freedom, and she lived with her sons Eston and Madison in Charlottesville, Virginia, until her death.

In 1802 Hemings became famous as the subject of a rumor promoted by a frustrated office seeker, James T. Callender. Angry because he had failed to secure a government appointment from Jefferson, Callender published a story in a Richmond, Virginia newspaper charging that Jefferson was the father of Hemings's children. Based upon gossip gathered in the neighborhood around Monticello, the story spread quickly as other newspapers reprinted the allegations. Although his friends and political associates denied the story and condemned Callender, Jefferson remained silent, unwilling to give further fuel to the controversy.

After a time, interest in the story flagged until Hemings's son Madison granted an interview in 1872 to an Ohio newspaper. Madison, who had been freed in Jefferson's will and subsequently moved to Ohio, contended that his mother became Jefferson's mistress while they were in France.

In 1998, Eugene Foster, a retired professor of **pathology** who taught at Tufts University and the University of Virginia, released the results of a study of Jefferson's DNA. Foster had decided to use DNA to resolve the Jefferson/Hemings controversy because historians had come to standstill with traditional sources.

Foster compared the Y-chromosomal DNA from the living male-line descendants of Jefferson and Hemings. He used Y-chromosomal DNA exclusively, because the Y-chromosomal DNA is passed unchanged from generation to generation, and is passed from father to son only. The rest of a person's DNA is diluted by at least half with every generation.

The DNA study was complicated by the shortage of male descendents. Thomas Jefferson did not have a son surviving long enough to reproduce, so it was necessary to locate the male-line descendants of Thomas Jefferson's paternal uncle, Field Jefferson.

DNA evidence is inconclusive whether Thomas Jefferson or one of his male relatives fathered the youngest son of his slave Sally Hemmings. THE NATIONAL PORTRAIT GALLERY/SMITHSONIAN INSTITUTION.

Five such descendants were found. Foster discovered three male-line descendants of Samuel and Peter Carr, the sons of Thomas Jefferson's sister, who also could have possibly been the fathers of Sally Hemings's children. Only male-line descendants of two of Sally Hemings' sons, Thomas Woodson (the oldest) and Eston Hemings (the youngest) were available. Madison Hemings had two sons who died without children and one who vanished into the western United States in the early twentieth century.

The DNA results showed that the five descendants of Field Jefferson have identical Y-chromosomal DNA alleles except for one microsatellite DNA. This difference is most reasonably accounted for by assuming that a mutation occurred. The descendant of Eston Hemings has the same set of Y-chromosomal DNA alleles as the descendants of Field Jefferson. The Carr descendants have similar DNA among them, but are clearly different from either the Jefferson or Hemings descendants. Four of the descendants of Thomas Woodson are quite similar among themselves, but different from Jefferson and Hemings although they do have similarities to the descendants of the Carr line. One of the Woodson descendants is quite different from all of the other individuals, which suggests that one of the genetic ancestors was not in the direct line from Thomas Woodson.

The DNA supports the claim that Thomas Jefferson could have been the father of Eston Hemings although it does not provide definitive proof, as the father could have been any male who had the same Y chromosome as Thomas Jefferson who was living in the Monticello region. Historical **evidence** implicates Randolph Jefferson, Thomas' brother, as the more likely father of Eston Hemings. With the paternity issue unresolved, the debate over Jefferson's relationship with Hemings continues, particularly among Hemings' descendents.

SEE ALSO DNA; DNA sequences, unique; STR (short tandem repeat) analysis.

Alec John Jeffreys

1/9/1950–
ENGLISH
GENETICIST

Alec John Jeffreys is a geneticist who is best known for the introduction of **DNA** analysis to **forensic science**. He discovered one of the most important tools for identifying human beings, genetic fingerprinting. This procedure analyzes each individual's **genetic code**. Each human being has about 100,000 genes in the chemical form of deoxyribonucleic acid (DNA). The genetic information coded in these genes—ranging from the color of hair to disorders such as hemophilia—varies greatly between individuals. No two humans, except for identical twins, have the same genetic code. Genetic fingerprinting has been used to catch criminals, establish paternity, and detect **gene** mutations.

Jeffreys was born in Oxford, England, to Sidney Victor and Joan Jeffreys. He attended Luton Grammar School and Luten Sixth Form College. Jeffreys went to Merton College in Oxford to study molecular biology, achieving a B.A. in 1972. He also earned an M.A. and D.Phil. at Merton in 1975.

At the University of Amsterdam, Jeffreys worked with Richard Flavell, another British molecular biologist, studying mammalian globin genes. From there, Jeffreys moved to the University of Leicester, where he made his most important contribution to science, discovering the unique genetic fingerprint in 1984. He found that the number of times sequences in DNA repeated seemed to vary from individual to individual, and that these repeated segments of genes were unique to each individual—just like a fingerprint.

Jeffreys devised a way to capture the distinctive fingerprint of each person's repeated fragments in an x ray. By taking x rays, Jeffreys could see the repeated segments of DNA as black images on film. He had, in essence, created the first **DNA fingerprint**.

In 1988, scientist **Henry Erlich** added to Jeffreys's work when he developed a method of DNA fingerprinting so sensitive that it could be used to identify an individual from an extremely small sample of hair, **blood**, **semen**, or skin. Erlich's technique used Jeffreys's traditional method and combined it with a technique called **polymerase chain reaction** (**PCR**), which was used to duplicate DNA and thus copy the genetic code. PCR multiplied the DNA from one single hair to an amount equivalent to that found in a million identical strands of hair. The amplified DNA was then used to obtain a DNA fingerprint.

Jeffreys continued to work in the field of genetic fingerprinting. In a famous 1989 **murder** case in Cardiff, England, PCR was combined with Jeffreys' traditional technique to extract and identify DNA from a miniscule amount of bone. A sample of bone from a skeleton found at an old house in Cardiff was sent to Erika Hagelberg, a scientist at the Oxford Institute of Molecular Medicine. Working with Jeffreys, Hagelberg found that the sample of bone had been in the ground so long and disintegrated so much that PCR could not generate the necessary lengths of DNA required for a fingerprint. So a different form of genetic fingerprinting had to be developed.

Working with Jeffreys, Hagelberg was able to find repeating DNA sequences other than the large ones usually present in a genetic fingerprint. They were finally able to show that the probability that the skeleton was Karen Price, a 15-year-old girl, was 99.9%. Two of Karen's acquaintances, Idris Ali and Alan Charlton, were put on trial for murder. It was the strength of the genetic **evidence** that finally sent them to prison, in Ali's case, for life.

At about the same time, Hagelberg and Jeffreys had been working on the new type of PCR typing to determine the identity of one of the most notorious war criminals of World War II, Josef Mengele. Known as the "Angel of Death" at Auschwitz, he sent thousands of Jews to the gas chambers as well as making thousands the subjects of medical research.

When the Soviets liberated Auschwitz in 1945, Mengele fled to South America. He was finally traced to a grave in southern Brazil in 1985. A sample of bone was sent to Jeffreys and, working with Hagelberg, he was able to identify a tiny amount of Mengele's DNA from the sample, which had been in the ground for six years.

The process of genetic fingerprinting can take as long as four to six weeks in a commercial laboratory today. Jeffreys made scientific history again in 1991 when he announced the development of a refined version of the test, allowing results to be obtained in as little as two days.

Jeffreys' technique of genetic fingerprinting has been used in a wide variety of ways, including to solve crimes like rape and murder, to identify the remains of soldiers, to identify people killed in Argentina by the military junta in the 1980s, and by biologists to protect endangered species. In a landmark study, Jeffreys and other researchers used the technique to assess the gene mutations apparent in children whose families had been exposed to radiation during the 1986 Chernobyl meltdown in the Ukraine.

Jeffreys is an international biomedical research scholar at the Howard Hughes Medical Institute, as well as working at the University of Leicester. Besides winning the Davy Medal from the Royal Society in 1987 and the Analytica Prize from the German Society of Chemistry in 1988, he became Wolfson Research Professor of the Royal Society in 1991.

In 2004 Jeffreys was awarded the Royal Society's Royal Medal "for his outstanding discoveries and inventions which have had major impacts on large areas of genetics. He is best known for the introduction of DNA analysis to forensic science, contributing not only the theoretical framework for application, but also the experimental method."

Jeffreys married Susan Miles in 1971. They have two daughters. His leisure interests include walking, swimming, postal history, and reading "unimproving novels."

SEE ALSO DNA fingerprint; DNA sequences, unique; PCR (polymerase chain reaction).

K

Kentaro Kasai

JAPANESE
FORENSIC SCIENTIST

Kentaro Kasai is a forensic scientist working in Japan who, in 1990, published the first scholarly paper proposing the use of the D1S80 locus (specific location on a **chromosome**) for forensic **DNA** analysis.

Every human somatic cell nucleus contains approximately 6.4 billion base pairs of DNA. Portions of that DNA encode more than 100,000 genes, the remainder of the DNA is non-coding. In the universe of humans, virtually 99.9% of all DNA is identical among all people, however, the remaining 0.1% makes critical distinctions, and allows for individual DNA typing. The scientific analysis of DNA, and the **forensic science** of **DNA profiling**, focuses on the highly variable regions of DNA. One form of that DNA variability is referred to as variable number of tandem repeats (VNTR).

Kentaro Kasai chose to focus his DNA analysis research on a variable number of tandem repeats locus labeled D1S80. D1S80 is located on human chromosome 1. It is composed of repeating units of 16 nucleotide long segments of DNA. The number of repeats can range from 15 to more than 40, depending upon the individual.

The D1S80 locus has been subjected to a variety of scientific tests in order to determine its specificity, reliability, and validity for use as a genetic identifying marker in criminal investigation and forensic science **identification**. Ethnically different samples have been used for validation (Native American, African American, and European American or Caucasian), using tissue and **serology** samples similar to those used in forensic settings: vaginal secretions, **saliva**, **semen**, **blood**, and hair, in order to ascertain whether there was uniformity of results across sample types within an individual. When the specimens were typed, there were found to be consistent and reliable results within each individual. The samples were each run twice, and also were sent to different (independent) labs for analysis. All typing results, from both laboratories, for each individual, were exactly the same. This is indicative of extreme reliability and validity of the D1S80 locus as a forensic science marker for individual identification.

The D1S80 locus was also tested for reliability through the use of restriction fragment length polymorphisms (**RFLP**) used as markers on genetic linkage maps, and through the use of polymerase chain reaction- (PCR-) based tests. In every analysis, the D1S80 locus has been proven to be a highly sensitive, reliable, and accurate marker for individual genetic (DNA) identification.

Through his pioneering the use of the D1S80 locus in DNA analysis, Kentaro Kasai has made an important and lasting contribution to the world of forensic science.

SEE ALSO DNA; DNA fingerprint; Mitochondrial DNA typing.

Sidney Kaye

AMERICAN
TOXICOLOGIST

With a career that began in the 1930s, Sidney Kaye has worked both as a toxicologist and an educator. He is the founder of four major forensic laboratories, and a co-founder of the **American Academy of Forensic Sciences**. Kaye also has worked as a professor of pharmacology, **pathology**, **toxicology**, and forensic **medicine** at four major universities. In addition, he has written more than 120 articles for **professional publications**, and is the author of several books, including the popular *Handbook of Emergency Toxicology*.

Kaye grew up in New York City, and attended New York University, earning a bachelor's degree in chemistry in 1935 and a master's degree in toxicology in 1939. He then began his thirty-year involvement with the United States military, first, in 1941, as a toxicologist in the Army, and later as a toxicology consultant for the Army, Air Force, and Navy. Kaye also went back to school, earning a doctorate in pharmacology from the Medical College of Virginia in 1956.

While working as a toxicologist, Kaye was responsible for the founding and management of four major forensic laboratories. The first, in 1942, was the toxicology section of the Medical Laboratory of the U.S. Army, Antilles department. Later, in 1945, Kaye founded the St. Louis Police Laboratory, and in 1947, the toxicology laboratories of the Chief Medical Examiner's Office of Virginia. In 1962, he founded the toxicology laboratories of the Institute of Forensic Medicine at the University of Puerto Rico. In addition, Kaye was on the steering committee that was responsible for creating the American Academy of Forensic Sciences, one of the largest **forensic science** organizations in the world.

Kaye's involvement in forensic science extends beyond his contributions as a toxicologist. He has also worked for more than forty years as an educator, instructing hundreds of students in the theory and practice of analytical and forensic toxicology. His academic career led him to faculty posts at Washington University School of Medicine, the Medical College of Virginia, the University of Virginia School of Medicine, and the University of Puerto Rico Schools of Medicine and Public Health. Kaye is also the author of numerous articles for scientific publications, and is perhaps best known as the author of the *Handbook of Emergency Toxicology*, a widely used guide that instructs on the identification, diagnosis, and treatment of poisoning. The book's fifth edition was printed in 1988.

SEE ALSO Careers in forensic science; Toxicological analysis.

Leonard Keeler

AMERICAN
POLYGRAPH EXPERT

American scientist Leonard Keeler is widely considered the developer of the polygraph machine. He, along with Berkeley police officer John Larson, was responsible for creating and using the modern version of the polygraph in the 1930s. Although there were minor changes to Keeler's machine since its advent, the basic composition and functions of the machine remained the same until the creation of the computerized polygraph in 1994.

Movement toward the creation of a machine to detect whether a suspect was telling the truth began in earnest around the turn of the twentieth century. In 1885, Cesar Lombroso began measuring the blood pressure of **murder** suspects. In 1914, two different methods of detecting truth were put into practice—one measured a person's breathing, and one measured the amount of a person's sweat. But it wasn't until the 1930s that work by Keeler and Larson produced what is considered the modern polygraph machine—one that records changes in blood pressure, pulse, respiration, and perspiration as an administrator asks the subject a series of questions. The machine then produces a four-line graph that is analyzed for fluctuations. Keeler, in particular, was responsible for adding a galvanometer to the machine, which measured the skin's electrical resistance. In 1948 Keeler began the first polygraph school, which instructed students on how to conduct and analyze the results of a polygraph test.

As a result of his invention, Keeler began to conduct polygraph tests for law enforcement officials across the country. Keeler used the polygraph on suspect Dr. Frank Sweeney in the Ohio serial murder case known as "The Mad Butcher." In that case he worked closely with well-known detective Eliot Ness. Keeler also tested suspects in the high-profile Colorado murder case of college student Theresa Foster in 1948. Keeler's role in **forensic science** was even documented in the 1948 film *Call Northside 777*. The movie is based on the true story of Chicago journalists James McGuire and Jack McPaul, whose series of articles in 1944 and 1945 shed light on the questionable conviction of Joe Majczek for the murder of a police officer in 1932. Keeler, who was involved in the Majczek case, played himself.

SEE ALSO Film (forensic science in cinema); Polygraph, case histories.

Kennedy assassination

On November 22, 1963, John F. Kennedy, the thirty-fifth president of the United States, was shot and killed while riding in the back seat of a limousine in a motorcade passing through Dealey Plaza in Dallas, Texas. The shooting occurred at 12:30 p.m. Central Standard Time, just after the president's limousine made a 120-degree left-hand turn off of Houston Street onto Elm Street in front of the Texas Schoolbook Depository. Also injured was Texas governor John B. Connally, who was riding in the limousine's front seat directly in front of the president.

The shooting took place over a period of six to nine seconds. Only after the driver of the limousine, Secret Service agent Bill Greer, turned and saw what proved to be the fatal wound to the president's head did he speed up to exit the plaza and head to Parkland Memorial Hospital, where the president was pronounced dead in Trauma Room #1 at 1:00 p.m. Just an hour later, after a fifteen-minute argument involving Secret Service agents who were cursing and brandishing their weapons, the agents removed the president's body, in violation of state law because no forensic examination had been conducted. They took the body to Love Field, where it was placed on Air Force One, the president's plane, and flown to Washington, D.C. There, an **autopsy** was conducted at the Bethesda Naval Hospital.

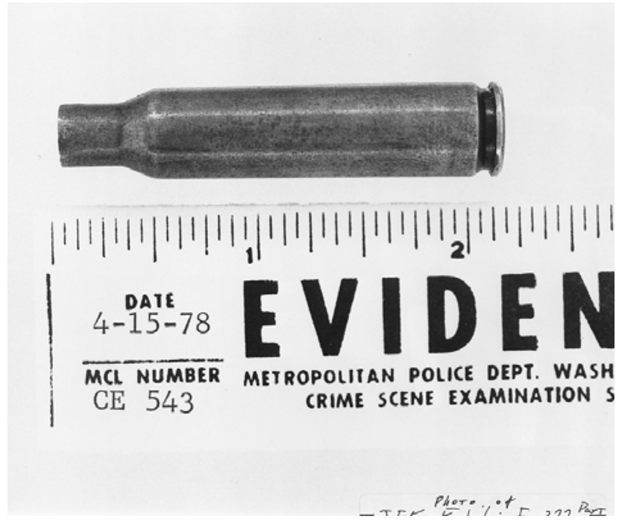
Eighty minutes after the **assassination**, Lee Harvey Oswald, an employee at the Texas Schoolbook Depository, was arrested for shooting a police officer. That evening he was charged with the **murder** of the president, but he was never tried for the crime because just two days later, while in police custody, Oswald was shot and killed by Jack Ruby. On November 29, a week after the assassination, President Lyndon B. Johnson formed a commission headed by Earl Warren, chief justice of the U.S. Supreme Court, to investigate the assassination. In September 1964, the Warren Commission issued its report, concluding that Lee Harvey Oswald, acting alone, was the assassin. The commission further concluded that Oswald fired three shots from a window on the sixth floor of the book depository, where three shell casings and the rifle were found; that one shot likely missed the motorcade; that the first shot to hit Kennedy likely hit him in the upper back and exited near the front of his neck, then caused Governor Connally's injuries; and that the second shot to hit the president struck him in the head. All three shots, the commission concluded, came from the same location, above and behind the president.

In the decades following the assassination, the forensic **evidence** was examined and reexamined by numerous experts, many of whom disputed the Warren Commission findings. They raised troubling questions, many of them focusing on the "grassy knoll," a small sloping hill in front of and slightly to the right (west and north) of the president. Numerous witnesses claim to have heard at least one shot come from the grassy knoll, and photographs taken by people in Dealey Plaza that day give some credence to the claim that another gunman was positioned behind a picket fence on the knoll. These claims appear to have been substantiated by the report of the 1976–79 House Select Committee on Assassinations (HSCA), which relied on acoustical evidence to conclude that indeed a shot came from the grassy knoll, that Oswald did not act alone, and that he was likely part of a larger conspiracy, although the reach and extent of that conspiracy remain the subject of passionate debate.

A major focus for forensic examiners was the number, sequence, timing, and direction of the fatal shots. Connally sustained his injuries virtually simultaneously with Kennedy having been struck in the neck, raising the question of whether one or two bullets, and hence one or two shooters, caused the injuries to the two men. Standing at the center of the Warren Commission's conclusion that Oswald was the lone gunman is the so-called single bullet theory, a theory generally credited to commission member Arlen Specter, later a U.S. Senator. According to the commission, a single 6.5 mm Western Case Cartridge Company bullet, Warren Commission Exhibit 399, caused all of the nonfatal wounds both to Kennedy and, an instant later, to Connally. The single bullet theory was crucial to the commission's conclusion because it precluded the existence of another shooter. Oswald was using a bolt-action rifle, so it would have been impossible for him to fire two shots virtually simultaneously. Two bullets would have meant two gunmen.

The bullet in question was found in Parkland Hospital Trauma Room #2 on a stretcher on which Governor Connally had lain, although even this detail has been disputed. The path the bullet followed was complex, leading critics of the Warren Commission to refer to it not as the single bullet, but as the magic bullet. The commission concluded that it traveled downward at a net angle of 25 degrees and entered the president's back 2 inches (50 mm) to the right of his spine and 5.75 inches (146 mm) below his collar line, leaving a small (4x7 mm) reddish-brown to black abrasion on his collar that suggested that the bullet was traveling slightly upward when it entered his body. It then slightly fractured the sixth cervical vertebra; passed through his neck, shedding fragments; passed through his throat; and exited his body at the bottom edge of the Adam's apple. The bullet then continued on its course, entering Connally's back just below and behind his right armpit. It destroyed a portion of his right fifth rib, exited his body below his right nipple, then entered the outside of his right wrist, possibly striking his cufflink, which was never recovered. It broke his right radius wrist bone, leaving behind metal fragments, then exited the inner side of the wrist, entered the front side of his left thigh, and buried itself 2 inches (50 mm) in his thigh muscle, leaving behind a tiny (1.5–2 mm) fragment in his thigh bone. This bullet, which had passed through several layers of clothing and flesh and struck two bones, was found in nearly pristine condition, having lost only about 1.5 percent of its weight, after having apparently backed itself out of Connally's thigh.

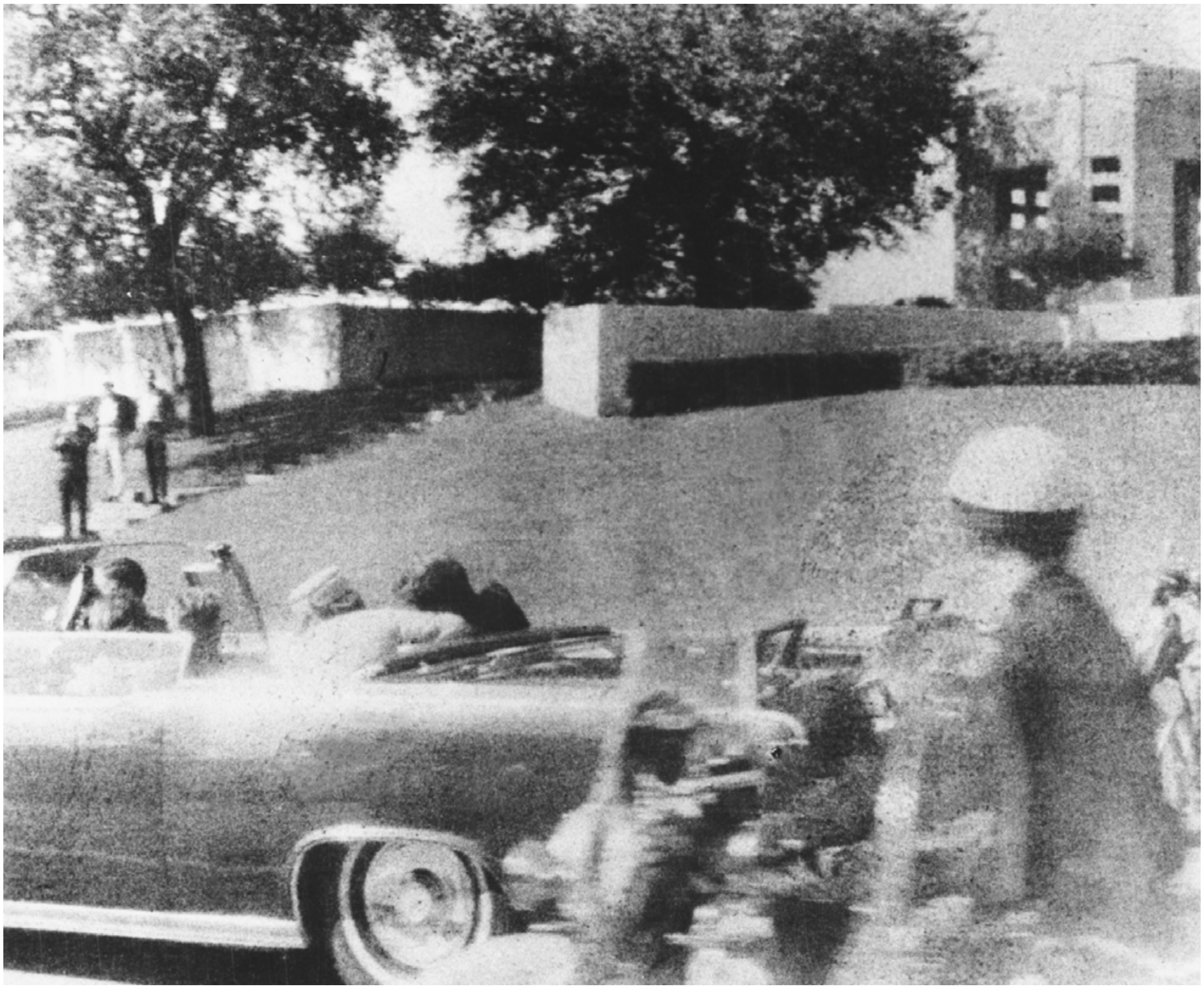
In **ballistics** tests conducted with the same type of bullet, the only bullet that survived in a condition similar to the bullet in evidence was one fired into a tube of cotton. These tests, combined with the zigzagging course that the bullet would have had to follow, have led some forensics experts to dispute the single bullet theory, though many others note that a bullet can behave in strange ways when it hits its target and rapidly decelerates. Further, some forensic pathologists assert that the official medical record, both at Parkland and at Bethesda, is a record of inconsistencies, in large part because it was based on testimony not from forensic pathologists with experience examining gunshot wounds, but by emergency room physicians at Parkland and general pathologists at Bethesda. They note, for example, that at least three times the emergency room doctors referred to the wound in Kennedy's neck as an entrance wound rather than an exit wound. Numerous other details have been scrutinized, such as the path the bullet followed from Kennedy's back to his throat. Following this path, the bullet would have had to hit the president's spine, severely deforming the bullet. They note too that it was traveling upward when it exited the president's throat, but then downward when it entered Connally's body. Further, they note inconsistencies in testimony about where the bullet entered the president's back.



Cartridge case found on 6th floor of the Texas School Book Depository after the assassination of President John F. Kennedy. Included as an exhibit for the Warren Commission. © CORBIS

Forensic pathologists have also focused on the second, fatal bullet to the president's head. Their primary purpose was to determine the direction of the bullet and the angle at which it entered the president's head. Normally, a forensic pathologist relies on the beveling of bone, similar to the appearance of glass when a BB has passed through it, to confirm the direction of a bullet when it passes through bone. During the president's autopsy, pathologists had to reconstruct **skull** fragments, at least one of which is missing, to show that the beveling of the bone establishes that the bullet entered from above and behind, consistent with the conclusion at which the Warren Commission ultimately arrived.

One difficulty that forensics experts faced was reconciling this conclusion with the movement of the president's head and body captured on the so-called Zapruder film, a 26.6-second, 486-frame, 8 mm film shot by amateur cameraman Abraham Zapruder from Elm Street as the shots were fired. A frame-by-frame analysis of the Zapruder film suggests that when the president was struck by the first bullet, he was sitting



President John F. Kennedy slumps over after being hit by an assassin's bullet as the Presidential motorcade made its way through Dallas, Texas on November 22, 1963. © BETTMANN/CORBIS

in a position inconsistent with the bullet's supposed angle of entry (he would have had to have been leaning forward, but the film shows him sitting bolt upright). More significantly, the film suggests that when the second bullet hit him, the president was forced backward in a way more consistent with a shot from in front, not above and behind. Specifically, they note that when the bullet struck, the president's head moved slightly, about 1–2 inches (25–50 mm) forward and down. Then, as the wound in his head opened, his right shoulder twisted forward and up. Kennedy's torso then lurched quickly backward and to his left. He then bounced off the rear seat cushion and slumped lifelessly. If the autopsy findings and the Zapruder film are indeed inconsistent, this inconsistency raises for some the possibility that the source of the bullet was not Oswald's rifle on the sixth floor of the book depository, but elsewhere. For others, such an inconsistency represents unanswerable questions that may have arisen because of acceleration and deceleration of the limousine.

A sizable majority of Americans accept the crux of the Warren Commission's findings and regard inconsistencies as inevitable human error. Debate about these and other details suggest the monumental difficulty of establishing a clear, accurate, consistent forensic record of a crime that took place in front of hundreds of witnesses.

SEE ALSO Autopsy; Ballistics; Bullet track.

Kennewick Man

The remains of an ancient human found along a river in Kennewick, Washington, in 1996 set off a heated debate about the ownership and future of the skeleton. Scientists argued that the skeleton, dubbed Kennewick Man, could provide new information about human migration in North America, while Native Americans claimed him as an ancestor and wanted to bury him according to their rites. Forensic anthropological findings and cultural **evidence** were presented in court procedures over the course of nine years while the fate of the Kennewick Man was debated.

The story of Kennewick Man began in July 1996, when two college students watching hydroplane races found a human skeleton along the Columbia River. The young men turned the remains over to local police, who realized that they were probably very old. The bones were then given to forensic anthropologist James Chatters for evaluation. Chatters reconstructed the skeleton, which was 80–90% complete. He determined that it was from a man who was probably five feet nine or 10 inches and about 40–50 years old when he died. He showed little evidence of arthritis, indicating that he wasn't used to carrying heavy weights and that he might have been a wandering hunter. Dental examinations showed that the **skull** contained 30 of the 32 teeth and that they were in good shape, indicating that he probably had a diet that included lots of soft foods like meat. He was taller and thinner than most ancient Native Americans and the back of his skull was not flattened from a cradleboard as is commonly observed in skeletons of ancient Native Americans. In addition, the man had a stone spear point lodged in his pelvis and there was evidence of severe trauma to his rib cage that probably limited the use of his arm. Using computerized tomography (CT), Chatters determined that the spear point was serrated and leaf-shaped and typical of the types of spears used between 8500–4500 years ago. He hypothesized that the skeleton was either from a European pioneer who had been attacked by native people using stone-age weapons or from an ancient human. Chatters sent pieces of the bones to a laboratory for carbon dating, which determined that the age of the skeleton was between 9,200–9,400 years old, making the skeleton one of the oldest, and most complete, ever found in North America.

Once the age of the skeleton was determined, several groups came forward, vying for control of the remains. A group of five Native American tribes in the region, the Umatilla, the Yakama, the Nez Perce, the Wanapum, and the Colville, wanted to accord the remains the same rites given to any Native American, namely a speedy burial. They cited the legal authority of the Native American Graves and Repatriation Act (NAGRA), which requires the return of American Indian remains to tribes. As news of the unique find spread throughout the scientific community, a coalition of eight anthropologists and archaeologists petitioned for their right to study the ancient remains prior to burial. The scientists believed that study of the Kennewick Man could reveal important information about early human migrations into North America. The Native American group believed that any manipulation of the remains would show enormous disrespect to the dead and vehemently opposed scientific investigation of the skeleton, which they called the Ancient One. Because some of the features of the Kennewick Man, such as his height and the shape of his skull, indicated that he might not be of Native American ancestry but rather of European descent, a group of people representing the ancient Norse religion called Asatru also petitioned the court for the right to the remains.

The ensuing legal battle raged for more than nine years. One of the key questions of debate in the courts concerned whether or not the skeleton was subject to NAGRA. NAGRA requires that all Native American remains be returned to the tribe for burial, however it was unclear if the Kennewick man was of Native American ancestry. Eventually the court ruled that some scientific study was required in order to establish the origin of the skeleton and between 1998 and 2000, the Department of the Interior coordinated these studies. A 1999 physical examination of the bones established that the Kennewick Man shared most physical characteristics with people from Southern Asia. In April 2000, samples of bone from the Kennewick Man's skeleton were removed and sent to two different laboratories for **DNA** testing. Because of the age of the bones, it was impossible to extract sufficient DNA for analysis and the results of the study were inconclusive. After a series of appeals by all sides, in February 2004, a U.S. Federal judge ruled that it was impossible to prove that the Kennewick Man's ancestry was culturally affiliated to any of the Native American tribes in the region and gave scientists the right to go forward with their investigation. In 2005, plans were outlined for study three-phase study involving as many as 23 different scientists.

SEE ALSO Anthropology; Anthropometry; Mitochondrial DNA analysis; Odontology; Skull.

Kidd blood grouping system

Bloodstains left behind at the scene of a crime or found on a suspect's clothing can be a valuable source of **identification**. Red **blood** cells contain a number of proteins known as antigens on their surface. The exact biochemical nature of these antigens is inherited and so varies from person to person. An individual's blood can be typed according to several different classes of **antigen**. One of these is the Kidd system, which was discovered in 1951.

There are three major Kidd blood groups, depending on which combination of variants of a protein called Jk a person has on their red blood cells. The two variants of Jk are called Jk^a and Jk^b. The combinations are Jk^a Jk^a, Jk^a Jk^b, and Jk^b Jk^b. Blood from people in the first group may contain antibodies against Jk^b and that from those in the third group may contain antibodies against Jk^a. An **antibody** is a protein component of the **immune system**, which binds to a relevant antigen and plays a part in destroying foreign cells or bacteria. In blood transfusion, the first and third Kidd types would be incompatible, because antibodies from one blood type would bind to the matching antigen on the other blood type and the cells would clump together.

Antisera, that is, reference blood samples containing a specific type of antibody, are used to find out the type of blood present in a blood stain. They react with antigens and cause a clumping reaction that is measured by various techniques. In the case of Kidd blood typing, an antiserum containing Jk^a antibodies would bind to Kidd types containing Jk^b antibodies. The first blood type system identified was the ABO system, where people have one of four types of blood: A, B, AB, or O, depending on which combination of genes affecting these antigens they inherit.

Besides Kidd and ABO, other blood typing systems include Rhesus, MNS, Kelly, Duffy, and Lewis. They are all inherited independently. Therefore someone with blood group O could have any of the three different Kidd types. The more blood types that can be co-analyzed on one sample, the more individualizing it becomes as **evidence**. Coincidental matches of blood found at the scene of a crime with that associated with a suspect become less likely with the number of typing reactions carried out. However, the amount of blood present in a stain may limit the number of typing determinations that can be done. Forensic blood typing is perhaps most useful for eliminating a suspect than, on its own at least, identifying one.

SEE ALSO Serology.

Paul Leland Kirk

1902–6/5/1970
AMERICAN
CRIMINOLOGIST

Paul Leland Kirk is a leader in establishing **criminology** as an academic discipline. He worked as a professor at the University of California, Berkeley (UCB), for forty-three years, making advances to the university's program and conducting important research in the field. Kirk also wrote the groundbreaking textbook *Crime Investigation.* In addition, he consulted on many criminal cases, including the well-known murder trial of Sam Sheppard.

Early on, Kirk became known for his work as a microchemist. He found microchemistry had practical applications in two areas—tissue **culture** studies and **criminalistics**. Through his work at UCB, Kirk began to develop a more structured and scientific approach to the study of criminalistics. As a result, in 1937, he was selected to head the criminology program at the university. Eight years later, he established a major in technical criminology. Then, in 1950, he worked with Berkeley police chief **August Vollmer** to formally establish the school of criminology at UCB. He later advised other institutions about establishing their own programs. Kirk also worked with C. R. Kingston analyzing the statistical aspect of **fingerprint identification**.

In addition to his work in academia, Kirk was actively involved in providing professional consultation on criminal cases. Among other areas of expertise, he became known for his skill in **blood spatter** analysis. This knowledge came into play as Kirk became involved in the famous case in 1954 of Dr. Sam Sheppard, an Ohio osteopathic surgeon accused of murdering his wife. Sheppard was tried and convicted of the crime. Afterward, Kirk was summoned to investigate the crime scene, and through detailed analysis of the **blood** spatters, concluded that Sheppard could not have committed the crime. During Sheppard's retrial, Kirk's testimony became key to the defense. In the end, Sheppard was acquitted of the crime. His story was used as the basis for the popular television series and motion picture *The Fugitive.*

Kirk is also known for his contributions to literature on criminology. In 1953, he published *Crime Investigation*, one of the first **crime scene investigation** books to include both practical information and theory. Here Kirk presents techniques for examining **physical evidence** at crime scenes, including chapters on fingerprints, **fibers**, hair, blood, tracks and trails, **firearms**,

Jack the Ripper's knife and a framed drawing of one of his victims. © ALEN MACWEENEY/CORBIS

and vehicular accidents. Because of its popularity, the book has since been reprinted many times.

SEE ALSO Crime scene reconstruction; Television shows.

Knife wounds

When investigating an assault or **murder**, the pattern of injuries to a victim can provide clues as to the nature of the weapon used. For example, the angle of a gunshot wound and the deposition pattern of the **gunshot residue** can be valuable to a forensic investigator in determining the location from which the gun was fired. Similarly, for knife wounds, the pattern of injury can be a clue to the knife that was responsible.

The pattern of a knife injury can also be a clue to the nature of an attack. For example, a slashing motion can inflict long but superficial cuts, whereas a jab can produce a deep **puncture wound**. A forensic investigator may be able to gauge the timing of the blows, to determine which of the blows may have dispatched the victim.

Because a knife can retain some of the victim's **blood** (and even that of the assailant), and because the knife needs to be held to be effective, a knife can be a storehouse of forensic information. Blood types, skin cells that house **DNA**, and fingerprints may all be present on a knife recovered at a crime or accident scene.

Knives come in all shapes and sizes. At the extremely small end of the scale, for example, are thumb knives, lapel daggers, and coin knives. Developed by the British in World War II, the coin knife looks like an ordinary piece of pocket change. The blade itself is crescent-shaped, and attaches to the back by a small hasp so that it can rotate outward. It is too blunt to be used for inflicting grievous bodily harm.

Knives and daggers have been concealed in belts (that is, on the inside of the belt and parallel to it), in belt buckles, and even in the plastic arms of eyeglasses. But, when the aim is to attack someone, a large knife is desirable. Domestically, kitchen knives often become the preferred choice.

Most formidable-looking of all is the Fairbairn-Sykes fighting knife, developed in World War II by two British officers, W. E. Fairbairn and E. A. Sykes. Based on knowledge gained from their experience in close combat while serving with the Shanghai police, the knife would quickly dispatch a victim by striking at his vital organs. Its blade was long, but the handle was nearly as lengthy, so as to ensure great control on the part of the user. First produced in 1941, it was readily adopted by Allied forces. British commandoes carried it on raids into Norway, and the United States Office of Strategic Services (OSS), which employed Fairbairn as an instructor, developed its own version. Revised over the years, the knife remained in production through the 1990s.

SEE ALSO Crime scene investigation; Death, cause of; Puncture wound; Wound assessment.

Knots and ligatures

Ligatures are materials such as ropes or wire that are used to tie or bind; they have various roles in criminal acts. Knots and ligatures may be used are used to bind, restrain, strangle, or hang victims. Their analysis is a specialized branch of **forensic science**.

A ligature is an important form of **physical evidence**. Ligatures can be made from rope, electric flex, nylon, clothing, bedsheets, chains, dog leads, washing lines, luggage straps, or various other objects. The perpetrator may come prepared, armed with rope perhaps, or may use what is at hand. However, an assailant may carry traces of the ligature material away, and this can be used, if his clothing is examined, to link him with the scene of the crime. Ligature materials are class **evidence**, able to link a suspect to a type of material, rather than individualizing evidence, which can link a suspect to a particular portion of material.

A ligature is generally used by making a knot within the material. There are several different types of knot that can be identified by the forensic expert, such as slipknots, reef knots, and overhand knots. This may be revealing of certain characteristics of the person who tied it, such as knot-tying skill, trade, and hobbies.

Like the ligature from which it is made, the knot is an important item of physical evidence. When found at the scene of the crime, it must first be carefully photographed. When handled, the utmost care must be taken not to actually untie it. If a victim has been tied, then it will have to be removed, but will be photographed as this is happening. When it is cut away, the ligature is severed in a direction away from the knot so as better to preserve it. Great care has to be taken in handling loose knots so they do not disintegrate. Knots made in wire may be obscured by dirt or mud, but their intricacies can be revealed by fluoroscopy or x-ray analysis. The knot itself may bear important evidence such as fingerprints or hairs and this should be collected before the knot itself is removed.

Knot and ligature analysis may be especially important in the investigation of cases of strangulation, which are often homicide. The ligature is gradually tightened around the neck until compression on the airways and blood vessels in the neck produces asphyxia, where oxygen supplies to the body and brain are cut off. The mark on the neck in such cases tends to reflect the material used for the ligature. If wire or thin cord was used, there will be a clear-cut, deep mark with sharply defined edges. If a soft fabric is pulled tight around the neck, it will tend to fold up into a series of ridges that will show up as interlacing areas of bruising. Sometimes the mark reproduces the pattern of the ligature, such as a weave mark whose width may suggest its size. Sometimes the ligature is left on the neck and, if so, the position of any knots gives the investigator a good idea of where the attacker was relative to the victim.

SEE ALSO Asphyxiation (signs of); Hanging (signs of).

L

Alexandre Lacassagne

1844–1921
FRENCH
FORENSIC SCIENTIST

Alexandre Lacassagne devoted his life to the study, teaching, and advancement of **forensic science**. He worked for decades as a professor at the University of Lyons, France, participated in numerous forensic investigations, and served as a consultant and expert at many criminal trials. Lacassagne is also known as one of the first people known to conduct bloodstain pattern analysis and was the first scientist to study bullet markings and their relation to specific weapons.

For much of his life, Lacassagne worked as a professor of forensic **medicine** at the University of Lyons, France. Many up and coming forensic scientists had the opportunity to study under him, including Edmund Locard, the founder of the world's first forensic laboratory. At the same time, Lacassagne regularly participated in forensic investigations for crimes committed across the country. Along with forensic investigation, he also served as a consultant and expert in many high profile criminal trials in France. He played a significant role in the 1895 trial of Joseph Vacher, a man charged with the rape and **murder** of a local woman. At the trial Lacassagne testified that Vacher's behavior didn't indicate insanity but antisocial sadism, a concept not used previously in French courts. Vacher was found guilty of the crime.

Lacassagne is also known as being the first scientist to try to match an individual bullet to a gun barrel. He did this by examining the bullet's striations, counting and comparing the number of lands and grooves. In 1889, Lacassagne published the article *La Deformation des Balles de Revolver*, in the *Archive de Antropologie Criminelle et des Sciences Penales*, outlining his findings regarding bullet markings. While he didn't come up with a system to classify these markings, Lacassagne's research and study is considered the beginning of the science of **ballistics**.

Lacassagne also was one of the first scientists to study and report on the significance of bloodstains left at a crime scene, and what they could indicate about the nature of the crime committed. In particular, he conducted research on the relation between the shape of **blood** spots and the position of the victim.

SEE ALSO Ballistic fingerprints; Bloodstain evidence.

Karl Landsteiner

6/14/1868–6/26/1943
AUSTRIAN
IMMUNOLOGIST

Karl Landsteiner was one of the first scientists to study the physical processes of immunity. In the field of **forensic science**, he is best known for his **identification** and characterization of the human

blood groups, A, B, and O, but his contributions spanned many areas of immunology, bacteriology, and **pathology** over a prolific 40-year career. He helped establish the science of immunochemistry.

Karl Landsteiner was born in Vienna on June 14, 1868. In 1891, he was awarded a medical degree by the University of Vienna. For the following five years he studied physiological chemistry in laboratories in Germany and Switzerland.

Landsteiner moved to Vienna's Institute of Pathology in 1897, where he was hired to perform autopsies. He continued to study immunology and the mysteries of blood on his own time. In 1900, Landsteiner wrote a paper in which he described the agglutination of blood that occurs when one person's blood is brought into contact with that of another. He suggested that the phenomenon was not due to pathology, as was the prevalent thought at the time, but was due to the unique nature of the individual's blood. In 1901, Landsteiner demonstrated that the blood **serum** of some people could clump the blood of others. From his observations he devised the idea of mutually incompatible blood groups. He placed blood types into three groups: A, B, and C (later referred to as O). Two of his colleagues subsequently added a fourth group, AB. In 1930 he received the Nobel Prize for medicine for his discovery.

In 1907, the first successful transfusions were achieved by Dr. Reuben Ottenberg of Mt. Sinai Hospital, New York, guided by Landsteiner's work. Landsteiner's accomplishment saved many lives on the battlefields of World War I, where transfusion of compatible blood was first performed on a large scale. In 1902, Landsteiner was appointed as a full member of the Imperial Society of Physicians in Vienna. That same year he presented a lecture, together with Max Richter of the Vienna University Institute of Forensic Medicine, in which the two reported a new method of typing dried blood stains to help solve crimes in which bloodstains are left at the scene.

In 1906, Landsteiner and Victor Mucha introduced the use of the dark-field method of diagnosis for the presence of the spirochete of syphilis. Landsteiner also determined the viral cause of poliomyelitis with research that laid the foundation for the eventual development of a polio vaccine. In 1908, Landsteiner reported the transmittal of poliomyelitis to monkeys from human material, thus substantiating the theory that the cause of the disease was a virus. In 1919, he went from his work as professor of pathologic anatomy at the University of Vienna to The Hague in the Netherlands as pathologist at the R. K. Ziekenhuis. In 1922, he went to New York City's Rockefeller Institute and continued at the institute until his death. In 1929, he became a citizen of the United States.

In 1927, Landsteiner and **Philip Levine** announced the discovery of the M and N agglutinogens, and in 1940, Landsteiner and a colleague discovered still another group of agglutinogens called the Rh factors. Of fundamental importance to the rise of immunochemistry was Landsteiner's demonstration that serological specificity is based on the chemical structure of antigens. Although he officially retired in 1939, Landsteiner continued his work in immunology until two days before his death in 1943, at the age of 75.

SEE ALSO Antigen; Blood; Bloodstain evidence; Immune system.

Laser

Laser technologies are used for a wide range of purposes in laser-based products, including CD players, **DNA** screening machines, forensic tools, missile guiding devices, mapping and topographic instruments, and surgical devices. A laser is basically an intense beam of light. Ordinary light is scattered in variable wavelengths and frequencies, whereas laser beams are highly organized light with all photons traveling in the same frequency and wavelength. Laser (or light amplification by stimulated emission radiation) is a technology that allows controlled photonic release from atoms in specific wavelengths, thus producing a directional monochromatic (single-color) light beam of high coherence (e.g., tightly organized photons with synchronized wave fronts of the same frequency). **Forensic science** applications of laser technologies include a wide range of devices and techniques, such as laser **spectroscopy**, interferometric measurements (laser mapping systems), laser scanning, bullet **trajectory** projections, and laser **photography**.

Laser technologies are a growing market in forensics and crime investigation, with new tools designed specifically for this field. **Crime scene investigation** and reconstruction **ballistics** can be a time-consuming task, with crucial **evidence** such as trace fingerprints sometimes overlooked by the human eye. Bullet trajectory calculations with tapes and traditional reconstruction methods may take several hours in complex crime scenes. The use of bullet trajectory laser rods improves precision and saves time. Laser rods are used to determine the exact point of origin and distance from which a gun was fired, or, when more than one person was shooting, the exact original location and trajectory angle of each bullet fired. Laser rods are placed in each bullet hole found in the scene and activated to emit light. Laser beams flowing from each hole will reproduce the complete trajectory pattern of all bullets fired, making visible the entire exchange in a manner that can be photographed. Therefore, forensic technicians are able to track the trajectory of each bullet back to its point of origin, as well as to identify bullets that ricocheted from objects and changed direction.

Another useful application of lasers in forensic science is spectroscopy. Spectroscopy involves the analysis of materials by studying the reflection and absorption of light for the **identification** of traces of substance residues such as accelerants, illegal drugs, or poisons. Laser spectroscopy determine the molecular structure of materials and chemical compounds. Infrared laser spectroscopy can determine molecular structures of polymers on surfaces and gas phase ions, and is used to detect explosive components or illegal drugs in samples. Some portable spectrometers can analyze evidence at the crime scene, inside plastic bags or **glass** bottles, water solutions, as well as residual particles on surfaces.

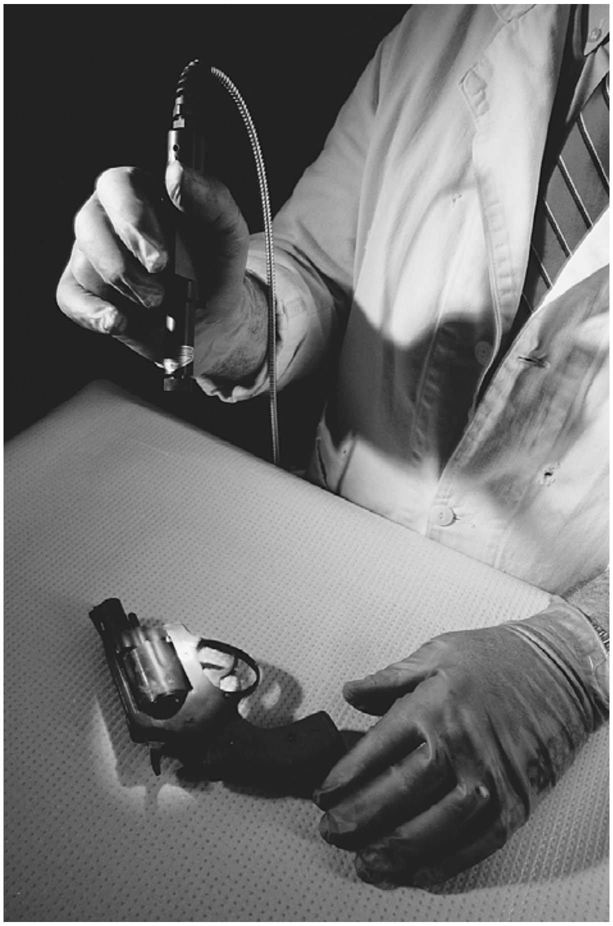
Laser **fluorescence** is another method of analysis that can be used at the crime scene. One practical example is the small portable lasers in the shape of narrow flashlights, which are used to scan surfaces of a scene in search of fingerprints. As the beam travels on the surface of objects, furniture, walls, or doors, fingerprints become visible due to the rapid absorption and release of light by atoms present in the printed substance. This time-saving scan allows the location of fingerprints in places where they would otherwise be hard to find, as well as the quick location of fingerprints in an entire area. Once located and mapped, fingerprints can be dusted with fluorescent powder to be photographed.

Often more than one method is used to detect toxic industrial components present in the environment, such as coupling plasma mass spectrometry with laser spectroscopy. These techniques are used by the Federal Bureau of Investigation (**FBI**) to identify security dyes and gas residues in stolen cash. Laser desorption mass spectrometry (LDMS) is a technique used to identify substances in fabric, dyes, and security inks. Ink security systems are used to protect cash in ATM machines and bank safe contents. The ink is pressurized to release a concentrated red dye spray from the ATM cassettes when triggered by an anti-tampering electronic sensor, spraying an indelible stain on the currency. The skin and clothes of criminals are also marked, thus creating evidence. Other security systems use tear gas and red staining or smoke and dye for similar purposes. Smoke and dye in bank vaults release a hot cloud of red smoke that marks valuables and criminals, whereas tear gas and dye systems intend to stain evidence and temporarily disrupt the robbery, gaining time for the police arrival at the scene. LDMS is used to identify these markers in currencies and other items of evidence, and also facilitates tracking stolen currency in circulation.

Laser radars are law enforcement devices that measure the speed of vehicles. Laser speed guns are portable and can be pointed by police officers directly to a vehicle. A pulse infrared light is emitted towards the targeted vehicle, reflecting on its surface and returning to the gun where a sensor calculates the nanoseconds elapsed between emission and reflection, determining the distance to the car. As the car is in movement and the laser gun pulses laser light thousands of times per second, repeating calculations and comparing the many results, it can accurately determine the speed of the vehicle. Some laser speed devices are mounted on poles in strategic places by the roadside, in connection with high-speed photograph **cameras** that take a picture of the car and license number when triggered by the laser radar.

Other laser-based measurement tools, such as 3-D laser stations, are used to reconstruct the events underlying road accidents involving several vehicles or mass crime scenes such as nightclub or supermarket bombings. The scene is first photographed from all angles, and then 3-D mapping laser equipment is used to scan the entire area, registering several point positions. Some laser scanners have the capacity to capture 5,000 measurements per second, such as the one that was used in forensic analysis of the terrorist nightclub bombing in Bali in 2003. Photographs and mapping data are then downloaded into software that calculates point-to point distances and angles, automatically reconstructing three-dimensional images of the scene.

Some DNA typing machines also use laser fluorescence to identify certain molecules during the automated DNA **sequencing** process of certain DNA segments known as short tandem repeats (STR). STR sequences and lengths are so specific to individuals that they led to the expression "DNA fingerprinting." Another DNA technique is laser micro-dissection, used for **sperm** identification in **semen** samples. This method has high sensitivity,



A technician at the San Francisco Police Department uses a laser to search for fingerprints on a gun. © ED KASHI/CORBIS

and permits the isolation of individual sperm cells from other cell types present in the sample. STR profiling can be accomplished from minute DNA samples with this technique, after DNA purification using high-sensitivity kits.

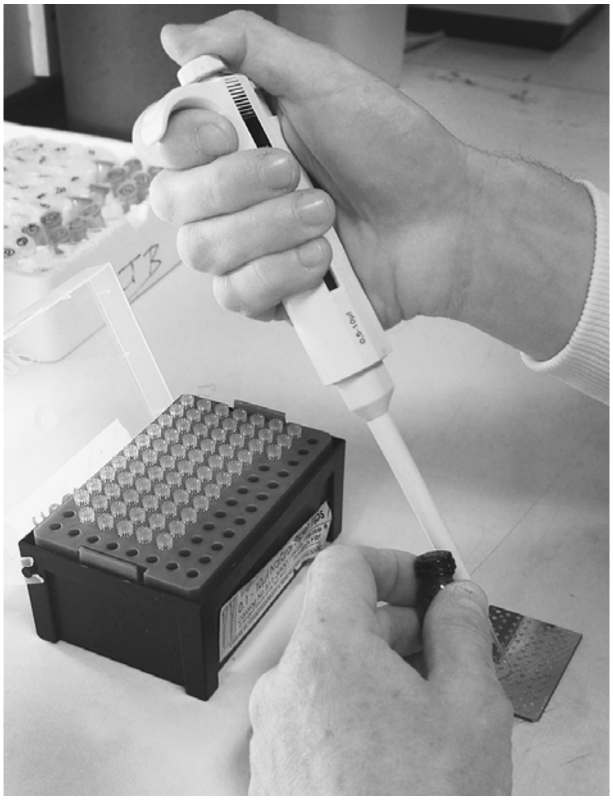
SEE ALSO Accident reconstruction; Alternate light source analysis; Ballistics; Biosensor technologies; Bomb detection devices; Bomb (explosion) investigations; Bullet track; Chromatography; Crime scene reconstruction; Digital imaging; DNA; DNA fingerprint; DNA sequences, unique; DNA typing systems; Electromagnetic spectrum; Energy dispersive spectroscopy; FBI crime laboratory; Gas chromatograph-mass spectrometer; Geospatial Imagery; Impression evidence; Ink analysis; Laser ablation-inductively coupled plasma mass spectrometry; Latent fingerprint; Metal detectors; Monochromatic light; Paint analysis; Radiation, electromagnetic radiation injury; Scanning electron microscopy.

Laser ablation-inductively coupled plasma mass spectrometry

Laser ablation-inductively coupled plasma mass spectrometry (abbreviated LA-ICPMS) is a high technology device that analyzes trace matter samples within **forensic science** and other areas of science. In LA-ICPMS, a pulsed laser focuses on and vaporizes a very small amount of a solid sample (the LA within the acronym LA-ICPMS). A gas stream transports the resultant vapor into high temperature plasma (the ICP) where the vapor sample is ionized before being extracted into a mass spectrometer for analysis (the MS). Because of its advanced mechanisms, LA-ICPMS provides very reliable analysis of forensic **evidence** alongside strong improvements in sample size, sensitivity, and speed, when compared with traditional methods. For example, LA-ICPMS can detect microscopic samples such as clothing **fibers** and **glass** fragments at a level of parts per billion (ppb), providing forensic experts the ability to determine a material's origin often as precisely as to a particular manufacturer or brand. This expensive technology is an important part in countering domestic and international crimes that increasingly requires more innovative and systematic use of forensic science.

Before the availability of LA-ICPMS as a method for analyzing forensic samples and characterizing **physical evidence**, forensic scientists used such traditional techniques as Fourier transform infrared (**FTIR**) analysis, microscopy, refractive index, and X-ray fluorescence (XRF). However, these older techniques were not always able to analyze small samples or discriminate between chemically, physically, and visually similar materials. Some older techniques also required lengthy preparation times for the samples and used hazardous substances within the analysis, which both increased the potential for sample contamination and destroyed large amounts of samples.

On the other hand, LA-ICPMS is a valuable tool for analyzing elemental and isotopic characteristics of samples and accurately comparing samples with chemical, physical, and visual similarities. The ability to analyze microscopic samples can help investigators with the job of connecting a criminal suspect to a crime scene, where earlier technology was unable to do so. For instance, a sample that is very small in size is more likely and easily moved undetected by a criminal from a crime scene.



A laboratory worker loads samples onto a plate for analysis in the laser mass spectrometry machine at Manchester Metropolitan University in 2001. The machine, which can be used to detect anthrax spores, takes a mass-fingerprint of unknown bacteria which can be reliably matched in seconds against a database of quality-controlled reference spectra and then used for real-time detection of suspect bacteria. © REUTERS/CORBIS

Shattered glass, for example, produces small splinters, which can become attached to clothing, shoes, and other materials that can uniquely identify a criminal. Unlike traditional forensics techniques, such distinctive signatures can only be analyzed with LA-ICPMS.

LA-ICPMS is also far less destructive than traditional forensic techniques. LA-ICPMS requires only a minute sliver of a sample, often less than one microgram, which preserves the original sample and enables further measurements if authentication is needed. For this reason, LA-ICPMS is often described as an almost non-damaging technique with respect to the forensic sample.

SEE ALSO Chemical and biological detection technologies; Infrared detection devices; Isotopic analysis; Laser; Scanning electron microscopy; Scanning technologies; Spectroscopy.

Latent fingerprint

Chance impressions, or what is more commonly known as latent fingerprints, are the oftentimes invisible patterns made by fingerprints that are usually left at crime investigations or on objects recovered from crime scenes, and forensically analyzed by latent **fingerprint** experts with the application of chemical or physical methods.

The use of fingerprinting as a means to identify criminals spread throughout Europe and North America during the early twentieth century after British police officer Sir **Edward Richard Henry** introduced the use of fingerprints to solve crimes in the 1890s. As scientists studied fingerprint **identification** in more detail, they discovered that the ridge arrangement of fingerprints is unique and permanent, unless accidentally or intentionally altered. As crime-detection methods improved, law enforcement officers discovered that any hard, smooth surface touched by hands could produce fingerprints made by the oily secretions found on skin. When these so-called latent fingerprints were dusted with powders or chemically treated, the resultant pattern (or impression) could be observed, photographed, and stored for later use.

Latent fingerprints, which today are important pieces of forensic **evidence**, are created either artificially, naturally, or as a combination of the two. They are artificially created when fingers become covered with a foreign residue such as grease or oil. Latent fingerprints are naturally created when very small sweat pores on friction skin (that is, the top of skin ridges located on the inner surface area of fingers and hands) excrete perspiration. This perspiration, along with oils from touching other parts of the body and hair or from contact with external substances, remain on these ridges, so when an object is touched by a finger a duplicate recording of these characteristics is usually left on the surface. These hidden (or latent) impressions can be made visible when latent print examiners apply chemicals, lasers and other light sources, powders, or other physical means.

Latent fingerprint evidence is generally divided into two categories: porous evidence, such as cardboard, paper, and unfinished wood, that readily allows for the preservation of latent fingerprints because residue soaks into the surface; and nonporous evidence, such as **glass**, finished wood, and plastic, which does not easily permit the preservation of latent fingerprints because substances only lie on the surface and can be intentionally or accidentally wiped away.

A positive identification of a latent fingerprint is normally achieved when, according to the expertise of a latent print examiner, the amount of similarity between the latent print (found at a crime scene, for example) and the inked fingerprint (taken from a suspect) is sufficient to make a corresponding match. Such matches are not based only on the degree of similarity (or number of matching points) between the two prints, but on various examinations made of the skin ridges. The resulting conclusion by the examiner is based on that person's experience, **training**, and understanding of the science behind latent fingerprint identification. A trusted latent print examiner must be knowledgeable in all areas of the science of fingerprint identification including classification methods, history, and procedures for locating, **processing**, and preserving latent prints at the crime scene or in the laboratory. As part of their duties, these examiners also give expert witness testimony with regards to latent fingerprints in all phases of the legal process.

New electronic procedures have been developed to detect and analyze latent fingerprints for crime detection. One such procedure is called **digital imaging**, the method of placing latent fingerprints into a digital format with the use of such equipment as digital **cameras**, computers, and scanners. Latent print examiners then use digital enhancement imaging software to adjust various features of the digital information such as brightness, contrast, and density in order to improve the quality of the evidence. Such electronic images are then input into an Automated Latent Print System (ALPS) computer, a database system that searches latent prints for possible matches. The ALPS computer assists the examiner in locating and retrieving records of known prints so that a list of possible matches can be made. Once a list is generated, another examiner (independent from the original investigation) conducts a scientific examination to verify the original identification.

On the federal level, the Latent Print Unit of the Federal Bureau of Investigation (FBI) conducts investigative work concerning the examination of latent fingerprints. When submitted as evidence to the FBI Laboratory, latent prints are input into the **Integrated Automated Fingerprint Identification System** (IAFIS) computer. The IAFIS then compares them against data from the FBI Criminal Justice Information Services (CJIS) Division, the largest international repository of fingerprint records.

Forensic technicians highlighting latent fingerprints. © MURIEL DOVIC/FRANCE REPORTAGE/CORBIS

Such efforts help to identify crime evidence involving latent fingerprints and solve serious crimes throughout the nation.

SEE ALSO Automated Fingerprint Identification System (AFIS); Chemical and biological detection technologies; Computer forensics; Digital imaging; DNA fingerprint; FBI crime laboratory; Fingerprint; Fingerprint analysis (famous cases); Ink analysis; Integrated Ballistics Identification System (IBIS); Ridge characteristics.

Latin forensic terms

Many Latin terms are used in the field of **forensic science** because forensics developed alongside the already established legal profession, which extensively uses phrases from the Latin language. The word forensic, itself, comes from the Latin word *forensis*, meaning of the forum. It originally applied to the marketplace areas within ancient Rome where many types of businesses and public affairs, such as governmental debates and actions by courts of law, were conducted. Entering the English vocabulary in 1659, the modern meaning of forensic is now limited to the areas of legal and criminal investigations.

Some commonly used Latin terms within the field of forensic science are listed below. A translation of the Latin appears in parentheses.

- *Aberemurder* (obsolete), willful murder
- *Abet* (to bait), to encourage another to commit a crime
- *Ab extra* (from outside), without
- *Actus reus* (guilty by act), wrongful deed performed with criminal intent

- *Ad hominem* (to the individual), relating to the preferences of a particular person
- *Amicus curiae* (friend of the court), person who is allowed to submit a point of view or intervene in a court case
- *Compos mentis* (of sound mind), legally responsible
- *Corpus delicti* (the body of the crime) fundamental facts that prove a crime
- *De novo* (new), trial that begins again without reference to previous trials
- *Fidei defensor* (defender of the faith), description of leaders especially with regards to British royalty
- *Flagrante delicto* (while the crime is blazing), caught in the act of a crime
- *Functus officio* (having served its purpose), expiration of someone's authority due to completion of duty or expired date
- *Habeas corpus* (that you have a body), writ issued to bring a party before a court or judge in order to release or continue to detain the party
- *In loco parentis* (in place of the parent), legal responsibility of a party to take on parental responsibilities
- *Indicia* (to point out), identifying marks or signs
- *In esse* (in existence), being
- *In extenso* (at full length), completely
- *In situ* (in its place), in its original position
- *Medias res* (the midst of things), middle of a series of events
- *Mens rea* (guilty in mind), intent or knowledge of performing a criminal act
- *Modus operandi* (**method of operation**), abbreviated M.O., particular way by which crimes are committed
- *Obiter dictum* (something said in passing), judge's observation on something not specifically before a court
- *Onus* (the burden), responsibility of governmental body or plaintiff to prove a case beyond reasonable doubt
- *Postmortem* (after death), **autopsy** performed after a person's death
- *Prima facie* (at first sight), **evidence** that appears to be sufficient to establish proof
- *Pro se* (on one's own behalf), person who presents their own case before a court without the use of lawyers
- *Res judicata* (the thing has been judged), case before a court that has already been decided by another court
- *Ultra vires* (without authority), outside the powers of legal authority.

In addition, many modern terms used commonly in forensic science have their roots in Latin. One such example is the word inquest, the term used for an inquiry into a death occurring under suspicious circumstances. The word comes from the Latin *in*, meaning into, and *quaro*, meaning to seek.

SEE ALSO Forensic science; Method of operation (M.O.).

Law Enforcement Training Center (FLETC), United States Federal

Many forensic investigators are police and other law enforcement officers. Thus, their **training** includes grounding in law enforcement. The Federal Law Enforcement Training Center (FLETC) is an organization, rather than a single facility, dedicated to training personnel from some 75 federal law-enforcement agencies. In addition, it provides training to personnel from state, local, and international agencies, and to those from federal agencies not immediately tasked with law enforcement duties.

FLETC is headquartered at Glynco, Georgia. Other facilities are located in Artesia, New Mexico; Charleston, South Carolina; and Cheltenham, Maryland. Founded in 1970, FLETC is now part of the Department of Homeland Security.

Studies of federal law enforcement training during the 1960s showed the need for a uniform system of training. Not only would this standardize the training process across the many law-enforcement branches of the federal government, but also it would prove most cost-effective. This would in turn make it possible to develop a center where a talented and educated cadre of instructors could provide comprehensive training using modern facilities and a course content that would ensure the highest possible level of proficiency among students. The result was the establishment, in 1970, of the Consolidated Federal Law Enforcement Training Center (CFLETC; the forerunner of FLETC) as a bureau of the Department of the Treasury.

The Glynco campus is similar to a town. Indeed, it has its own zip code. On the site is a practical exercise complex comprised of 34 buildings, including enclosed firing ranges; a driver training complex; numerous physical training areas; classroom buildings, which include laboratories and other specialized facilities; a computer resource learning center and library; and a television studio with the capability of broadcasting to field units throughout the United States and globally.

FLETC added a second major facility in 1989, when the former Artesia Christian College campus in Artesia, New Mexico, became the FLETC Artesia Center. Artesia remains the principal advanced training facility for the Immigration and Naturalization Service (INS), U.S. Border Patrol, Bureau of Prisons, and other organizations with headquarters or large concentrations of personnel in the western United States. Subsequent expanded responsibilities have led to the establishment of the other facilities.

The principal basic programs at FLETC are the Criminal Investigator Training Program (which has specific relevance to forensics); the Land Management Training Program, designed primarily for officers of agencies with a land management mission, such as the U.S. Forest Service or the National Park Service; and the Mixed Basic Police Training Program, which was created for uniformed services with a security or police mission, examples being the U.S. Secret Service Uniformed Division or the U.S. Capitol Police.

These and other programs provide a combination of classroom instruction on hands-on practical exercises. Areas of study include **firearms**, driver training, physical techniques, legal and behavioral sciences, marine operations, enforcement operations and techniques, and security specialties. There are also advanced courses in specialized areas ranging from law enforcement **photography** to seized computers and **evidence** recovery (which involves forensic analysis).

In addition to training for federal, state, and local agencies—in some cases through specially designed agency-specific courses—FLETC offers training to foreign agencies. This training focuses on three main areas: the Law and Democracy Program of the U.S. government, the Antiterrorism Assistance Program, and the International Law Enforcement Academy sponsored by the Bureau for International Narcotics and Law Enforcement Affairs.

SEE ALSO Careers in forensic science; Technology and forensic science; Training.

Roxie C. Laybourne

9/2/1910–8/7/2003
AMERICAN ORNITHOLOGIST

Roxie C. Laybourne originated the science of forensic ornithology. Often called the "feather detective," Laybourne used feathers to identify bird-strike accidents in military and commercial aircraft, to solve crimes for the Federal Bureau of Investigation (**FBI**), to identify feathers unearthed by archeologists, and to recognize species of endangered poached or illegally killed birds.

In 1960, a Lockheed aircraft took off from Boston Logan airport, then crashed into Boston Harbor after flying through a flock of birds. Sixty-two people died on the crash. Laybourne gathered bits of charred materials from the engine intake areas, and by examining them under a microscope, suggested the cause of the crash was clogging of one of the engines with birds she identified as starlings. As a result of her work, aircraft manufactures made modifications to the fan blades of their engines, the military strengthened the cockpits of their aircraft, and airports took measures to discourage potentially hazardous bird species from nesting near airports. Laybourne continued to investigate bird strikes to engines or cockpits of commercial, private, and military aircraft, and became the world's foremost authority in identifying bird species by the remains of their feathers.

Laybourne later applied her skills to solve a **murder** case in conjunction with the FBI. Even though the victim was murdered, then thrown off a cliff into the sea, Laybourne matched a tiny portion of a down feather recovered from the suspect's truck with the down contained in the victims jacket. In another case, Laybourne matched feathers found at a murder crime scene with those in a pillow used to silence the fatal gunshot. Laybourne also worked with United States customs agents to identify illegally imported bird species.

Laybourne was born in Fayetteville, North Carolina, and raised in a rural area of the state near the town of Farmville. As a child, she climbed trees to get a better look at birds, especially owls, and spent hours watching turkey vultures flying overhead and catching thermal air currents. Laybourne earned an undergraduate degree from Meredith College in Raleigh, North Carolina, followed with a master's degree in **botany** from George Washington University.

After graduation, Laybourne worked for the National Fisheries Laboratory in Beaufort, N.C., and the North Carolina State Museum. In 1944, Laybourne joined the Smithsonian Institution, where she worked for over 40 years in the bird division perfecting her system for identifying birds and overseeing the institute's collection of over 650,000 bird specimens. Laybourne died at the age of 92 at her farm in Manassas, Virginia.

SEE ALSO Aircraft accident investigations; Trace evidence.

Henry C. Lee

11/22/1938
CHINESE-AMERICAN
FORENSIC SCIENTIST

As one of the world's most famous international experts in **forensic science**, Henry C. Lee has assisted law enforcement organizations in the investigation of over 6,000 major cases around the world, served as a consultant for over 300 law enforcement agencies, and served as an expert witness in over 1,000 high-profile criminal and civil court cases. In fact, during the latter half of the twentieth century and into the present century, the legendary investigator has figured prominently in many famous cases including the 1963 **assassination** of President John F. Kennedy; the 1986 Connecticut "Woodchipper" **murder** in Newtown; the 1993 death of White House Counsel (for President Clinton) Vincent Foster, the 1995 O.J. Simpson murder trial; the 1996 murder of JonBenet Ramsey in Boulder, Colorado; the 2001 murder of Chandra Levy, the former Washington, D.C. intern; and the 2002 kidnapping of Salt Lake City teenager Elizabeth Smart.

Lee was born in China and grew up on the island of Taiwan. In 1960, Lee completed his degree in police science from the Taiwan Central Police College. That same year, Lee gained his first professional job at the Police Department Headquarters in Taipei, the largest city on Taiwan, where he attained the rank of captain. In 1965, he and his wife, Margaret, moved to the United States in order to complete additional education. Seven years later, in 1972, Lee earned a bachelor's of science degree in forensic science from John Jay College of Criminal Justice in New York City. During this time, from 1968 to 1974, Lee was employed as a research technician within the biochemistry department at the New York University (NYU) Medical Center.

In 1974, Lee earned a master's of science degree in science, followed by a doctor's of philosophy degree in biochemistry a year later, both from New York University. Lee was promoted to research scientist within the biochemistry department for the NYU Medical Center, a title that he held from 1974 to 1975. After completing his advanced degree in 1975, Lee became employed by the University of New Haven at West Haven, Connecticut, where he created its Forensic Sciences program; became the director (1975–1979) of the Forensic Science Laboratory in Meriden, Connecticut; and worked as an assistant professor of the Criminal Justice Division (1975–1977).

Also, in 1975, Lee volunteered for the Connecticut State Police in order to develop its modern forensic laboratory and to introduce the concept of Major Crime Squad as a means for criminal investigation. In 1977, Lee became the director of the Center of Applied Research, a position that he held until 1980. He was promoted to associate professor of forensic science at the University of New Haven in 1977 and, in 1978, granted tenure as a full professor and chairman of the forensic science program. In 1979, Lee was appointed as the first chief criminalist for the state of Connecticut and then, a year later, became the director of the Connecticut State Police Forensic Science Laboratory; both positions that were held until 2000.

In 1996, Lee became the director and founder of the Henry C. Lee Institute of Forensic Science. Then, in 1998, Lee became the commissioner of the Connecticut State Police, Department of Public Safety, a position he held until 2000. Then, in June 2000, Lee became chief emeritus at the Division of Scientific Services within the Connecticut Department of Public Safety, a position he currently holds. Also in 2000, Lee became a research professor for the University of Connecticut and a distinguished professor of **criminology** at the Central Connecticut University.

Throughout his career, Lee completed various special **training** classes from the Federal Bureau of Investigation (FBI) Academy, Bureau of Alcohol, Tobacco and Firearms (**ATF**), Royal Canadian Mounted Police (RCMP), Connecticut State Department of Administrative Service, and other crime investigation organizations. Lee is also the recipient of many awards including the Distinguished Service Award from Taiwan National Police Administration (1962); the **American Academy of Forensic Sciences** Distinguished Criminalist Award (1986); the Distinguished Service Award from Connecticut Police Commissioners Association (1992), the Medal of Justice from the Justice Foundation (1996); and the Lifetime Achievement Award from the Science and Engineer Association (1998).

Lee and his team of forensic scientists have made seminal contributions to the advancement of forensic science such as the enhancement of bloody fingerprints, creation of new methods for extracting **DNA** from samples, and estimation of **blood** volume at a crime scene. For his achievements and contributions in criminal investigations, biochemistry, material science, forensic science, fire and **arson** investigation, home and industrial security, and law enforcement, Lee has received many awards, citations, commendations, and medals from civic groups, governments, police departments, and universities around the world. Lee is especially known within the forensic science industry for his knowledge, experience, dedication, humor, and common sense; and with the extraordinary ability for finding the smallest clues that decide crucial trial cases. In 1992, Lee was elected as a distinguished Fellow of the American Academy of Forensic Sciences.

Lee has either authored or co-authored about 30 books covering such areas as DNA, fingerprints, crime scene investigations, and **trace evidence**. His most recent books include *Henry Lee's Crime Scene Handbook* (2001), *Blood Evidence: How DNA is Revolutionizing the Way We Solve Crimes* (2003), and *Cracking More Cases: The Forensic Science of Solving Crimes: the Michael Skakel-Martha Moxley Case, the JonBenet Ramsey Case and Many More!* (2004).

Lee has also published over 300 articles in professional journals and conducted over 800 seminars and workshops covering such topics as DNA, fingerprints, **crime scene investigation** and reconstruction, criminal justice, and bloodstain pattern analysis. In addition, Lee has been the editor of several academic journals including being a member of the editorial board of the Journal of Forensic Sciences. In 2004, Court TV-The Investigation Channel premiered the new series, *Trace Evidence: The Case Files of Dr. Henry Lee*, which featured Lee discussing some of his most interesting criminal cases.

SEE ALSO Bloodstain evidence; Crime scene investigation; Crime scene reconstruction; DNA; Kennedy assassination; Simpson (O. J.) murder trial.

Less-lethal weapons technology

Knowledge of weaponry is valuable for a forensic examiner in determining the cause of injury. One group of weapons that can be encountered, and which can produce various injuries and wounds, includes those known as less-lethal weapons.

Less-lethal weapons are tools and techniques designed for riot control and other security functions with the intention of neutralizing hostile activity without killing or causing permanent bodily harm. Varieties of less-lethal weapons technology range from batons and beanbag rounds (non-lethal bullets fired from an ordinary or modified rifle or shotgun) to electric Tasers, pepper spray and tear gas, and equipment that emits loud noises, bright lights, or even bad smells.

As early as 1972, a report by the United States National Science Foundation identified no less than 34 varieties of less-lethal weapons technology then in the research or developmental stages. Among these were electrified water jets; stroboscopic light and pulsed sound weapons; infrasound weapons, which would use low-frequency noises inaudible to the human ear; guns for firing drug-filled rounds; "stench darts," which would emit a powerful and unpleasant smell; and a device called an "instant banana peel," designed to make pavement slippery. Less-lethal weapons technology in development at the beginning of the twenty-first century used sticky foam which, when fired at an attacker, made it impossible for that person to move.

Among the most well known of such devices is the M26 Advanced **Taser**, which can be used to neutralize an individual by means of electric shock. Similarly, electronic riot shields and electro-shock batons also use voltage to neutralize attackers. Manufactured since the mid-1980s, electrified riot shields make use of special plates fitted with metal strips. In the handle of the shield is a button which, when pushed, can send as much as 100,000 volts—twice the capacity of an ordinary Taser—through the metal, an act accompanied by the emission of loud noises and bright sparks.

Numerous varieties of less-lethal weapons are fired from an ordinary rifle or shotgun, or one that has been modified for that purpose. This technology originated with British colonial forces in Hong Kong, who used wooden rounds. Varieties of less lethal ammunition include baton rounds or plastic bullets; wooden bullets; hollow-point rounds; rubber balls; beanbag rounds; and nylon bags filled with lead pellets. All are capable of making a penetrating wound, but more likely result in deep bruising.

Less-lethal weapons technologies also make use of sounds, smells, or light. The basic idea behind such techniques is not new; biblical texts report that prior to attacking the city of Jericho, the Israelites marched around it seven times, shouting and smashing cymbals to intimidate the inhabitants. In World

War II, the U.S. Office of Strategic Services (OSS) issued to its operatives in Asia a "psychological harassing agent" called "Who, Me?" According to an OSS manual, the gas "is to be squirted directly upon the body or clothing of a person a few feet away. The odor is that of Occidental feces, which is extremely offensive..."

In the late twentieth century, a British government research project was tasked with developing means of using noxious odors for crowd control in Northern Ireland. Among the items in development, according to a *Financial Times* report, were chemical compounds intended to produce "transient symptoms of nausea and gagging." The principle is not different from that of tear gas and pepper spray (itself a variety of tear or CS gas), chemicals long used to quell riots or neutralize attackers.

Researchers at U.S. national laboratories are also reportedly in the process of developing various means for using sound and light as weapons. For example, ultra-sound generators, as well as microwave and acoustic disabling systems, may be used to disturb the inner ear, throwing an individual off balance. Another item of future technology is a radiator shell that would use superheated gaseous plasma, or ionized gas, to produce bursts of light.

SEE ALSO Crime scene investigation.

Philip Levine

8/10/1900–10/18/1987
PRUSSIAN
SEROLOGIST

Many of Philip Levine's greatest contributions to the fields of **serology** and **forensic science** occurred when he was working with the Nobel Prize-winning Austrian immunologist **Karl Landsteiner** (1868–1943). Together, they sought evidence in their research that there were more than the ABO blood groups previously identified by Landsteiner.

Levine was born in a small village in Polish Russia in 1900. He moved with his family to Brooklyn, New York, when he was eight years old. Levine grew up in New York, graduated from City College, and went to Cornell Medical School. After graduation from medical school and completion of a Master's Degree, he accepted a position at the Rockefeller Institute as an associate (eventually, assistant) to pathologist Karl Landsteiner, with whom he worked for seven years.

Landsteiner and Levine believed, based on blood transfusion reactions occurring when persons of the same blood type were transfused, that there were more blood groups than A, B, AB, and O. They embarked on research aimed at discovering additional blood groups. The pair immunized rabbits with human red blood cells from forty-one different types of human sera. Of those, four were found to have a distinctive agglutinin, meaning they caused reactions that were different than those of A, B, AB, or O blood groups. Through the course of their work, the distinct properties and inheritance patterns of M, N, S, s, and P were described.

The M, N, and S antigens are typically found on red blood cells. Antibodies to M are relatively common; they are the most often found antibodies in children who have never received transfusions. Antibodies against N are almost nonexistent. Anti-M antibodies can be found in individuals who have received multiple transfusions, as well as in women who have had more than one live birth; they are almost never associated with hemolysis of red cells. Antibodies against S and most of the M, N, and S antigens have been associated with both hemolytic transfusion reactions and with hemolytic disease of the newborn.

Landsteiner and Levine discovered the P blood group through their continuing search for additional blood groups. Most of the anti-P antigens they identified were only cold reactive, so were therefore not of major concern in transfusion. P system antigens are common and are naturally occurring. As a result, many of the antibodies to P system antigens result from immune response to other organisms.

Levine went on to become a bacteriologist and serologist, and in 1935 he accepted a position at Beth Israel Hospital in New York. There, he studied Rh factors; this was to become his greatest scientific contribution. His work on Rh incompatibility between mothers and newborns more fully explained transfusion reactions occurring in individuals transfused with their own blood type, and laid the groundwork for future successful organ transplantation surgery.

Philip Levine's discovery and detailed study of the M, N, S, and P blood groups, as well as his research concerning the Rh factor, has had a tremendous impact on the field of forensic science, due in large measure to the dramatically increased ability both to specify paternity and to pinpoint the connection between a blood sample and an individual crime victim or perpetrator via the use of progressively more refined (and defined) blood group typing.

SEE ALSO Antibody; Antigen; Blood; Paternity evidence.

L-Gel decontamination reagent

L-Gel is a coating that was developed at Lawrence Livermore National Laboratory (LLNL) in Berkeley, California. The coating is effective at decontaminating areas exposed to both chemical and biological agents. As such, L-Gel is potentially applicable to **forensic science**, both in the decontamination of a crime scene and in the pathologist's laboratory.

The need to decontaminate spills of liquid or powdered poisons or infectious organisms is potentially urgent. In order to prevent injury from chemical or biological warfare agents, for example, the source agent must be contained before anyone touches the material, or before the agents become dispersed in air currents.

The development of L-Gel began in the 1990s. Among those striving to develop a nonhazardous, portable, and inexpensive decontamination reagent were LLNL researchers. Their L-Gel formulation incorporates a chemical compound called potassium peroxymonosulfate into a material called silica.

Potassium peroxymonosulfate is an oxidant. That is, it contributes an electron to the chemical bonds of the target compound, which disrupts the bonds that hold the target together or make it active. Bleach is another oxidant. However, bleach produces noxious fumes, making its use in confined settings dangerous. Bleach is also corrosive, and could damage equipment and tissue that is being decontaminated.

The oxidant is incorporated into a gel. The thick gel is able to cling to surfaces better than water, and remains where it has been applied. A water-based solution will spread out and could even run down an inclined surface, which could further disperse the poison or infectious microbe. Another advantage of a gel is that the oxidant is kept in contact with the target longer than would be possible if the oxidant was dissolved in water.

L-Gel is effective at killing over 99% of populations of bacteria including *Bacillus anthracis* (the bacterium that causes **anthrax**) and *Yersinia pestis* (the bacterium that causes plague). Surfaces as varied as carpet, wood, and stainless steel are all efficiently decontaminated with L-Gel.

SEE ALSO Anthrax; Biohazard bag; Pathogens.

Lie detector SEE Polygraph

Lincoln exhumation

The story behind the 1901 **exhumation** of the body of Abraham Lincoln, felled by a bullet from the gun of assassin John Wilkes Booth in 1865, began nearly three decades earlier with the actions of a bumbling counterfeiting ring in central Illinois. The ring's master engraver, one Ben Boyd, was imprisoned, and the gang was running out of counterfeit bills. The gang's leader, "Big Jim" Kinealy, came up with a plan that would restore the gang's fortunes: stealing Lincoln's body and holding it until the government paid a $200,000 ransom and freed Ben Boyd. Initially, the plot was thwarted when one of Kinealy's conspirators had too much to drink and revealed the plot to a woman, who in turn revealed it to a number of acquaintances. Soon, the plot was known throughout Springfield, Illinois, and gang had to beat a hasty retreat from the city.

Kinealy, however, did not give up. In Chicago, he opened a saloon, where one of his regular customers was a man named Lewis G. Swegles. In time Kinealy admitted Swegles to the gang, not knowing that Swegles was a Secret Service agent on the trail of the counterfeiters. In concert with Swegles and other members of the gang, the plot to steal Lincoln's body was hatched anew and scheduled for execution on the night of November 7, 1876, election day, when the conspirators figured that Oak Ridge Cemetery in Springfield would be deserted because people would be preoccupied with the outcome of the election. The plan was to place the body in a sack, transport it by horse-drawn wagon to northern Indiana, and hide it amid the sand dunes there until the national furor over the theft died down, ransom demands could be made, and the ransom was paid and Boyd was released.

Accordingly, that night the gang went to the cemetery, cut the lock off of the door of Lincoln's tomb, raised the marble lid of the sarcophagus, and were in the process of lifting the casket out when Swegles, whose job was to have driven the wagon into position, alerted eight detectives in hiding. The detectives rushed to the tomb, weapons drawn, but the grave robbers escaped. After their capture ten days later, Lincoln's son Robert hired prominent attorneys to prosecute them. At a trial eight months later, two men, Terrence Mullen and John Hughes, were found guilty and sentenced to a year in Joliet State Prison, where they began serving their sentences on June 22, 1877.

By 1900, the monument at Lincoln's tomb was in need of major reconstruction. Over the fifteen months during which it was being rebuilt, Lincoln's pine coffin was laid in a temporary grave nearby. Finally, in August 1901, the monument was complete and the coffin was reinterred. But in September, Robert Lincoln visited the tomb and decided that the project was not complete. Remembering the 1876 incident, he wanted to ensure that no one would ever be able to disturb the resting place of his father. So he ordered that the coffin be placed in a cage some ten feet below ground and encased in concrete. He got the idea from the burial of George M. Pullman, inventor of the Pullman sleeping railroad car.

On September 26, 1901, the new tomb was ready. When it was time to transfer the coffin into the tomb, discussion arose about whether the coffin should be opened, for there were persistent rumors that Lincoln's body was not in the coffin, and this would be the last opportunity to put those rumors to rest. Some observers thought that opening the coffin would be disrespectful, while other believed that the remains should be identified. The decision was reached to open the coffin.

Accordingly, Leon P. Hopkins and his nephew, Charles L. Willey, both plumbers, carved a piece out of the top of the lead-lined coffin, exposing the fallen president's head and shoulders. Each of the twenty-three people present said that a choking smell emerged from the coffin. Then each passed before the coffin and looked down. All agreed that the features of the body in the coffin were clearly those of Abraham Lincoln. Still visible were the whiskers on his chin, a wart on his cheek, and his coarse black hair, although his eyebrows had vanished. Also clearly visible was his black suit, the same suit he had worn to his second inauguration, although it was covered by a yellow mold.

Afterwards, the section of the coffin that had been removed was soldered back into place, the coffin was lowered into the cage, and the whole was covered with two tons of cement. Lincoln's body had been moved seventeen times since his death, but it would be removed no more.

In 1928, one of the witnesses who viewed the body, J. C. Thompson, said: "As I came up I saw that top-knot of Mr. Lincoln's, his hair was coarse and thick, like a horse's, he used to say, and it stood up high in front. When I saw that, I knew that it was Mr. Lincoln. Anyone who had ever seen his pictures would have known it was him. His features had not decayed. He looked just like a statue of himself lying there." Another witness, Fleetwood Lindley, who was just thirteen when he saw the body, was the last of the twenty-three witnesses to pass away. Just before his death in 1963, he said in an interview: "Yes, his face was chalky white. His clothes were mildewed. And I was allowed to hold one of the leather straps as we lowered the casket for the concrete to be poured. I was not scared at the time, but I slept with Lincoln for the next six months."

Credit for the condition of Lincoln's body must go to undertaker Dr. Charles D. Brown, of the firm Brown and Alexander. Assisted by Harry P. Cattell, Brown embalmed the president's body, first draining Lincoln's blood through his jugular vein. Then, an incision was made in his thigh and the embalming fluids were pumped in, hardening the body like marble. Brown and Cattell then shaved the president's face, leaving behind a tuft on the chin. They set the mouth in a slight smile and arched his eyebrows. They then dressed the president in his suit. The condition of Lincoln's body supported the claims made in a Brown and Alexander advertising flyer, which touted the benefits of their patented embalming procedure over other methods of preserving bodies: "...the mortal remains will be kept in the most perfect and natural preservation, and that cherished countenance looked at once more, by those who may be led to remember and repeat these holy words of consolation: 'He is not dead but sleepeth,' until we meet again in a better world."

In a letter to his mother, Army Assistant Surgeon Edward Curtis, one of two doctors who performed the **autopsy** on President Lincoln, described to her what happened when he found the bullet that had killed the president: "There it lay upon the white china, a little black mass no bigger than the end of my finger—dull, motionless and harmless, yet the cause of such mighty changes in the world's history as we may perhaps never realize...silently, in one corner of the room, I prepared the brain for weighing. As I looked at the mass of soft gray and white substance that I was carefully washing, it was impossible to realize that it was that mere clay upon whose workings, but the day before, rested the hopes of the nation. I felt more profoundly impressed than ever with the mystery of that unknown something which may be named vital spark as well as anything else, whose absence or presence makes all the immeasurable difference between an inert mass of matter owning obedience to no laws but those covering the physical and chemical forces of the universe, and on the other hand, a living brain by whose silent, subtle machinery a world may be ruled." Lincoln's autopsy, burial, and reburial site in Springfield, Illinois, attracts over one million visitors a year.

SEE ALSO Exhumation.

Lindbergh kidnapping and murder

In 1936, Bruno Richard Hauptmann was executed after a jury found him guilty of the brutal kidnapping and **murder** of twenty-month-old Charles Lindbergh, Jr., the son of American aviation hero Charles Lindbergh. The elder Lindbergh had become a celebrity in 1927 when he electrified the world by making the first nonstop solo airplane flight across the Atlantic. After returning home to a hero's welcome, he married Anne Morrow, the daughter of the U.S. ambassador to Mexico, and the couple's son Charles, Jr., was born in 1930. The reclusive Lindbergh, who shunned the public and the press, was thrust back into the glare of the spotlight in 1932, when his son disappeared from the family's rural home near Hopewell, New Jersey, and was later found murdered. Americans followed with intense interest the investigation and the sensational trial of Hauptmann for what was dubbed the "Crime of the Century."

The Lindberghs generally spent the weekends on their isolated 390-acre Hopewell estate and returned to the Morrow family estate in Englewood, New Jersey, on Monday mornings. That weekend, however, young Charles had a cold, so the family decided to remain in Hopewell one more day. On the cold and rainy evening of March 1, 1932, sometime between 8:00 p.m., when the child's nursemaid went to the second-floor nursery to look in on him, and 10:00 p.m., when Lindbergh went to the nursery to check in on his son before going to bed, the child had disappeared. Lindbergh later reported hearing a thumping noise from upstairs at about 9:00 p.m. Both the local and state police, with Lindbergh's help, conducted an unsuccessful search of the grounds for the child. (The state police investigation was led by H. Norman Schwarzkopf, the father of General H. Norman Schwarzkopf, Jr., the U.S. commander of Operation Desert Storm in Iraq in 1991.) The initial investigation turned up ladder impressions in the ground outside the nursery window, a carpenter's chisel nearby, and, about a hundred yards away, a broken ladder. Inside, a ransom note was found in the nursery, the first of fourteen notes that would be received during the investigation, all apparently written by the same hand on the same type of paper with the same blue ink:

> Dear Sir!
>
> Have 50000$ redy with 2500$ in 20$ bills 1500$ in 10$ bills and 1000$ in 5$ bills. After 2–4 days we will inform you were to deliver the Mony.
>
> We warn you for making anyding public or for notify the polise the child is in gute care.
>
> Indication for all letters are singnature and 3 holes.

The final line refers to a peculiar feature of all the notes: In the bottom right-hand corner of each was a pair of interlocking blue circles, each about an inch in diameter, with the overlapping area of the circles colored red and punched with three small holes.

A second note, delivered on March 5, upped the ransom demand to $70,000. A later note agreed to use the services of Lindbergh admirer John F. Condon as a go-between, with communication conducted through ads in a New York newspaper under the code name "Jafsie," from Condon's initials, J.F.C. Another included instructions for the type of box in which the ransom money was to be delivered. The first meeting between Condon and the kidnapper took place in Woodlawn Cemetery in the Bronx, where Condon insisted on proof that the kidnapper held the child before paying any ransom; soon the child's sleeping suit was delivered to the Lindbergh home.

At a second meeting, on March 31, Condon delivered to the cemetery two packages of unmarked gold certificates, whose serial numbers would later be widely circulated in nearly a quarter of a million booklets. Gold certificates were used to pay the ransom because the nation was just about to go off the gold standard for its currency and gold certificates, which had to be turned in by May 1, 1933, would be conspicuous if the kidnapper attempted to pass them. The first of the bills reappeared on April 2, and in the months that followed additional bills turned up. On May 1, 1933, $2,980 of the ransom bills were turned in at the Federal Reserve Bank in New York City by one J. J. Faulkner, but Faulkner was never identified or found.

The child, however, was not returned when the ransom was paid. Instead, another note indicated that

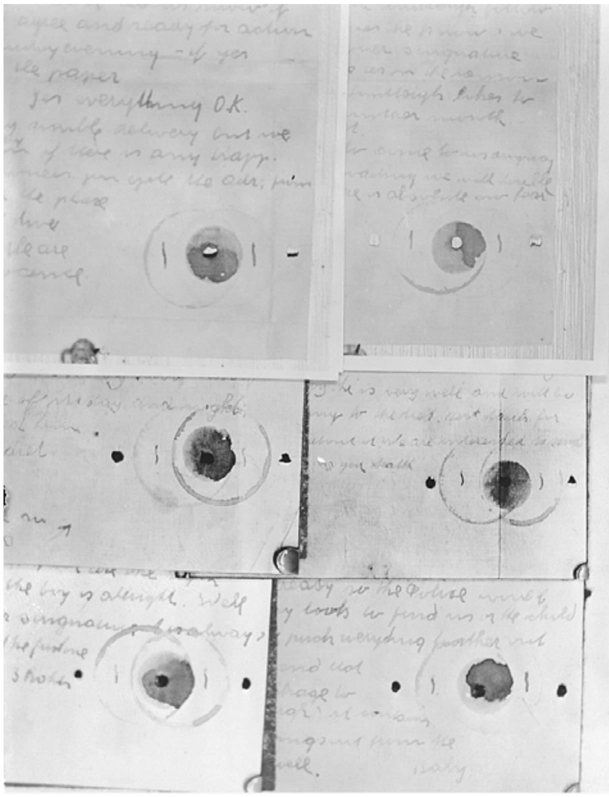
March 1932 newspaper clipping shows Charles A. Lindbergh, III, son of aviator Charles A. Lindbergh, Jr., who was kidnapped from his Hopewell, New Jersey, home on March 1, 1932. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

he could be found on a boat near Elizabeth Island, but a search for the boat proved unsuccessful. Then on May 12, a truck driver named William Allen discovered the child's body, now little more than a skeleton, in the woods about four miles from the Lindbergh estate. The body's left leg from the knee down, as well as the left hand and right arm, were missing. An **autopsy** showed that the likely **cause of death** was a blow to the head, but it otherwise provided no clues, and the investigation languished. Finally, on September 15, 1934, a gas station attendant became suspicious when a customer with a German accent used a $10 gold certificate to pay for a 98-cent gas purchase. Thinking the certificate might be counterfeit, he recorded the car's license number and contacted the police. The police traced the car to Hauptmann, a German immigrant, who denied having any more of the bills, but a search of the garage at his home in the Bronx, New York, turned up over $14,000 of the currency. He was arrested, and after a six-week trial conducted in a circus-like atmosphere in Flemington, New Jersey, found guilty on February 13, 1935. He was executed by electric chair on April 3 the following year.

The prosecution built much of its case on the forensic **evidence**. One important piece of evidence was the ladder, which was examined by a number of wood experts, including Arthur Koehler of the U.S. Forest Products Laboratory in Wisconsin. Koehler examined slivers of the ladder sent to him and concluded that the ladder was made of pine from North Carolina, Douglas fir from the West, birch, and Ponderosa pine. He even traced some of the lumber to a mill in South Carolina and from there to a lumber dealer in the Bronx. The hand-made ladder in some respects showed the work of a skilled carpenter. Hauptmann was a carpenter, and in fact had constructed the garage in which the ransom currency was found. During the search of Hauptmann's home, one of the investigators noticed a missing beam in the home's attic. The pattern of the nail holes in one of the uprights of the ladder found on the Lindbergh estate matched the pattern of nail holes left when the beam was removed from Hauptmann's attic.

The most crucial evidence, however, was the ransom notes themselves. The notes were examined by several analysts, who all concluded that they came from the same hand. They noted consistent misspellings, such as *note* rather than *not*, as well as inversion of letters such as *g* and *h*. They also noted peculiarities in the way that *x* and *t* were written and the illegibility of the word *the*. The letter *o* was open, and *t*'s were uncrossed. Additionally, some of the words in the ransom notes ended with incorrect *e*'s, a feature found in some of Hauptmann's other writing. The notes' grammatical errors and phraseology suggested that the writer was a native German speaker. In the original ransom note, for example, the word *gute* in the phrase "gute care" suggests a German speaker using the German word *gut* rather than the English word *good*.

During the investigation, one of the handwriting experts, Albert S. Osborn, wrote out a paragraph that the police could dictate to a suspect to write down to determine if he or she could have written the notes. The paragraph contained such words as *our* (*ouer* in the ransom notes), *place* (often spelled plase), and money (mony). Later, when Hauptmann was arrested, he was asked to provide samples of his handwriting, as well as to copy the ransom notes repeatedly over a period of hours. When Osborn and his son, Albert D. Osborn, first examined these writing samples, they were not convinced that Hauptmann wrote the ransom notes. The police then forced Hauptmann to write more notes, dictating the way he was to spell certain words. Again, the Osborns concluded that there were too many dissimilarities between Hauptmann's writing and that of the ransom



Ransom notes from the kidnapping and murder case of Charles Lindbergh, Jr. © BETTMANN/CORBIS

notes, as well as discrepancies among the writing samples themselves. Only after the cash was discovered in Hauptmann's garage did they change their opinion and conclude that Hauptmann's writing and that of the ransom notes matched. Meanwhile, at least one other expert believed that the writing was that of Isador Fisch, Hauptmann's business partner, who, Hauptmann claimed, had given him the money for safekeeping before leaving for Germany. Nonetheless, despite violations of **handwriting analysis** protocol, the state's handwriting experts convinced the jury that Hauptmann had written the notes.

SEE ALSO Handwriting analysis.

Linguistics, forensic stylistics

Forensic linguistics, or forensic stylistics as it is sometimes called, applies linguistic techniques to legal and criminal issues. This discipline subjects written or spoken materials (or both), to scientific analysis for determination and measurement of content, meaning, speaker **identification**, or determination of authorship.

In the analysis of a crime, it is important to study the written or spoken language of the perpetrator, as it can offer insight into the offender's age, race, gender, level of education, religious or spiritual beliefs, geographic and socioeconomic background, culture, and ethnicity.

Most adults' speech patterns retain vestiges of the geographic region, and sometimes of the local dialect, from the area in which they spent their childhood. Written communications provide fewer clues, although vocabulary and the use of colloquialisms (such as the variability in usage of "you" and "you all"; "pop," "soda," and "soda pop"; or "hot dog," "frank," and "wiener") may suggest geographic region. Written language stylistics generally reveals language of origin; the ordering of verbs, nouns and subject words in sentence structure is typically dictated by native spoken/written language. English speakers write in subject-verb-object order, non-English speakers more often write in subject-object-verb order ("You had better grasp the seriousness of my threat" versus "The seriousness of my threat you will be grasping").

Spoken and written nuances, grammar usage, generational characteristics, references to specific television shows, commercials, movies, music genre, or performers can all suggest general age. Although perpetrators sometimes attempt to disguise their gender, longer communications typically allow the individual to let down his/her guard sufficiently so as to reveal gender nuances. Females typically use more self-deprecating, more emotional, more polite, and less self-confident language than males. Females are more likely than males to overtly apologize for their actions, to utilize emotional words, and to use intensifiers.

Vocabulary, sentence complexity, abstract logic, and sophisticated word usage are likely to indicate higher levels of education. Use of technical or specific language can suggest occupation; biblical references may relate to religious or philosophical persuasion.

Forensic stylistics extends the principles of psycholinguistics to criminal, civil, law enforcement, or other legal venues. The field of psycholinguistics is concerned with the relationship between linguistics and the psychological processes underlying them. During the last third of the twentieth century, psychologists (in concert with other behavioral health professionals) studied and attempted to quantify linguistic features associated with character styles and personality traits, such as impulsivity, rage, anxiety, mania, depression, paranoia, sadism, narcissism, and the need to exert power and control over others, with the goal of utilizing this knowledge to understand or to predict criminal behavior.

Forensic linguistic analysis is utilized in cases involving assessment of threat, adjudication of authorship (submission of issues to a third party who has the power to deliver a binding decision), workplace and school violence, statement and confession analysis, and false allegations.

Specific word usage in spoken or written threats can give investigators a great deal of information concerning likelihood of action, suspect's motivation, personality characteristics, demographics, and degree of psychological stability (relates to the likelihood of impulsive action and the ability to safely manage stressful situations). The Behavioral Science Unit of the Federal Bureau of Investigation is engaged in a longitudinal research project concerning the relationship between language use in threatening communications and the likelihood that the author/speaker will act on the threats made.

In adjudication of authorship, forensic linguists compare specific characteristics of current communications (tone, sentence structure, idiomatic usage [unique to a particular style], vocabulary, punctuation, spelling, and grammar) with a known corpus (body or group) of writings from the suspect, to match for authorship.

There has been significant media coverage of workplace and school violence in recent years. Terminated or disgruntled employees have killed supervisors and coworkers, estranged spouses have taken mass revenge at job sites, and angry, depressed, or marginalized students have opened fire on classmates. Although these attacks are often characterized as "coming out of the blue," analysis by experts in forensic stylistics generally reveal that the perpetrators planned their actions, or at least contemplated them, far in advance of their occurrence. Disgruntled employees and chronically distressed students often express their discontent in the presence of others, and their vocalizations tend to escalate in intensity and specificity over time. It is not uncommon for them to talk about weapons they have, or plan to acquire, before the violent event occurs. These verbal threats are often minimized or ignored until the act occurs.

Confession and statement analysis are used to determine the truthfulness of the speaker's words, the information communicated via word choices, and references to the information omitted. Forensic linguists can study these patterns to determine the best method of approach with individual suspects.

The study of false allegations is particularly interesting; this is the situation in which an alleged victim may be found either to be misrepresenting the facts or to be causing the circumstances in question. Specifically, a victim may intentionally accuse an innocent party in an effort to protect the true offender (or for myriad other reasons) or to punish the accused; an alleged victim may fabricate the reported event entirely (report being threatened when s/he is the actual author of the communications; or report the occurrence of a crime when none has occurred, etc.).

Forensic linguists also study the contents of suicide notes, to determine whether they were, in fact, authored by the deceased, or whether they might have been fabricated as a means of disguising a homicide.

The analysis of cybercrime is an emerging field of expertise for forensic stylists. Hackers use written code to break into, or to sabotage, programs and computer systems; sometimes the code can be linked to a particular individual, through the use of stylistics.

A key role in criminal investigations is played by forensic linguistics/stylistics. Analysis of the spoken or written words of the offender can greatly assist forensic scientists in identifying a perpetrator, in linking seemingly unrelated crimes, in determining authorship of disputed documents, in assessing the veracity (truthfulness) of statements and confessions, in preventing or understanding school or workplace violence, in uncovering false allegations, and in assessing the danger level, and potential for violence, in threatening communications.

SEE ALSO Computer virus; Criminal profiling; Document forgery; Geographic profiling; Identity theft; Lindbergh kidnapping and murder; Psychological profile; Psychopathic personality.

Literature, forensic science in

People have always been fascinated by detective fiction. Reading a well-written thriller or crime story can be a satisfying experience and, in many books, the details of forensic investigation can drive the narrative along and add drama to the plot. It can also be educational in explaining the role of science in solving a crime. Forensic laboratories and crime scenes can help create an atmosphere that will keep the reader involved. Some great investigator heroes and heroines have emerged from the detective genre, from Arthur Conan Doyle's Sherlock Holmes to Kathy Reichs's Dr. Temperance Brennan. They have different styles and approaches but they always solve the crime.

Sherlock Holmes, the private investigator created by the Scottish author Sir **Arthur Conan Doyle** (1859–1930), is probably the most famous hero in detective fiction. Holmes was inspired by one of Conan Doyle's teachers at medical school, Joseph Bell, who always emphasized the importance of observation in making a diagnosis, advice that is equally applicable to forensic investigation. Conan Doyle wrote 56 short stories and four short novels between 1887 and 1927. They are still in print today.

Holmes endures, while the exploits of some of the later fictional detective heroes have long been forgotten. Maybe Holmes continues to fascinate us because of his scientific approach to solving crime. Britain's Royal Society of Chemistry even made him their first fictional Fellow in 2002 to mark the way he used chemistry in his investigations and sparked people's interest in the subject. Holmes was always something of an academic; he explored the use of tobacco ash, the shapes of ears, the dating of documents, tattoos, and footprints as clues. These are all used today as **evidence** in modern forensic investigation.

The first Sherlock Holmes novel, *A Study in Scarlet*, was published in 1887. Here Holmes meets Dr. Watson, who is to become his assistant, for the first time. They talk of a test that can detect human **blood** with a sensitivity of one part blood to one million parts water. This was several years before the discovery of a test that could identify human blood and even longer before the routine use of **luminol**, a chemical that detects invisible blood by turning it bright green, at crime scenes. Another Holmes novel, *The Sign of Four*, published in 1890, refers to many forensic techniques including soil **identification** and the **toxicology** analysis of alkaloids on a poisoned dart. There is still much to learn from Holmes about **forensic science**, and many of the techniques he utilized came into use and are applicable today.

The figure of the gentleman private detective persisted with Lord Peter Wimsey, the creation of the English writer Dorothy L. Sayers (1893–1957). The classic novel *The Documents in the Case* features forensic **botany** and chemistry. It depicts a death wherein the victim was first thought to have died by eating a poisonous mushroom mistaken for a nonpoisonous species. However, analysis of the residue of a mushroom stew reveals that muscarine, the active ingredient of the poisonous mushroom *Amanita muscaria*, is in the synthetic rather than the natural form, meaning the poison had to have been added by the perpetrator.

Death by arsenic poisoning is very common in crime fiction, much less so in modern life. In Sayers's novel *Strong Poison*, the villain tries to build up his tolerance to the poison by taking small, increasing, doses. This enables him to share an arsenic-laced omelet with his victim, Philip Boyes. The poison has little effect on the perpetrator but Lord Peter is able to discover the presence of arsenic in his nails and hair.

A Sayers short story, *In the Teeth of the Evidence*, features forensic **odontology**, the study of the structure and development of teeth. Lord Peter works with a dentist friend in the investigation of a concealed murder by looking at the teeth of the dead man and comparing them to his supposed dental records. The chart shows a fused porcelain filling done in 1923, but examination of the corpse reveals a filling material first used in 1928. The establishment of true identity hinges on the dental evidence, the rest having been destroyed in a fire, and leads to the arrest of the perpetrator.

In more recent times, there has been a clear shift towards the more professional kind of forensic hero. One popular example is Adam Dalgliesh, the hero of English author P. D. James's detective mysteries. Dalgliesh writes poetry, which perhaps gives him a flavor of earlier gentleman heroes. Of the several novels featuring Dalgliesh, perhaps one of the most compelling is *Death of an Expert Witness*. It is actually set in a forensic laboratory where, as the title suggests, the victim is a scientist. The book contains many examples of how forensic science is used in investigations and draws on the author's own experience in the Department of Home Affairs, working in the criminal and police departments.

Other modern crime writers feature the forensic scientist as protagonist. Perhaps the best known is Kay Scarpetta, the heroine in many novels by the American author **Patricia Cornwell**. Scarpetta is a **medical examiner** in Richmond, Virginia, and the novels draw on Cornwell's own experience of working in a medical examiner's office. In *Body of Evidence* (1991), many forensic techniques are on display as integral parts of the plot. A major character called Benton Wesley shows how to use psychological **profiling** to catch a perpetrator. There is also a detailed discussion on fiber analysis including how evidence is collected and its examination on a stereomicroscope.

Another Cornwell novel, *Post Mortem* (1990), discusses the latest techniques for gathering evidence at the scene of a crime. An **autopsy** description involves the use of a **laser** to find fingerprints on skin that could identify a perpetrator. There are also laboratory scenes involving blood grouping, **DNA** analysis, protein analysis, and other biochemical techniques. Scarpetta is a sympathetic personality, so the exposition of forensic science from her viewpoint is sure to engage the reader.

Another modern detective character in literature is Kathy Reichs's Dr. Temperance Brennan, who is a forensic anthropologist. The author is herself a forensic anthropologist with an international reputation working in the locations she describes, so her work feels authentic and teaches much about how crime investigation is actually carried out. In recent books such as *Bare Bones* and *Monday Mourning* there is much detail about the work of an expert witness, the dating of bones, **wildlife forensics**, and the discovery of the **cause of death**. There's an irony in the name, for Tempe, as she is known, is a recovering alcoholic. Therefore, a heroine is shown who, although an expert, is somewhat vulnerable. Another newcomer on the forensic science fiction scene is Tess Gerritsen, a writer of medical thrillers, whose medical examiner character Dr. Maura Isles autopsies her twin sister in *Body Double*. The story hinges on **serology**, the study of serums, and DNA evidence. As in Reichs's books, the heroine is also put at risk, a development that is a long way from the Holmes books, where the protagonist stays aloof from the action.

Karin Slaughter is another contemporary author working in the forensic investigation field. She writes about Dr. Sara Linton, who is a pediatrician working as a medical examiner, and about Linton's relationship with a police officer and the investigations they carry out together. In *Blindsight* there is a detailed description of **bullet track** analysis in a killing and of an old rape case.

The English crime writer Ruth Rendell writes from the point of view of the criminal, except in the Inspector Wexford novels where she writes about the police and the investigators. The novel *Adam and Eve and Pinch Me*, written in 2001, makes an interesting point about both **psychology** and forensic investigation. The killer, a woman called Minty, suffers from obsessive-compulsive disorder. She washes frequently and cleans up everything around her all the time. When she goes to the movies with her victim, she leaves no **trace evidence** behind after she stabs him to death, much to the frustration of the forensic investigators.

A novel drawing on forensic science is, of course, far more satisfying if the detail is there, and if it is correct. Authors who have worked in the forensic field, like Kathy Reichs, are naturally authentic. Many other authors want to write about crime and need to include forensic detail. Often they will consult a Web site organized by a forensic professional wanting to help writers. One such site is run by Douglas Lyle, a physician experienced in forensic work and also a writer of fiction. He maintains a Web site where he answers writers' questions and helps their work seem more believable.

SEE ALSO Film (forensic science in cinema).

Literature, popular

The field of **forensic science** initially developed as a scientific application to the legal profession in the nineteenth century. It is probably not a coincidence that the writings of popular fictional literature with regards to detective work also began that same century. E. F. Bleiler, Charles Dickens, Edgar Allen Poe, and **Arthur Conan Doyle** were among some of the nineteenth century writers who popularized established law enforcement and early forensic science theories and practices in the detective stories they wrote about. Further detective writings of this literature expanded into the twentieth century and now into the twenty-first century.

In the 1827 book *Richmond*, Bleiler wrote about **circumstantial evidence** that links a person to a crime when someone else is in reality the guilty person, as did Dickens in *Bleak House*. Like other writers in those early years of detective stories, Dickens employed **physical evidence** to implicate suspected criminals. Poe, who is generally credited with establishing the category of detective fictional literature, wrote numerous books involving fictional crime solution including *The Murders in the Rue Morgue*, where the crime centers on an unlikely location, and *The Purloined Letter*, which uses the principle of ratiocination (reasoned train of thought). Poe also introduced the detective C. Auguste Dupin, who is frequently considered the first fictional detective.

British physician and novelist Sir Arthur Conan Doyle created the famous detective Sherlock Holmes in four novels and fifty-six short stories that highlighted the sound deductive reasoning of the investigator. Among Doyle's books are *The Adventures of Sherlock Holmes* and *The Hounds of the Baskervilles*. Because of the popularity of Doyle's investigative hero, the detective-type story has remained a very popular form of storytelling. In fact, the brilliant detective stories of Doyle are generally considered the beginning point when discussing classic detective books.

Other detective writers who followed Doyle into the twentieth century include G. K. Chesterton (who created a series of detective stories relating the escapades of mild-mannered Father Brown, a Roman Catholic priest turned crime fighter), Arthur Morrison (who invented investigator Martin Hewitt), M. McDonnell Bodkin (who created the first detective family), and R. Austin Freeman (who introduced the first science-based detective, John Thorndyke).

Later on in the twentieth century, other writers weaved tales of detective work including Agatha Christie (who is remembered for her complicated plots and her memorable detectives, Miss Marple and Hercule Poirot, and for such books as *Curtain* and *The Murder of Roger Ackroyd*), Dorothy L. Sayers (who created the charming detective Lord Peter Wimsey featured in such books as *Whose Body?*), Raymond Chandler (who created the tough detective Philip Marlowe), Erle Stanley Gardner (whose lawyer-detective Perry Mason appeared in over eighty books such as *The Case of the Deadly Toy* and *The Case of the Duplicate Daughter*), Rex Stout (who created the stout detective Nero Wolfe), Dashiell Hammett (who wrote about private eye/ detective Sam Spade in such books as *The Maltese Falcon*), and the collaborate writers of Frederic Dannay and Manfred B. Lee (who wrote under the pseudonym of Ellery Queen while writing about legendary detective Ellery Queen in such detective books as *The Roman Hat Mystery*).

A notable writer of 2005 is Kathleen (Kathy) Reichs, who has taken her experiences as a forensic anthropologist and turned it into another career writing best selling novels on real-life aspects of forensic **anthropology**. As one of only a select number of forensic anthropologists certified by the American Board of Forensic Anthropology, Reichs has traveled worldwide in order to assist critical forensic investigations on such incidents as the United Nations Tribunal on Genocide in Rwanda and the September 11, 2001 disaster in New York City. With her lead character, Temperance Brennan, Reichs has published such popular fictional books based on forensic science as *Déjà Dead*, *Death du Jour*, *Deadly Decisions*, *Fatal Voyage*, and *Grave Secrets*.

SEE ALSO Literature, forensic science in; Television shows.

Lividity

The term lividity refers to an unnatural color of the skin. Lividity can be a useful reaction in determining the position of a body at the **time of death** and even whether a body was moved within the first few hours after death.

There are various forms of lividity. In a living person, a blow can result in the localized rupturing of cells and the pooling of **blood**. When the blood cells begin to decompose, the release of the blood forms a bluish-purple bruise.

In a living victim, bruising can be indicative of the nature of the trauma. For example, choking can leave a distinctive pattern of neck bruising that mirrors the pressure applied by the fingers.

Lividity can also result when blood flow ceases after death. The blood that was formerly flowing through the body can be drawn to the lowest point in the body by the influence of gravity. For example, if a victim was lying on her right side at the time of death, lividity would be evident on the right side of the face, hip, and on the areas of the right arm and leg that were closest to the ground.

As blood pools in a corpse under the influence of gravity, the lividity can become more intense in color. This trend has inspired attempts to correlate the degree of lividity with the approximate time of death. However, the development of lividity is too variable to be an accurate indicator of the time of death. Other indicators, such as **rigor mortis**, are more reliable.

Movement of a body in the first few hours after death can be evident by patches of lividity on different areas of the body. To continue the example cited above, the right-side pattern of lividity accompanied by a more intense lividity on the lower back and buttocks could indicate movement of the body onto the right side after death.

Typically, postmortem lividity appears as a bluish-purple or reddish-purple color in the regions of the body that are in close contact with the ground.

Areas that are further removed from the ground can be pink at the periphery of the discoloration.

Exceptions to these aforementioned colors can be important forensic clues to the **cause of death**. For example, in **carbon monoxide poisoning**, lividity can be cherry red in color. When a compound called methaemoglobin forms in the blood, as occurs in exposure to lethal concentrations of potassium chlorate, nitrates, and aniline, lividity tends to be a dark, chocolate-like brown color. Death due to intense cold (**hypothermia**) or the refrigeration of a recently deceased body will produce a bright pink lividity. The latter color can also be produced if the area of the body was covered by wet clothing.

Lividity typically appears as patches or blotches that coalesce over time to produce a more generalized area of discoloration. After about 12 hours, the lividity becomes fixed. Then, even if the body is shifted, the pattern of discoloration will remain the same.

SEE ALSO Blood; Crime scene investigation; Rigor mortis.

Living forensics

Forensic science has by tradition been identified with investigations of questionable and criminal deaths. However, only recently a new discipline, called living forensics, has begun as a way for forensic scientists to deal with survivors of traumatic physical injuries and illnesses. As a result, living forensics is defined as the part of forensic science that deals with the unbiased solutions to legal issues in cases involving living victims. (Forensic **pathology** is the other part of forensic science, which traditionally has involved only victims who are deceased.)

The application of living forensics deals with most of the wide range of subjects within forensic science, including the living victims of alcohol and drug abuse/addictions; domestic violence such as abuse of children, elders, and spouses; food, **medicine**, and drug tampering and poisoning; incest; medical malpractice; nonfatal assaults; pedestrian and motorized vehicle accidents; abuse while in the custody of law enforcement and correctional facilities; rape; suicide attempts; and work-related illnesses and injuries.

Forensic scientists who work within living forensics are trained to identify living victims of abuse, neglect, and violence in a wide variety of locations such as health clinics, correctional facilities, emergency centers, hospitals, occupational health centers, nursing homes and senior citizen living centers, schools, rehabilitation centers, and the community at large.

Forensic scientists, in addition to dealing with these subject areas, help to support the civil and constitutional rights of the living victim. Many of the important ways that these rights are guaranteed include recognizing **physical evidence** with regards to known or potential criminal acts, collecting and safeguarding such **evidence**, and preserving the overall **chain of custody** of this evidence.

Because living forensics is emerging as a forensic field, healthcare personnel and other people in positions to identify abuse, violence, and neglect of living victims are just now being made aware of such criminal acts so they can deal with the appropriate procedures to document and safeguard such evidence. As the field of living forensics matures, evidentiary materials (evidence) will be more properly detected, collected, preserved, and transmitted to appropriate authorities within law enforcement and the criminal justice system. These advancements will help to reduce the costs of prosecuting criminals and increase the protection that society needs for living victims of such criminal acts.

SEE ALSO Careers in forensic science; Evidence, chain of custody; Food poisoning.

Edmond Locard

1877–1966
FRENCH
CRIMINALIST

Edmond Locard had a paramount role in the European and worldwide development of **criminalistics**, the practice of gathering **evidence** for scientific examination and crime solving.

Locard was born in 1877 in the city of Lyon, France, about 300 miles southeast of Paris. In 1902, He obtained his doctoral degree in medicine. At that point, his interest in science pertaining to the law was already clear, as his thesis was entitled "La médecine légale sous le Grand Roy" (Legal Medicine under the Great King). After receiving his degree, he became the assistant of French medical doctor **Alexandre Lacassagne** (1844–1921), often referred to as the father of modern forensic medicine, of the University of Lyon. Lacassagne became Locard's mentor. A few years later, Locard decided to study the law, and in 1907, he passed the bar examination. Both a medical doctor and an attorney with a great interest for the study of sciences pertaining to criminal law, Locard had the right educational background and motivation to develop his passion and realize his dream.

In 1908, Locard began traveling the world. He first stopped in Paris, France, to study with French anthropologist **Alphonse Bertillon** (1853–1914), and to understand the anthropometric system of criminal **identification**. Locard subsequently visited the police departments of Berlin, Germany, Rome, Italy, and Vienna. His trip took him to the United States where he visited the police departments of New York and Chicago. He finally returned to Lyon in 1910 after a visit to Swiss criminalist Rodolphe Archibald Reiss in Lausanne, Switzerland.

After arriving back in Lyon, Locard's interest in modern and scientific investigation methods dedicated to police work was at its highest. In addition, Lyon was undergoing an increasing number of violent crimes, especially murders. In 1910, Locard was able to convince the Lyon police to establish a laboratory for collecting and examining evidence from crime scenes. They provided him with a few rooms in the attic of the court house in order to set up his laboratory.

In 1912, the laboratory was officially recognized by the Lyon police. Locard then headed the first official police crime laboratory in the world. This laboratory received world recognition and many great criminalists obtained their knowledge and experience under the guidance of Locard in the years that followed. One of these was the Swedish criminalist **Harry Söderman** (1902–1956), to whom Locard became a mentor.

In 1929 in Lausanne, Switzerland, Locard founded the International Academy of Criminalistics with Swiss criminalist Marc Bischoff, Austrian criminalist Siegfried Trkel, Dutch criminalist C.J. van Ledden Hülsebosch, and German criminalist **Georg Popp**. Unfortunately, this academy did not survive WWII. Several other police laboratories were created based on the model and influence of Locard. Even after WWII, the French police served as a model to many other countries. Locard was the driving force behind the development of modern scientific and technical police. He died in 1966. Subsequently, a significant decline occurred in criminalistics activity in France.

Locard published more than 40 works in French, English, German, and Spanish. His most famous work, still referenced daily, is the seven volumes of the Traité de criminastique (Treaty of Criminalistics), published between 1931 and 1935. Many of his books represent significant contributions to the field of criminalistics, and forensic scientists often still read his writings. His publications include several works about police investigations that he personally conducted. Locard was also passionate about philately (stamp collecting), and he wrote a few books on this topic.

Locard's contribution to forensic sciences is immense. His most important contribution is the principe de l'échange (principle of exchange). Locard stated "Toute action de l'homme, et a fortiori, l'action violent qu'est un crime, ne peut pas se dérouler sans laisser quelque marque." Translated, it means that any action of an individual, and obviously the violent action constituting a crime, cannot occur without leaving a trace. From this sentence, the whole principle of exchange of traces between two objects entering in contact was established. For example, when a car hits another car, paint from the first car will be deposited on the second one and vice-versa. Similarly, when somebody sits on a chair, **fibers** from his/her clothing will be deposited on the chair and fibers from the cloth of the chair will be deposited on the person's clothing.

Söderman later wrote of Locard, "He put the analysis of handwriting on a firmer footing, systematized the analysis of the dust in the clothes of suspects, invented a modified method of analyzing **blood** stains, and invented poroscopy, whereby the pores in the papillary ridges of fingerprints are used as a means of identification."

SEE ALSO Fingerprint; Handwriting analysis; Locard's exchange principle.

Locard's exchange principle

Edmond Locard (1877–1966) studied law at the Institute of Legal Medicine and worked subsequently as an assistant to the forensic pioneer **Alexandre Lacassagne** prior to directing the forensic laboratory in Lyon, France. Locard's techniques proved useful to the French Secret Service during World War I (1914–1918), when Locard was able to determine where soldiers and prisoners had died by examining the stains on their uniforms.

Like **Hans Gross** and **Alphonse Bertillon** before him, Locard advocated the application of scientific methods and logic to criminal investigation and **identification**. Locard's work formed the basis for what is widely regarded as a cornerstone of the forensic sciences, Locard's Exchange Principle, which states that with contact between two items, there will be an exchange. It was Locard's assertion that when any person comes into contact with an object or another person, a cross-transfer of **physical evidence** occurs. By recognizing, documenting, and examining the nature and extent of this evidentiary exchange, Locard observed that criminals could be associated with particular locations, items of **evidence**, and victims. The detection of the exchanged materials is interpreted to mean that the two objects were in contact. This is the cause and effect principle reversed; the effect is observed and the cause is concluded.

Crime reconstruction involves examining the available physical evidence, those materials left at or removed from the scene, victim, or offender, for example hairs, **fibers**, and soil, as well as fingerprints, footprints, genetic markers (**DNA**), or handwriting. These forensically established contacts are then considered in light of available and reliable witness, the victim, and a suspect's statements. From this, theories regarding the circumstances of the crime can be generated and falsified by logically applying the information of the established facts of the case.

Locard's publications make no mention of an "exchange principle," although he did make the observation *"Il est impossible au malfaiteur d'agir avec l'intensité que suppose l'action criminelle sans laisser des traces de son passage."* (It is impossible for a criminal to act, especially considering the intensity of a crime, without leaving traces of this presence.). The term "principle of exchange" first appears in *Police and Crime-Detection*, in 1940, and was adapted from Locard's observations.

SEE ALSO Criminal profiling; DNA; Fingerprint; Forensic science; Handwriting analysis.

Lock-picking

An important facet of a forensic investigation is the examination of the crime scene. Attention to all the details can be invaluable in determining the nature and course of the events. One telltale clue to a crime can be signs of forced entry. Crude means of entry, such as the breaking down of a door or smashing of a window, are easy to discern. Lock-picking is less evident.

One of the simplest types of lock to pick is known as a pin-and-tumbler design. This lock uses a row of pins, divided into pairs, which rest in a row of shafts running perpendicular to the clock's main cylinder plug and its housing mechanism. Insertion of the right key forces the top and bottom pins apart at just the right distance so that all of the upper pins rest in the outer housing and all of the lower pins rest in the plug. At that point, no pins bind the plug to the housing, meaning that the cylinder can be turned freely, releasing the bolt that holds the locking mechanism in place.

To open such a lock without a key, one needs a long, thick piece of metal with a curved end (a pick), which can be inserted carefully inside the lock as one would a key. Moving with finesse, it is possible to adjust all the pins into place so that the cylinder can be turned as though the key had been used. Or one can apply a sloppier variation, known as raking, in which a pick is inserted and pulled out quickly with a tension wrench, such as a flathead screwdriver, while the cylinder is turned.

Experienced lock-pickers use a wide array of tools. They are likely to go to work using an entire tool kit with picks, "rakes" (picks for raking a lock), and tension wrenches, all of which are small enough that a basic lock-picking kit could fit into a pocket. To be equipped for a greater range of eventualities, a lock-picker may use a kit that includes other tools, such as a burglar alarm evasion kit, a key-impression kit (for making a key based on impressions that a lock makes on a key blank), a key-pattern device (for copying old-fashioned warded keys, made to fit into lever locks), files, and other items.

Even more sophisticated is an electric lock-opening device, which is used in tandem with a pick to move the pins into the proper position. Additionally, a lock-pick gun can be used to open most pin-tumbler mechanisms. By squeezing the trigger, one strikes the pins with the pick, after which a tension wrench is applied to turn the lock cylinder.

There are other varieties of techniques and tools, just as there are variations in lock design, such as the wafer-tumbler lock, in which tumblers in the shape of wafers take the place of pins. Most aspects of lock-picking are simple in concept, but far from easy in application. It is the less than deft attempt at lock-picking that can leave telltale lock damage as a valuable forensic clue.

SEE ALSO Crime scene investigation.

Douglas M. Lucas

CANADIAN
FORENSIC SCIENTIST

In 1960 Douglas M. Lucas was the first forensic scientist to utilize the technique of gas **chromatography** as a means of **identification** of petroleum products used as accelerants in suspected cases of **arson**. In so doing, he recognized the inherent difficulties in attempting to minutely identify accelerants by brand type or commercial manufacturer.

In forensic fire investigations (suspected arson, acts of terrorism, etc.) it is extremely important to analyze the explosion, blast, or **fire debris** for the presence of small amounts of suspected volatile accelerants, which can be used to prove that the fire or blast was caused intentionally.

Accelerants are chemical fuels that cause fires to burn at higher temperatures, to spread exceptionally rapidly, or to be extremely difficult to contain or extinguish. **Accelerant** residue often remains at the crime scene. If identified, the presence of an accelerant can be used as forensic legal **evidence** of arson. However, even when it is collected immediately after the incident, carefully packaged, promptly transported, and analyzed by the best methods, test results have not always been conclusive or perfectly accurate.

Part of the difficulty in accurate analysis is that petroleum distillates, typically used as accelerants, typically undergo physical and biochemical changes as they burn or evaporate. In addition, arsonists generally use compounds of gasoline, kerosene, or diesel fuel as accelerants. Those crude oil products are made from mixtures that may contain thousands of different **organic compounds**, most of which contain only carbon and hydrogen atoms (hydrocarbons).

In order to identify volatile accelerants in a forensic scientific (laboratory) setting, it is first necessary to isolate the liquid suspected of being an accelerant from the surrounding fire or blast debris. It is then analyzed using gas chromatography, which results in the production of a graph called a chromatogram. The chromatogram is then computer analyzed and compared with chromatograms of known accelerants until a match is found.

Gas chromatography is one of the most effective techniques for detecting accelerants in explosion, blast, or fire debris. The basic gas chromatography technique utilizes uses a stream of gas (nitrogen or helium) as a carrier to move a mixture of gaseous materials along a long column or tube filled with a separating compound. Gas chromatography involves separating mixtures of gases into their individual chemical components based on the different boiling points of their hydrocarbons. Each gas in the mixture can then be identified, because each produces a distinct chromatogram.

Lucas set the worldwide standard for volatile accelerant identification in forensic arson investigations; gas chromatography remains considered among the most accurate scientific means of identifying flammable or combustible accelerant residues. In addition, Lucas authored "Ethical responsibilities of the forensic scientist: exploring the limits," published in the *Journal of Forensic Science* in 1989.

SEE ALSO Arson; Crime scene cleaning; Fire debris; Fire investigation.

Luminol

When investigating suspected crime scenes where the visible **evidence** of crime was removed by the perpetrator, nothing is more useful than luminol, a chemi-luminescent compound, which reacts to red **blood** cells (**hemoglobin**) and gives off a blue-greenish light. Luminol (5–amino–2,3–dihydro–1,4–phthalazine-dione) was accidentally discovered in 1928 by the German chemist H.O. Albrecht, and was first used at a crime scene in 1937 in Germany. Luminol is highly sensitive to bloodstains or residues, even to old stains, in walls, carpets, upholstery, wooden floors, or painted surfaces.

When a luminol solution is sprayed on surfaces, it reacts with metal ions, such as iron, which are stored and transported by hemoglobin cells (red blood cells). Very discrete iron concentrations on a surface, such as 1 part per million, are enough to catalyze luminol's chemi-luminescence (react and cause a glow). However, luminol sensitivity is not blood-specific, and the compound also reacts with other substances, such as **saliva**, rust, potassium permanganate, animal proteins, vegetable enzymes, and other organic **fluids** and tissues. Therefore, luminol tests are not conclusive for blood and cannot be admitted for evidence in court.

A biomarker (or a chemical marker) produces conclusive identification when it combines high sensitivity to a particular substance with high specificity, e.g., it is significantly more sensitive to that substance than to others. For instance, 100% sensitivity plus 95–99% specificity to a given compound number one, compared with 40–60% sensitivity and 30–40%

specificity to substance number two, would indicate strong evidence of the presence of compound number one. Luminol, however, only meets the first criteria, a high sensitivity to blood and to other protein-containing animal fluids, whether human or not. Another aspect of a luminol reaction is its different degrees of sensitivity from one substance to another. Luminol shows higher sensitivity to animal or human blood, organic tissues and fluids than to other compounds containing metal ions, such as paints, metallic surfaces, household products, or vegetable enzymes. Therefore, the light emitted by luminol has different intensities and time duration, depending on the material of contact. In other words, the lesser the sensitivity, the shorter the period of luminol chemiluminescence. Such variations constitute useful leads to experts investigating the scene.

In spite of the above-described limitation, luminol is very useful in **crime scene investigation**. The inside of an apparently clean room in which blood and other crime evidence is not visible can be sprayed with luminol over suspected surfaces. If a reaction occurs in a carpet, for instance, closer examination may reveal bloodstains or residues on the floor beneath it. It can also indicate direction of bloodstains, spatters, and reveal concealed bloody **shoeprints**.

When biological samples have to be collected for **DNA** or other tests, luminol should only be used after samples are seized. Luminol's chemical reactions with blood and other body proteins destroy some important genetic markers required for DNA fingerprinting.

SEE ALSO Blood; Blood, presumptive test; Blood spatter; Bloodstain evidence; Chemical and biological detection technologies; Crime scene investigation; DNA fingerprint; Fluids; Genetic code; Hemoglobin.

WORLD of FORENSIC SCIENCE

WORLD of FORENSIC SCIENCE

VOLUME 2

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Because they are actively working in criminal investigations, some advisors, contributors, and biographical subjects requested the release or inclusion of a minimum of personal information.

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INTRODUCTION

World of Forensic Science portrays the vast scope and influence of modern forensic science. From its origins in pre-scientific human fascination with the causes, manner, and circumstances of death, to the increasingly vital role of forensic science in law, security, and global economic and health issues, *World of Forensic Science* contains articles dedicated to providing insight into the science, applications, and importance of forensics.

To cover a topic of such scope and impact as forensic science is a daunting task. Interest in forensics spans human history, impacts philosophical and religious thoughts about death, and now, fueled by television and movies, is reflected in popular culture. Human interest in forensics dates to our earliest recorded histories. Egyptian Pharaohs first appointed officials to make inquiries into questionable deaths as early as ca. 3000 B.C., and accounts of ancient Roman law include references to the use of forensic experts in legal proceedings. Medieval English Common law, upon which portions of modern United States law is based, called for forensic determinations in the handling of estates.

Forensic science also has played—and in some cases continues to play—an important part in philosophical and religious thoughts about death. In some religions, for example, the determination of the manner of death may impact whether a body is fit for burial in certain grounds. Religious beliefs can also impact forensics, as there are still areas of the world and groups that consider autopsies as desecration.

As a formal science, forensics grew lockstep with advances in many branches of science during the nineteenth and twentieth centuries. The interval from scientific invention to forensic application narrowed as forensic scientists borrowed from the latest innovations of virtually every field of science to solve mysteries. However, just as advances in microscopes and atomic science allowed forensic applications to aid in the investigation of crimes at the most minute molecular and cellular level, the breadth of applications of forensic science underwent exponential expansion. In modern times, in addition to solving local crime, the next global pandemic or bioterrorist attack might well be first detected by a forensic scientist initially investigating a mysterious death.

World of Forensic Science is a collection of nearly 600 entries that evidence the wide diversity of forensic science. Articles on topics such as art forgery and wine authenticity indicate the far-reaching economic impact of forensic science. Heart-wrenching applications of forensic science, from uncovering the mindsets, methods, and motives of modern terrorists to discovering the far-reaching extent of natural disasters, are discussed in articles ranging from the "Identification of Beslan victims in Russia" to "Identification of tsunami victims"

Articles on a number of topics related to genetics, DNA fingerprinting, and microbiology show how recent advances in research quickly find their way into forensic application. A range of articles related to basic science reflects the fact that modern forensic investigators must be able to understand and properly apply tools from virtually every scientific discipline.

Nature is often innately tricky enough to confound scientists seeking to uncover its mysteries, but forensic scientists must also pit their skills against those deliberately trying to conceal or mislead. The importance of skill and experience to the forensic investigator is evidenced in the authoritative writing of many articles, including Ed Friedlander's article on autopsy procedures and Nancy Master's article on latent fingerprint analysis. (Friedlander serves as chairman, Dept. of Pathology, Kansas City University of Medicine and Biosciences, is board-certified in anatomic and clinical pathology, and has conducted an estimated 700 autopsies. Masters is the 2004 Dondero Award winner for identification in forensics.)

While selected topics acknowledge the relationship of forensic science to history and culture, and others describe the brutal realities of sensational crimes involving serial murders, ritual killers, or bombers, it was our intent to keep *World of Forensic Science* focused on science. The editors hope that *World of Forensic Science* serves to inspire a new generation of forensic scientists and investigators. It is also our modest wish that this book provide valuable information to students and readers regarding topics often in the news or the subject of civic debate.

K. Lee Lerner & Brenda Wilmoth Lerner
Editors
Santa Rosa Island, Pensacola, FL, and London, U.K.
April 2005

How to Use This Book

The articles in the book are meant to be understandable by anyone with a curiosity about topics in forensic science. Cross-references to related articles, definitions, and biographies in this collection are indicated by **bold-faced type**, and these cross-references will help explain and expand the individual entries. *World of Forensic Science* carries specifically selected fundamental topics in genetics, anatomy, physiology, microbiology, and immunology that provide a basis for understanding forensic science applications.

This first edition of *World of Forensic Science* has been designed with ready reference in mind:

- **Entries are arranged alphabetically**, rather than by chronology or scientific field.
- **Bold-faced terms** direct the reader to related entries.
- **"See also" references** at the end of entries alert the reader to related entries not specifically mentioned in the body of the text.
- A **sources consulted** section lists the most worthwhile print material and web sites we encountered in the compilation of this volume. It is there for the inspired reader who wants more information on the people and discoveries covered in this volume.
- The **historical chronology** includes many of the significant events in the advancement of forensic science.
- A **comprehensive general index** guides the reader to topics and persons mentioned in the book. Bolded page references refer the reader to the term's full entry.

Although there is an important and fundamental link between the composition and shape of biological molecules and their detection by forensic testing, a detailed understanding of chemistry is neither assumed or required for *World of Forensic Science*. Accordingly, students and other readers should not be intimidated or deterred by the complex names of chemical molecules. Where necessary, sufficient information regarding chemical structure is provided. If desired, more information can easily be obtained from any basic chemistry or biochemistry reference.

M

Herbert Leon MacDonell

AMERICAN
FORENSIC SCIENTIST

Herbert L. MacDonell has conducted important research and investigation in the field of **forensic science** for over forty years. MacDonell is the inventor of the MAGNA Brush **fingerprint** device, and is considered an expert in **blood** splatter analysis. MacDonell has written and lectured about a wide range of forensic science topics, and has consulted on several high-profile criminal cases.

MacDonell attended the University of Rhode Island, earning his M.S. degree in 1956. He soon went into the field of forensic science, and in 1960 invented the MAGNA Brush fingerprint device. The brush, which changed the way fingerprint **evidence** was processed, uses a magnet and metallic powder to identify a latent print. Because the MAGNA Brush has no bristles, it reduces the likelihood of damaging the ridge detail of the print. He also began extensive research and experimentation with blood splatter analysis. In 1971, he wrote the booklet *Flight Characteristics and Stain Patterns of Human Blood*, published by the U.S. Department of Justice. It contains MacDonell's findings and instructs crime scene investigators on how to interpret blood spatters.

MacDonell continued his successful career by taking the position of director of the Laboratory for Forensic Science in Corning, New York. Because of his breadth of experience, he has consulted on criminal cases across the country and around the world. He testified in the O.J. Simpson case on blood evidence matters, and was involved in the investigations of the assassinations of Senator Robert F. Kennedy and Dr. Martin Luther King Jr. He has also appeared on a number of news television programs, including *Good Morning America*, *20/20*, and *Dateline NBC*.

Along with author Alfred Allan Lewis, MacDonell wrote the 1984 book *The Evidence Never Lies: The Casebook of a Modern Sherlock Holmes*. MacDonell serves as the subject of the book, and profiles a number of cases that he worked on and solved. He has also written numerous articles for a variety of **professional publications**. In addition, MacDonell has shared his expertise in academic settings, as a lecturer at various conferences and universities. He also serves as the director of the Bloodstain Evidence Institute, which runs a study program for forensic science students. MacDonell was the 1974 winner of the John A. Dondero Award from the **International Association for Identification**.

SEE ALSO Bloodstain evidence; Simpson (O. J.) murder trial.

Mad cow disease investigation

Bovine spongiform encephalopathy (BSE, also popularly known as mad cow disease) and Creutzfeldt-Jakob disease (CJD, which occurs in humans) are ailments in which the functioning of the brain is progressively impaired.

Beginning in the 1980s in the United Kingdom, mad cow disease has been a sporadic concern in that country and others. By 1992, three cows in every 1,000 in Britain were estimated to have the disease. Then in the winter of 1997, another outbreak led to the slaughter of 100,000 cattle as a measure to stop the spread of the disease. In more recent incidents, detection of the disease in the Canadian province of Alberta in 2003 led to a ban on imports of Canadian beef to the United States. As of mid-2005, the ban is still in effect, although it is anticipated to be lifted before year's end.

The detection of mad cow disease and the determination of the extent of the disease involved a large, coordinated epidemiological (disease-tracking) and **forensic science** investigation.

Initially, a cow may be suspected of being infected because of behavioral changes, including loss of coordination, clumsy gait, and even the appearance of foam at the mouth (hence the origin of the mad cow moniker). Typically, the suspect cow will be removed from the herd and slaughtered. Then, examination of tissues and **fluids** commences. These examinations can involve microscopy of tissue sample and the use of antibodies to identify the causative agent.

Mad cow disease is associated with visually abnormal pinpoints (or plaques) in the brain, and in a changed texture of the brain tissue. These alterations are detected when the brain tissue is microscopically examined as part of an **autopsy** of a cow suspected of having the disease. The brain tissue, particularly in the cortex and cerebellum, becomes filled with large open spaces (vacuoles) and becomes spongy in texture. The "spongiform" part of the BSE descriptor comes from this texture characteristic.

In Canada, cattle have been tagged with an identifying code since 2001. The identifier enables the movement of cattle to be tracked from the herd (and from herd to herd) to the slaughterhouse. This enables the pattern of an illness outbreak, including mad cow disease, to be better investigated.

Mad cow disease, CJD, and maybe even other diseases such as scrapie, transmissible mink encephalopathy, fatal familial insomnia, and kuru, are thought to have a common cause, namely **prions**. Prions are particles that are made solely of protein. Even though they lack genetic material, they are infectious.

Mad cow disease causes a progressive neurological deterioration in cattle that is similar to the course of CJD in humans. Infected cattle are more temperamental, have problems with their posture and coordination, have progressively greater difficulty in rising off the ground and walking, produce less milk, have severe twitching of muscles, and lose weight even though their appetite is undiminished. The suspected incubation period, the time from when the animal is first infected until symptoms appear, ranges from two to eight years. After appearance of symptoms, deterioration is rapid and the animal dies or is destroyed within six months. The disease is one of a group of related diseases called transmissible spongiform encephalopathies (TSEs) in animals.

Bovine spongiform encephalopathy was confirmed as a disease of cattle in November 1996. Since then, with the exception of cases in Canada and a single case in the United States in 2004, almost all reported cases have been in cattle born in the United Kingdom. Other countries in Europe and Asia have reported BSE, but in far fewer numbers than in the U.K. As of November 2001, the total number of confirmed cases of BSE in U.K. cattle was just over 181,000. In 1993, a BSE epidemic in the U.K. peaked at almost 1,000 new cases per week. While the cause of this near-exclusivity has yet to be conclusively determined, a common practice in the United Kingdom was to feed cattle "offal," the ground up waste from the slaughter process. Cattle feed was also prepared from the ground bones and tissues of sheep, cattle, and other animals, providing a means of delivering prions from infected animals to healthy ones. The exact origin of the prions is not known. Sheep, susceptible to a similar disease called scrapie, known for many years, are considered a likely source.

Until the 1900s, scientists thought that the transmission of the BSE agent to humans did not occur. However, several post-mortem, forensic studies (autopsies and brain tissue examination) conducted in the 1990s debunked this assumption. In 1994, cases of young people (median age was 26 years) with a CJD-type disease began appearing in the U.K., often in related geographical areas. As CJD affects mostly people over age 65, and symptoms differed slightly and developed more slowly in those affected in the new outbreak, the disease was given the distinct name of variant CJD, or vCJD. An intensive investigation was launched that eventually revealed vCJD as most likely caused by eating beef from cattle infected with BSE. As of 2005, 105 cases of vCJD have been identified in young adults mostly in the U.K., with three cases occurring in France and one in Ireland. The largest number of cases occurred during 1999 (27), and has decreased to less than five cases per year afterward, suggesting that the outbreak of the disease is waning. Chances of contracting vCJD by eating beef in the U.K. are very small as of 2005, due to measures implemented more than a decade earlier (longer than the usual vCJD incubation period) to protect the **food supply** from BSE-infected beef.

As well, studies on mice published in 2004 have cast doubt on the previous view that the infectious agent of mad cow disease is localized exclusively in only the brain, spleen, spinal cord, and lymph tissue. Prions were additionally detected in the kidney, pancreas, and liver tissues of infected mice. This finding has profound forensic implications, since typically an investigation of mad cow disease focuses on examining samples from the brain and the other traditional locations. The presence of prions elsewhere would be overlooked. As there is no conclusive diagnostic test for variant CJD while an affected person is alive, other than a costly and invasive brain biopsy that will offer no benefit for the outcome of the disease, forensic examination of brain tissue at autopsy is the usual method of providing a definitive diagnosis of CJD and variant CJD in humans, and BSE in cattle.

SEE ALSO Animal evidence; Autopsy; Prions.

Mail sanitization

Forensic investigations sometimes require the analysis of substances found in contaminated mail. Identifying **toxins** or harmful residues present in mail, along with their concentrations, provides **evidence** in criminal cases and information necessary to decontaminate the mail. Mail sanitization is the process in which mail is decontaminated. The possible methods for mail sanitization work by exposing mail to radiation, high pressure, or gases. Microorganisms, such as the bacterium that causes **anthrax**, cannot survive these conditions. The process of mail sanitization can be applied as a precautionary measure to kill microorganisms that may be contained in the mail or to sterilize mail that is known to be contaminated with dangerous microorganisms.

Shortly after the September 11, 2001, terrorist attacks, the United States Postal Service (USPS) was the vehicle for **bioterrorism** attacks on Americans. Mail containing the anthrax bacterium was detected. Five persons who were infected by the anthrax bacterium died from the disease. As a direct result of this, the USPS developed an Emergency Preparedness Plan with the goal of protecting USPS employees and customers from future bioterrorism attacks. The Plan is composed of six initiatives:

- Prevention—reducing the risk that the mail could be used as a vehicle for bioterrorism.
- Protection and health-risk reduction—reducing the risk that USPS employees and customers could be exposed to biological weapons and preventing contaminated mail from contaminating other mail.
- Detection and identification—detection and **identification** of biological weapons as early in the mail stream as possible.
- Intervention—routine decontamination of mail as a precautionary measure.
- Decontamination—elimination of known biological weapons in the mail.
- Investigation—enhancement of criminal investigation methods.

Mail sanitization applies to the intervention and decontamination initiatives. Achieving mail safety is no small undertaking when one considers the complexity of the USPS system and volume of mail that is processed. The postal service handles nearly 680 million pieces of mail each day. This mail primarily consists of letters, "flats" such as catalogs and magazines, and packages. Mail enters the USPS system in many different ways, including street collection boxes, post offices, personal mailboxes, and business mail entry units. The USPS has about 300 processing and distribution centers that manage outgoing mail. The computer-controlled sorting equipment and data processing systems located at these centers distribute mail to its destination. Mail is moved from processing and distribution centers to final destination processing centers by ground, rail, or air transportation. Once at a final destination processing center, mail is then sorted and distributed to the recipients.

The USPS is studying several different methods of decontamination to find one (or more) that can effectively sanitize mail. To be useful in mail sanitization, the decontamination method must thoroughly penetrate letters, flats, and packages but not damage the mail in any way. Irradiation has been found to be the only acceptable method for decontaminating mail. The addition of a sanitization step to the USPS mail system may slow down the mail delivery rate.

Ionizing radiation kills bacteria. The energy from ionizing radiation is transferred to molecules which, when absorbed by the molecules, breaks chemical bonds and destroys chemical structures. Reactive chemicals (ions and free radicals) that are produced by this process cause even further damage. This results in significant damage to the **DNA** and proteins of bacteria, causing the bacteria to die.

The USPS is considering three sources of ionizing radiation as candidates for mail sanitization: x rays, gamma rays, and electron beams. All three are used to sterilize medical equipment and to kill microorganisms in food to prevent spoilage. They each can kill the anthrax bacteria. Radiation can easily penetrate and sanitize most types of mail, however, it may damage film, electronics, and live objects such as seeds.

X rays are a type of high-energy electromagnetic radiation. X-ray particles, or photons, are generated when electron-dense materials are bombarded by high-energy electrons. X rays have a high-energy content and can penetrate most objects.

Gamma rays are another type of high-energy electromagnetic radiation. Gamma rays are released by decaying radioactive compounds such as cesium 137 or cobalt 60.

An electron beam, or e-beam, is a stream of electrons that is propelled by a high accelerating voltage. The energy content of the e-beam is determined by the accelerating voltage and is lower than both x rays and gamma rays.

Of the three ionizing radiation sources, e-beam technology is the safest and most readily adaptable system for mail sanitization. In 2001, the USPS bought eight e-beam machines and planned to install them in Washington, D.C., and the New York and New Jersey areas. The e-beam machine requires high power and chilled water and must be contained by a structure with 10 to 15 foot-thick concrete walls and a six foot-thick concrete ceiling. E-beam technology has been used to sanitize incoming federal government mail only.

Types of non-ionizing radiation that have been used for sterilization are ultraviolet (UV) light irradiation and microwave irradiation. Both are effective at killing microorganisms, but by different ways.

UV light radiation damages DNA by causing DNA strand breaks and binding DNA bases together (thymine dimers). Bacteria with damaged DNA cannot reproduce or survive. UV light radiation cannot penetrate objects and is used to sterilize surfaces and air only. In addition, some microorganisms are resistant to the effects of UV radiation. Therefore, UV radiation is an unacceptable method to sanitize mail.

Microwave radiation is a low-energy non-ionizing radiation. The energy in microwaves is transferred to water molecules in microorganisms. The water molecules heat up and the heat is transferred to surrounding molecules, thereby damaging and ultimately killing the microorganism. Microwave radiation sanitization has shortcomings. Most importantly, it is difficult to control the heating effects and it is common to have "hot spots" and "cold spots." Also, the water content of dormant bacterial cells (**spores**) is low, so microwave radiation may not destroy them. Microwave radiation would be ineffective for mail sanitization.

Ultra-high-pressure (UHP) sterilization is accomplished by applying a pressure of almost 100,000 psi, which causes physical changes to DNA and proteins. The resulting cellular damage kills the microorganisms. Without added heat, UHP sterilization techniques may be less effective against bacterial spores than against growing bacterial cells.

UHP sterilization is being developed for the food industry and has been shown to be effective on both solid and liquid foods. The UHP sterilization cycle time can be less than 30 minutes and the process is non-destructive to the object being sterilized. This method could be applied to mail as a sanitization method, however, a UHP sterilization system for mail will not be available for several years.

Certain gases have anti-microbial properties and are used for disinfection and sterilization. Large amounts of gas would be needed to sterilize mail and it is not evident that gases can kill microorganisms within sealed letters, flats, and packages. Gaseous sterilization of mail is not currently a viable option for mail sanitization, though the USPS has identified several possible candidates for gaseous sanitization:

- Chlorine dioxide—an oxidizer that disrupts proteins and protein synthesis. It was used to disinfect an office building that was contaminated with anthrax spores.
- Ethylene oxide—an alkylating agent that damages proteins, leading to bacterial or viral death. It is used to sterilize medical equipment.
- Methyl bromide—a toxic pesticide that has been used to fumigate large buildings. It is an ozone-depleting chemical and will not be used after 2006.
- Ozone—an oxidizing agent used to disinfect water and decontaminate unoccupied spaces. Its effect on spores is variable depending upon the specific bacterial strain.

SEE ALSO Anthrax; Biological weapons, genetic identification; Decontamination methods; Toxicological analysis; Toxicology; Toxins.

Malicious data

A forensic examination such as **forensic accounting** often involves tracing an electronic data trail. Roadblocks can be deliberately introduced to obscure the trail and thwart those attempting to uncover the wrongdoing. As well, data can be deliberately introduced with the aim of compromising or destroying the quality of the information housed in a database or computer file. Forensic accounting and criminal investigations both attempt to identify so-called malicious data.

Malicious data is data that, when introduced to a computer—sometimes by an operator unaware that he or she is doing so—will cause the computer to perform actions undesirable to the computer's owner. It often takes the form of input to a computer application such as a word-processing or data spreadsheet program. It is thus distinguished from a malicious program such as a **computer virus**, compared to which malicious data is perhaps even more stealthy.

An example of malicious data at work is the Melissa "virus," which spread through the e-mail systems of the world on March 26, 1999. Though the media called Melissa a virus, this was a misnomer; rather, it was a case of malicious data wedded to a macro virus, or a virus that works by setting in motion an automatic sequence of actions within a software application. Melissa did not damage computers themselves, yet it produced a result undesirable to anyone but its creator. By taking advantage of a feature built into the Microsoft Word program, it sent itself to the first 50 addresses in the user's Outlook Express, an e-mail program also produced by Microsoft. Melissa, for which computer programmer David L. Smith was eventually charged, caused $80 million worth of damage, primarily in the form of lost productivity resulting from the shutdown of overloaded mailboxes.

In practice, malicious data is much like a malicious program, yet it is difficult to protect against malicious data using the methods typically used to circumvent malicious programs, such as file access control, firewalls, and the like. Malicious data has been used, not simply for pranks such as Smith's, but to transfer funds out of the operator's financial accounts, and into those of the perpetrator. In this crime, the operator is a participant, albeit an unwitting and unwilling one.

SEE ALSO Computer forensics; Computer hackers; Computer security and computer crime investigation.

Marcello Malpighi

3/10/1628–8/29/1694
ITALIAN
PHYSICIAN

In the second half of the seventeenth century, Marcello Malpighi used the newly invented microscope to make a number of important discoveries about living tissues and structures, earning himself enduring recognition as a founder of scientific microscopy, histology (the study of tissues), embryology, and the science of plant anatomy.

Malpighi was born at Crevalcore, just outside Bologna, Italy. The son of the owners of a small plot of land, Malpighi studied **medicine** and philosophy at the University of Bologna. While at Bologna, Malpighi was part of a small anatomical society headed by the teacher Bartolomeo Massari, in whose home the group met to conduct dissections and vivisections. Malpighi later married Massari's sister.

In 1655 Malpighi became a lecturer in logic at the University of Bologna. One year later, he assumed the chair of theoretical medicine at the University of Pisa. In 1659 he returned to Bologna as lecturer in theoretical, then practical, medicine. From 1662 to 1666 he held the principal chair in medicine at the University of Messina. Finally, in 1666, he returned again to Bologna, where he remained for the rest of his teaching and research career. In 1691, at the age of sixty-three, Malpighi was called by his friend Pope Innocent XII to serve as the pontiff's personal physician. Reluctantly, Malpighi agreed and moved to Rome, where he died on November 29, 1694, in his room in the Quirinal Palace.

Early in his medical career, Malpighi became absorbed in using the microscope to study a wide range of living tissue—animal, insect, and plant. At the time, this was an entirely new field of scientific investigation. Malpighi soon made a profoundly important discovery. Microscopically examining a frog's lungs, he was able for the first time to describe the lung's structure accurately—thin air sacs surrounded by a network of tiny blood vessels. This explained how air (oxygen) is able to diffuse into the blood vessels, a key to understanding the process of respiration. It also provided the one missing piece of **evidence** to confirm William Harvey's revolutionary theory of the blood circulation: Malpighi had discovered the capillaries, the microscopic connecting link between the veins and arteries that Harvey—with no microscope available—had only been able to postulate. Malpighi published his findings about the lungs in 1661.

Malpighi used the microscope to make an impressive number of other important observations, all "firsts." He observed a "host of red atoms" in the blood—the red blood corpuscles. He described the papillae of the tongue and skin—the receptors of the senses of taste and touch. He identified the rete mucosum, the Malpighian layer, of the skin. He found that the nerves and spinal column both consisted of bundles of fibers. He clearly described the structure of the kidney and suggested its function as a urine producer. He identified the spleen as an organ, not a gland; structures in both the kidney and spleen are named after him. He demonstrated that bile is secreted in the liver, not the gall bladder. In showing bile to be a uniform color, he disproved a 2,000-year-old idea that the bile was yellow and black. He described glandular adenopathy, a syndrome rediscovered by Thomas Hodgkin (1798–1866) and given that man's name 200 years later.

Malpighi also conducted groundbreaking research in plant and insect microscopy. His extensive studies of the silkworm were the first full examination of insect structure. His detailed observations of chick embryos laid the foundation for microscopic embryology. His botanical investigations established the science of plant anatomy. The variety of Malpighi's microscopic discoveries piqued the interest of countless other researchers and firmly established microscopy as a science.

SEE ALSO Microscope, comparison; Microscopes.

Manslaughter SEE Murder vs. manslaughter

Markov (Georgi) murder investigation

The 1978 **murder** of Bulgarian dissident playwright and broadcaster Georgi Markov is one of the most unusual events of the Cold War. While walking on a busy London street, Markov was struck by a poison pellet fired from an umbrella. After his death, it took British authorities weeks to discover that Markov had been poisoned by **ricin**.

Born in 1929 to an army officer, Markov witnessed the Communist takeover of Bulgaria in 1944. Subsequently, as a student at Sofia's Polytechnic University, Markov was imprisoned for his anti-communist beliefs in 1950 and 1951. He became a chemical engineer and briefly ran a metallurgy factory. During his career as an engineer, Markov wrote newspaper articles and short stories. In 1962, he became a literary star with the publication of the novel *Men*, and he began to socialize with the Bulgarian elite.

Markov defected to the West in 1969. Within ten days of his defection, an article appeared in a Communist party newspaper criticizing Markov's works. Within two months, all of his plays had been taken off the stage. Within the year, the Bulgarian press was describing Markov as a traitor. In 1973, a special court in Sofia sentenced Markov in absentia to six and a half years imprisonment and the confiscation of his property.

In 1975, Markov began to share his stories of life in Bulgaria on Radio Free Europe and the British Broadcasting (BBC) radio. He was particularly known for his harsh criticism of the autocratic rule of the communist leader, Todor Zhivkov. Markov's shows were broadcast into Bulgaria and he was seen as providing inspiration to the Bulgarian dissident movement.

Markov had been warned that the Bulgarian government was planning to kill him, but he believed that his enemies would attempt to administer poison orally. On September 7, 1978, Markov left his BBC office at Bush House in London to take the train home to Clapham in southwest London. As he passed a bus stop on Waterloo Bridge in the middle of the day, Markov felt a sudden, stinging pain in the back of his right thigh. Turning sharply, he saw a man behind him bending down to retrieve an umbrella. The man murmured, "I'm sorry" and then immediately hailed a taxi. Though in pain, Markov continued home. Only in the early morning hours of September 8, when his temperature rose suddenly did Markov go to the hospital. He lingered for four days and then died on September 11.

Physicians were unsuccessful in diagnosing Markov's illness. However, the circumstances of the attack and Markov's political leanings prompted the British government to order an **autopsy**. A post mortem, conducted with the help of scientists from Britain's germ warfare center at Porton Down, established that he had been killed by a tiny pellet containing a 0.2 milligram dose of the poison ricin. The platinum and iridium pellet, smaller than a pinhead, was detected only because it had not dissolved as expected.

Ricin is derived from the castor oil plant. It is known as a masquerade poison because ricin-caused symptoms are easy to confuse with those from a viral or bacterial infection. Victims experience abdominal pain, nausea, cramps, seizures, and dehydration. Death usually ensues from cardiac arrest due to an electrolyte (key minerals such as sodium and potassium) imbalance.

Riverboats pass beneath a span of Waterloo Bridge in London, where the Bulgarian dissident Georgi Markov was murdered with a ricin-filled dart fired from an umbrella in 1978. © PATRICK WARD/CORBIS

Scotland Yard announced the medical examiner's findings and reported that a similar attack had failed in France. In Paris, another Bulgarian defector, Vladimir Kostov, was attacked with an umbrella in late August. Kostov was ill for a few days with stiffness and fever, but he recovered. By chance, the poison pellet that struck Kostov had lodged in muscle in his upper back, away from major blood vessels.

Markov's assassin has never been captured. In June 1992, General Vladimir Todorov, the former Bulgarian intelligence chief, was sentenced to sixteen months in jail for destroying ten volumes of material on the case. A second suspect, General Stoyan Savov, the deputy interior minister, committed suicide rather than face trial for destroying the files. Vasil Kotsev, widely believed to have been the commander of the **assassination** plot, died in an unexplained car accident. The Soviet KGB is also suspected of providing technical assistance.

Markov's spectacular death proved to be a public relations disaster for Bulgaria. In 1998, Bulgaria's democratically elected President Peter Stoyanov stated that the Markov assassination was one of the darkest moments in his country's communist era. Stoyanov said authorities would continue to investigate the case. Scotland Yard has also kept the case open.

SEE ALSO Assassination; Assassination weapons, biochemical; Death, cause of; Medical examiner; Ricin.

Marks and scars SEE Body marks

James Marsh

9/2/1794–6/21/1846
ENGLISH
CHEMIST

With a distinguished career as an English chemist in the 1830s and 1840s, James Marsh (1794–1846) is historically well-known for the research and development of a dependable, simple laboratory test for the **identification** of minute traces of arsenic.

The Marsh test (or the Marsh Arsenic test), as it is known today, involved the testing of given samples of food, fluid, or deceased human tissue by forensic toxicologists from the middle part of the nineteenth century to well into the latter half of the twentieth century. In fact, the test was often used by **Mathieu Joseph Bonaventure Orfila** (1787–1853), the person who is often considered as the originator of forensic **toxicology**. The Marsh test gave experts an effective and accurate way to detect small amounts of arsenic—a sometimes-fatal chemical contaminant when placed accidentally or intentionally within the body. In Marsh's day, arsenic poisoning was a very large problem throughout the world, and was often not discovered by ordinary analysis. The development of this testing method and accompanying apparatus by Marsh helped to promote the scientific advancements of poisoning investigations, along with assisting the outcome of several notable **murder** trials.

Little is known about Marsh as he grew up in England and began his professional career at the Royal British Arsenal (also called the Woolwich Arsenal), which was located east of London in the town of Woolwich. His scientific abilities were probably first noticed in 1836 when leaders of the neighboring town of Plumstead asked advice of him as to the possible reason of arsenic poisoning within the deceased body of a local leader. As a qualified chemist who was familiar with the accepted German methods of testing autopsies, Marsh applied yellow precipitates, ammonia solvents, and various other laboratory materials to the tissues of the dead body and to the coffee that was alleged to have contained the poison. Marsh presented his **evidence** at the inquest, which clearly identified arsenic in the victim's body. However, at the trial the jury did not understand his technical testimony and acquitted the accused grandson of the decedent. (The grandson later confessed to the crime after being convicted of later wrongdoings.) Because of this work, Marsh is considered today as the first person to present the results of toxicology analysis in court.

Because of his inability to convince the jury, Marsh became determined to develop new laboratory tests that could prove the presence of even small traces of arsenic and make the results understandable to even uninformed people. Basing his investigations on the previous work (of transforming arsenic to a related gas called arsine) by Swedish scientist Karl Wilhelm Scheele (1742–1786), Marsh produced hydrogen from a reaction of adding solid zinc metal to a glass receptacle containing either hydrochloric acid or sulfuric acid. When Marsh added tissue or body fluid to the hydrogen-generating container, its reaction with the zinc and acid would create hydrogen gas. If any type of arsenic was present, the hydrogen gas when heated by Marsh would react with it to produce arsine gas, which fumed off to deposit a silvery-black film—that is, metallic arsenic—on a porcelain bowl.

Marsh was able to produce visible stains on the bowl when only very small amounts of arsenic were present. In fact, as little as 0.1 milligrams (0.0000035 ounces) of arsenic were detected by using the test designed by Marsh. Later, Marsh designed a U-shaped glass tube with a narrowed nozzle at one end to provide a controlled reaction and to help ignite the exiting gas. Marsh wrote a report based on his pioneering research and resulting test that was published in the *Edinburgh Philosophical Journal* in October 1836, and followed with two other Marsh test articles in 1837 and 1840.

Upon publication of the article, toxicologists and other scientists around the world experimented with the information that Marsh provided. French toxicologist Orfila, already famous in his own right, made important improvements to the Marsh test such as recommending that all reacting chemicals be shown free of arsenic before being used in an investigation. In 1840, the Marsh test was instrumental in making a conviction in a major murder case, one that was decided by a report by Orfila. Specifically, Orfila applied the Marsh test to decide the controversial trial of Marie Lafarge, who was charged with murder in the arsenic poisoning of her husband. Based on his results, Lafarge was found guilty and sentenced to death (which was later reduced to life in prison). Due to the scientific work of Orfila and his expert application of the Marsh test, procedures were first formalized for proving poisoning in court cases with the use of **toxicological analysis**.

Throughout his career, Marsh worked at the Woolwich arsenal where he was employed in the fields of electromagnetism and artillery technology. While still employed at the arsenal, March died in London at the age of 51. After his death, the Marsh test was extensively applied by forensic toxicologists until more technically-advanced methods of instrumental analysis such as atomic absorption **spectroscopy** and x-ray fluorescence spectroscopy replaced it in the latter half of the twentieth century.

SEE ALSO Autopsy; Toxicological analysis.

Nancy E. Masters

AMERICAN
FORENSIC LATENT PRINT ANALYST

For more than thirty years, Nancy E. Masters has made significant contributions to the field of **fingerprint identification**. As a latent print analyst, she has participated in crime scene investigations and testified as an expert in court trials in accordance with her extensive **training** in examining fingerprints found at crime scenes. Masters also has developed curriculum, written books, and lectured nationally and internationally on the subject of latent print techniques.

Masters attended Sacramento State University, Sacramento, California, earning a bachelor's degree in political science in 1969 and a secondary teaching credential in 1972. She launched her career in **forensic science** immediately, working for the California Department of Justice (CDJ) in its Fingerprint Program from 1967 to 1981. Masters then moved into the CDJ's Latent Print Program, as a latent print analyst, for the next seven years. During this time, and throughout her career, Masters continued her training and education in the field by attending seminars and programs run by the Federal Bureau of Investigation, the **International Association for Identification**, and the CDJ. She was awarded the California Governor's Safety Award in 1987.

In 1988, Masters began working with the CDJ's Criminalistics Institute. As an instructor there, she developed curriculum for courses on latent print techniques, latent print comparisons, and specialized latent print techniques, including physical, chemical, photographic, and **laser** techniques. Using her experience and knowledge, she has instructed law enforcement personnel throughout the world.

Masters has also significantly contributed to literature on the subject of fingerprint identification. In 1995, she wrote the textbook *Safety for the Forensic Identification Specialist*, with a second edition released in 2002. In the book, Masters instructs technicians on safety issues while dealing with fingerprint **evidence**, **physical evidence**, and crime scene hazards. She was also a contributing author to the *Clandestine Laboratory Manual of Instruction and Procedure*, used by law enforcement agencies in the United States.

Since 1996, Masters has continued her work in fingerprint identification as a consultant for the CDJ and other entities. She has also worked as a speaker and article author, contributing to trade journals such as the *Journal of Forensic Identification* and the *FBI Law Enforcement Bulletin*. In 2004, she won the John A. Dondero Award from the International Association for Identification.

SEE ALSO Careers in forensic science; Evidence.

Fuseo Matsumur

JAPANESE
TRACE EVIDENCE EXAMINER

Louis Pasteur, the nineteenth century medical researcher, once noted, "Where observation is concerned, chance favors only the prepared mind." And so it occurred, almost a century after Pasteur's death, that an ordinary **trace evidence** examiner in Japan made a rather profound observation. In 1977, Fuseo Matsumur was preparing microscope slides for an investigation being conducted by the Japanese National Police Agency. The crime involved the **murder** of a taxi driver, and Fuseo's task was to glue hair samples from the crime scene to glass slides for later microscopic examination. While carrying out this routine task, Matsumur made a seemingly simple observation: the fumes from the Superglue® (cyanoacrylate adhesive) he was using caused his fingerprints to become visible on the glass slides.

Fingerprint "dusting," the print retrieval technique commonly seen on television, is somewhat limited in its use, because the perspiration which forms a fingerprint evaporates rather quickly, leaving nothing to attract and hold the dusting powder. Long after the moisture in a fingerprint has evaporated, however, the amino acids found in human sweat remain behind, sometimes for months. These amino acids attract the fumes from Superglue® and other brands of cyanoacrylate adhesive, forming a sticky image of the latent print, which is then dusted and lifted with a wide piece of transparent tape.

While Matsumur knew none of the science behind what he had observed, he recognized its potential importance in the field of **criminology**. Matsumur quickly relayed his observation to Masato Soba, a print examiner at the agency, who began exploring the technique further. Soba's subsequent work, along with that of researchers in other organizations, has led to numerous advances in this technique, though the basic concept remains unchanged. A typical analysis today involves placing the evidentiary objects inside a sealed box with an open container of cyanoacrylate. The glue is heated to release its fumes, and after about 15 minutes, when the prints have become clear, the box is pumped clear and the objects are removed and dusted. Prints discovered using this method can be removed with tape and placed on a transparent plastic card.

"Fuming" has become a routine procedure in criminal investigations today, allowing investigators to collect otherwise unusable latent prints.

SEE ALSO Crime scene investigation; Fingerprint; Latent fingerprint.

Luke Sylvester May

12/2/1892–7/11/1965
AMERICAN
DETECTIVE

Considered one of the first American criminalists, Luke S. May had a long career as a detective dedicated to the advancement of scientific method in relation to crime investigation. He pioneered striation analysis in tool mark comparison, and invented the Revelarescope. In addition, May was a regular contributor to the popular magazine *True Detective Mysteries*, and wrote many books on **forensic science** topics.

May cultivated an interest in **criminology** as a young man, reading works by authors as diverse as **Arthur Conan Doyle** and **Hans Gross**. At the age of seventeen, he began working as a private detective in Salt Lake City, Utah. A few years later, he opened Revelare International Secret Service, an independent detective agency, with noted forensic experts J. Clark Sellers and John L. Harris. With an emphasis on scientific method and forensic specialties like **fingerprint identification**, May and his colleagues were able to provide lab services to law enforcement officials before the officials had these capabilities on their own.

In 1919, May moved to Seattle, Washington, and opened Scientific Detective Laboratories, parting way with Sellers and Harris. It is here that May invented his best-known forensic tool, the Revelarescope, in 1922. The instrument, a comparison magnascope, featured two lenses that projected a split image on a ground glass screen. May's invention was used in a high-profile child abduction case in Washington, one that produced a ground-breaking decision in the use of tool mark identification. At this time, May also intensified his role as an educator, allowing criminology students to study with him at his laboratory. He later served as an instructor in the law programs at the University of Washington, University of Oregon, and Willamette University.

May was well-known as an ongoing contributor to the popular true crime magazine, *True Detective Mysteries*. He collaborated with writers to create a number of case articles for the magazine, and also wrote a question-and-answer column regarding investigation techniques. In 1936, May wrote *Crime's Nemesis*, a book in which he outlines the details of some of his most unusual cases. May also wrote two crime investigation handbooks, *Scientific Murder Investigation* and *Field Manual of Detective Science*, in 1933.

SEE ALSO Literature, forensic science in; Microscopes.

Walter C. McCrone

6/9/1916–7/10/2002
AMERICAN
CHEMICAL MICROSCOPIST

For more than sixty years, Walter C. McCrone worked as a chemical microscopist, consultant, and educator. He is best known for his work on analyzing The Shroud of Turin and the Vinland Map, but McCrone also made significant contributions to his field by establishing the McCrone Research Institute, a not-for-profit center for teaching microscopy. He is also the author of more than 600 articles and sixteen books and chapters, including the well-known text *The Particle Atlas*.

McCrone pursued his interest in chemistry early on. He attended Cornell University, earning an undergraduate degree in chemistry in 1938 and a doctorate in organic chemistry in 1942. Continuing his work in the academic field, McCrone worked for Cornell for two years before becoming a chemist and professor at Armour Research Foundation (now Illinois Institute of Technology).

After twelve years at the Armour Research Foundation, McCrone left to start his own consulting firm. He founded McCrone Associates, a company that grew from a one-man shop to a renowned facility serving more than 2,000 clients each year. And while he enjoyed his work as an independent consultant, McCrone was also interested in promoting the education of microscopy. So in 1960, McCrone founded the McCrone Research Institute in Chicago, Illinois. The not-for-profit organization has taught more than 22,000 students in every facet of applied microscopy, as well as conducted research in that field. Later, McCrone opened its sister organization, McCrone

Scientific, in London, England. In addition, McCrone continued to write about his research and findings in the field of microscopy, publishing 600 technical papers and sixteen books and chapters. His best-known publication is *The Particle Atlas*, a handbook for solving materials analysis problems.

McCrone is also known for his analytical work on a number of famous antiquities. In the 1970s, he analyzed the Vinland Map, a map possibly depicting parts of North America some sixty years before the arrival of Christopher Columbus. McCrone found the ink on the map to contain a mineral commonly found in inks after 1920. In 1978, McCrone was asked to analyze the Shroud of Turin, a strip of cloth thought to be the shroud Jesus Christ was buried in. After studying the shroud, McCrone concluded that the material was instead a medieval painting. While many contested McCrone's findings, carbon dating tests conducted ten years later upheld McCrone's assessment. In 2000, he received the American Chemical Society National Award in Analytical Chemistry for his work on the Turin Shroud.

SEE ALSO Anthropology; Art forgery; Microscopes.

Measurements of anatomical features SEE Biometrics

Medical examiner

The medical examiner (ME) is the person in charge of the forensic investigation of a death that has occurred in his or her area of jurisdiction, whether it is a homicide, suicide, accident, or other suspicious death. He or she has a number of tasks to carry out, chief of which is the determination of the cause and manner of the death through performing an **autopsy**. The medical examiner also takes charge of the analysis of **evidence**, works with the police investigating the scene of the crime, and presents evidence in court. In short, the ME is involved in both the medical and legal sides of a forensic investigation.

The role of the medical examiner is one that has been evolving since the nineteenth century. There has always been a tradition in investigating unexplained deaths. Initially, the people appointed to take charge of these investigations were known as coroners and they were elected or appointed but did not necessarily have any special legal or medical **training**. During the nineteenth century, the practice of **medicine** became more professional in many countries, with an increasing requirement for proper academic training. At the same time, **forensic science** and **pathology** were being established as disciplines in their own right. The old office of **coroner** was out of step with these new trends. Increasingly, regions began to demand that the coroner have medical knowledge so that scientific principles could be brought to bear on the investigation of a death. In 1877 Massachusetts became the first state to pass a law replacing the office of coroner with that of medical examiner and requiring that the ME have a license to practice medicine.

Increasing urbanization in the United States during the early years of the twentieth century led to several cities introducing the ME system. This change was accelerated by various scandals where deaths had allegedly been improperly or inadequately investigated by ill-qualified coroners. Today, there is a mixture of the coroner and the ME system in many counties, with the former still tending to predominate in rural areas.

Many modern medical examiners have training not just in pathology, but in forensic pathology and so are well qualified to carry out all the medical and legal tasks involved in investigating a suspicious death. However, the ME is not actually required to be a forensic pathologist, as there are not enough specialized forensic pathologists to meet the needs of every community. When a death requires investigation and the relevant region does not have an ME who is a forensic specialist, the area will contract out the work to the nearest center which does offer such services.

The medical examiner has many varied duties when investigating a suspicious death. First and foremost is the task of establishing the cause and manner of the death. For instance, the person may have died of asphyxia and this would be the **cause of death**. However, there are many different manners in which asphyxia can occur—drowning, strangulation, or hanging, for example. The **time of death** also needs to be determined as accurately as possible so it can be put into context with the events unfolding at the crime scene. It is also important for the ME to establish the identity of the victim, if this is not already known. Where the body has wounds, they should be thoroughly investigated and correlated with any weapons that may have been used to inflict them. The presence of **body marks** and signs of disease may also be significant and must be recorded and interpreted.

The autopsy findings are clearly highly relevant in establishing the cause and manner of death. However,

Medical examiner presents video evidence during a manslaughter trial in Massachusetts in 2002. © REUTERS/CORBIS

autopsy findings must be supported by other available sources of evidence, including witness reports, evidence collected at the scene of the crime such as bloodstains or weapons, and the results of crime lab testing. All of this involves working closely with the police and forensic scientists, assisting them with tasks such as the collection of evidence directly from the body. Sometimes there are surviving victims, who will be important witnesses, at the scene of a crime. The medical examiner is usually charged with examining their wounds and determining their cause and timing, because this is also a valuable source of evidence.

When a sudden and unexplained death is reported to the medical examiner, he or she takes the usual systematic approach to investigating it, as any good doctor would with a living patient presenting with a medical complaint. The only difference, of course, is that the ME cannot take a direct history from the deceased. Instead, the ME must gather as much information as possible from witnesses, family members, the police, and anyone else who might be able to shed light on the death. The ME may require people to give evidence, such as **blood** samples or fingerprints, that may help in the investigation.

When it comes to examining the body, there may be no obvious signs of physical trauma. Often this suggests a death from natural causes. Consultation of the medical records of the deceased and discussion with their physician can establish whether this is likely. An autopsy might then be carried out to confirm any tentative conclusions the ME comes to. Tests for drugs, alcohol, and poisons may also be carried out to see if they played a role in the death. When the investigation is complete, the ME prepares a report which covers the essentials of the case and lays out a conclusion of the cause and manner of death.

While the cause of death can often be established by the ME, deciding on the manner is an opinion based upon their reading of the evidence and circumstances. They will record a verdict such as homicide, suicide, accident, or an open verdict. This opinion will not necessarily be accepted in court and may be challenged by the police, lawyers, or the victim's family. Thus, even if a verdict of homicide is returned by the medical examiner, the police will not necessarily bring a prosecution. Families often object to a verdict of suicide, in cases of drug overdose for instance, and will appeal for it to be changed to accidental death. The ME's verdict on the manner of death may also change if new evidence emerges. A death previously thought to be natural may turn out to be a homicide or suicide, for instance. Finally, it is the ME's job to prepare and sign the death certificate.

The medical examiner often works with a forensic investigator, who is the person who deals with the body at the crime scene. It is usually the forensic investigator who makes the first examination of the body and takes its temperature, which is needed to estimate the time of death. The investigator also directs the taking of photographs of the body and the removal of trace or insect evidence from it. Then the forensic investigator wraps and transports the body to the ME's office. Throughout, the body is in the custody of the medical examiner, while the crime scene is under the control of the police. The forensic investigator provides a useful interface between the two entities.

The forensic investigator often assists the medical examiner in the morgue, with the performance of the autopsy and the preparation of the autopsy report. The task of communication with family members, the media, and the police in matters relating to the ME's office might also fall to the forensic investigator. Finally, the forensic investigator may represent the ME by testifying in court.

The range of cases referred to the medical examiner can be very wide. He or she will be called in to look at any traumatic death that is due to injuries that could be homicidal, self-inflicted, or suicidal. The death need not, however, be violent to be referred. Any death that is unusual, unexpected, or in some way suspicious would have to be investigated. For instance, if a fit, healthy teenage girl was found dead in bed, this would be a clear case for the medical examiner. Sudden deaths occurring within hours of the onset of symptoms need to be examined also; this could indicate a poisoning, although such crimes are relatively rare these days. It is also usual for deaths in police custody, in prison, or during medical or surgical procedures to be investigated. Discovered bodies, such as those washed up on a seashore or found in a shallow grave, also clearly require a full investigation.

The medical examiner need not always perform an autopsy. The frequency with which this is done varies from place to place, but usually up to a quarter of reported deaths are followed up with an autopsy. Often, the deceased person's physician will be involved in the autopsy if it is felt that the death occurred from natural causes. Sometimes all that is needed to clarify a death is a cursory external examination. An experienced forensic pathologist will be able to assess the extent of the investigation needed. Some cases are challenging and it is always important for the medical examiner to come to the right conclusion. Often the medical examiner is the only expert witness that a judge and jury can rely on to explain complex medical matters.

SEE ALSO Autopsy; Death, cause of; Death, mechanism of; Pathology; Toxicology.

Medicine

Medicine is one of the branches of the health sciences. It deals with restoring and maintaining health, but is also used in determining the causes of death. It is a practical science that applies knowledge from biology, chemistry, and physics to treat diseases. Biological knowledge is derived from anatomy, biochemistry, **physiology**, histology, **epidemiology**, microbiology, genetics, **toxicology**, **pathology**, and many other disciplines. Biology forms the basis for understanding how the human body works and interacts with its environment. An understanding of chemistry is required to determine the interactions between different drugs, to detect chemicals in the body, and design drugs for treatment. Physics has an impact on understanding how the body works and on understanding how the various instruments and equipment are used in diagnosis and treatment. The need to understand interactions between all of these areas makes medicine one of the most complex scientific disciplines.

In its early days medicine was not based on science. Many aspects of it were considered forms of magic, encompassing everything from disease causes to treatments. This was because the disease process was not understood. There was no knowledge of infectious agents (such as bacteria and viruses). Therefore, unless the cause of a disease was obvious and visible, sickness was considered a punishment from gods or an interference of an evil spirit. As a result, some treatments were logical, while others were irrational and often involved magic incantations and spells.

The practice of medicine goes back to at least 3000 B.C., when the first written medical records appeared in Mesopotamia. Babylonian medical texts provided the first anatomical descriptions and an early code of conduct for doctors. Their understanding of diseases was very basic; they recognized trauma and **food poisoning**, but a lot of the illnesses were still a mystery. Despite advances in anatomy and surgery, ancient Egyptians, as the Babylonians before them, still believed in supernatural causes for many illnesses.

The scientific basis of medicine was laid down by Hippocrates, who rejected magical causes of diseases. He believed in medical examination and keeping detailed records of a disease history. His influence on medicine is present even today, in form of the "Hippocratic Oath," which all new doctors have to take. It sets out ethical guidelines for doctors.

The importance of clinical examination of the patient was made even more important by Claudius Galen, another Greek physician. He worked extensively on anatomy and experimented with live animals.

Great advances in all areas of medicine, especially in epidemiology and hygiene, took place in the middle ages. Avicenna, a Persian physician, was the first to recognize the contagious nature of tuberculosis. In his many works, he gave important advice to surgeons, especially on cancer treatment and advanced use of oral anesthetics (painkillers). Another great advancement of the times was the use of silk thread for stitching wounds, developed by Abul Qasim al-Zahrawi.

A number of scientific discoveries, starting from the late 1800s with the work of E. Jenner, L. Pasteur, R. Koch, A. Flemming and others, established that microbes are the cause of infectious disease; these diseases can be prevented by vaccinations; and there are drugs that can kill the infectious agents (microbes). These findings shaped modern western medicine.

Furthermore, discoveries in physics, such as x rays, ultrasounds, magnetic resonance, and lasers, led to the development of equipment that allows quicker and better diagnosis, as well as easier and safer surgical procedures.

As a result of these scientific and technological changes, the knowledge that medical students have to acquire is immense. Therefore, all doctors learn the same basics but later they have to specialize in narrower areas in order to be highly skilled and able to effectively treat all of the diseases of a particular organ or tissue.

There are doctors specializing in various areas of medicine, such as emergency medicine, intensive care medicine, internal medicine, pediatrics, surgery, neurology, obstetrics, and others. While obstetrics is a relatively narrow area, dealing with childbirth and female health, surgery or internal medicine is further subdivided into sub specializations. Some of those subspecialties are hematology (**blood** and its diseases), cardiology (heart and cardiovascular system), oncology (cancer), ophthalmology (eyes), orthopedic surgery (mostly skeletal system), or neurosurgery (brain). On the other hand, pediatrics deals with childhood diseases and most of the specialties and subspecialties have their pediatric equivalent. Some doctors specialize in narrow medical fields, while others specialize in areas requiring wide medical knowledge such as sport, aerospace, or forensic medicine.

The most important doctor for the majority of the population is the family doctor (or general practitioner, GP). It is the GP who makes the first examination and keeps a record of the medical history of the patient. He or she also makes an assessment if more tests are required before a diagnosis can be made or if a referral to a specialist is required.

The process of determining the cause of a disease and prescribing treatment is quite complex. It consists of clinical examination, diagnosis, and treatment.

Clinical examination can consist of a number of different aspects, including visual, pathological, toxicological, and genetic analysis. Visual examination addresses the general symptoms: a patient's appearance, heart rate etc. Pathological analysis is often required to identify any non-obvious cause of disease. The tests can include blood or urine analysis, electrocardiogram (ECG), ultrasound, computed tomography (CT) scan, biopsy, histology of removed tissues, or bacteriological analysis of body **fluids**. Most people have blood and urine tests during their lives. **Toxicological analysis** is usually carried out on blood, but can be done on tissue samples (bones or hair) and can detect alcohol, certain drugs, toxic metals, and other compounds (for example dioxins). Genetic testing is not usually required for the majority of patients, but in cases of inherited diseases, or genetic predisposition, they can be carried out. Often it is not just the adults that undergo this procedure. Amniotic fluid surrounding the embryo can be tested to determine if a child will develop a life-threatening disease.

Diagnosis is based on the combination of all of the examinations that have been performed and the accumulated knowledge of the doctor. Depending on the illness, it can be quick and simple or time consuming and difficult.

Treatment is the ultimate result of a visit to the doctor. It can include prescription of drugs, surgery,

Couple visits with their newborn who will be placed in foster care. Toxicology tests revealed that the baby was born addicted to cocaine.

or special diet. Any treatment can be simple or complex depending on the illness.

Not all doctors treat patients. Pathologists study disease processes. They analyze clinical tests and base their diagnosis on the results. They can work with isolated tissues and samples, or, in the case of forensic pathologists, the deceased. Pathological analysis is very important in the diagnosis of an illness in the case of regular pathology and in determining a **cause of death** in forensic pathology. Forensic pathology is a part of a forensic medicine, a branch of medicine answering questions important to the law.

Forensic medicine is important in determining the cause of death, **time of death**, and **identification** of the remains. This allows doctors to determine the cause of death as accident, suicide, or **murder**. A forensic pathologist describes the state of the body (**decomposition** if any), and subsequently examines the body for a cause of death, but also notes any abnormalities found on the surface or in the tissues. The surface of the body is initially checked for the presence of trauma injuries (bruises, broken bones), cuts or stab wounds, thermal injuries (burns), firearm injuries (gunshot wounds), or **defensive wounds**. An internal examination of the body is carried out on organs or isolated tissues (histology). It might reveal presence of water in lungs (drowning), or asphyxia (lack of oxygen).

The analysis of a corpse is often carried out in the same way as for normal patients using x rays, toxicology, and genetics. Forensic medicine requires great attention to detail and a wide medical knowledge, especially in the areas of anatomy and physiology.

Modern western medicine is not the only existing medical system. There is also traditional medicine and complementary or alternative medicine. Traditional medicine includes folk and indigenous practices. The best known and most widely accepted areas are Chinese medicine and western herbal medicine. Complementary medicine uses non-invasive and non-pharmaceutical methods. Examples of alternative treatments include yoga, chiropractic or osteopathic manipulation, or various massage methods, as well as many others.

The first written evidence of Chinese medicine comes from 1766 B.C. The philosophy of medicine and methods used by Chinese doctors differed widely from those of the ancient Mediterranean and current modern medicine. The Chinese have based their medicine on a philosophy of yin and yang, and on The Five Elements (metal, wood, water, fire, and earth). A healthy person would have a harmonious mix of these elements. Among the practices developed in Chinese medicine are acupuncture, moxibustion (a technique that involves the use of heat, through burning specific herbs, to facilitate healing), and traditional herbal medicines. A physical examination with a doctor can include detailed interview, pulse taking, breath analysis, and tongue inspection. Some of the traditional Chinese treatments are quite widely accepted by modern western medicine, for example acupuncture.

A new approach to practicing medicine is the development of integrative medicine. It combines the modern western practices with alternative treatments. It only accepts methods for which there is scientific evidence for safety and effectiveness. Acupuncture, herbal treatment, music, and massage therapy are just some of the accepted treatments. The aim of this approach is not to just treat the illness, but to provide support to patients and induce their general well-being.

SEE ALSO Autopsy; Epidemiology; Pathology.

Medicolegal death

Medicolegal death is the term used to describe any unclear or vaguely suspicious death that must be investigated such as unexpected, sudden, or violent deaths. Besides all cases of homicides such as those involving criminal violence, medicolegal death investigations usually include persons who were in detention centers and jails, in apparently good health, poisoned, apparent suicides, with diseases that could threaten the health of the public, undergoing medical treatment (or when death occurred less than 24 hours after admission to a hospital) or a surgical procedure, infants and children, prominent or famous involved with accidents, or unclaimed after death.

Generally, members of the medical examiner's office or coroner's office are authorized to investigate all medicolegal deaths. The basic tool used in any death investigation is the **autopsy**, either a medical examination performed by a pathologist in order to determine the **cause of death** or a medicolegal examination performed by a **medical examiner** (and ordered by legal authorities) in order to ensure that justice is carried out and to determine the cause of death under the auspices of medicolegal death. During a medicolegal autopsy, a law enforcement representative, such as the investigating police detective at the crime scene, will be present during the examination in order to contribute any information that might be important to the investigation. In addition, relatives or friends of the deceased may be asked to make a positive **identification** either at the scene of the crime or later during the medicolegal autopsy.

The series of steps that is usually required for a medicolegal autopsy include: (1) an examination of the scene of the death (such as taking photographs of the body and the surrounding area), (2) an identification of the body (with the help of photographic identification cards and acquaintances of the victim), along with appropriate tagging of the body, (3) an external examination of the corpse (including a detailed description of all injuries and wounds), (4) a dissection and internal examination (including skeletal and dental characteristics), along with a recorded verbal account of the autopsy, and (5) a toxicological examination of all body **fluids**, organs, and tissues (for **evidence** of alcohol, drugs, poisons, and other relevant forensic substances).

SEE ALSO Autopsy; Coroner; Death, cause of; Identification; Medical examiner; Pathology; Toxicology.

Mens rea

To hold a person criminally responsible before law, *mens rea* must be established. *Mens rea*, from the Latin *mens*, meaning mind and *rea*, meaning guilty or guilty mind, is presently established according to several criteria.

Consideration for criminal responsibility can involve intent, knowledge or recognition of one's own acts, recklessness (irresponsible acts that put at risk or cause harm to a third part's well being or property), and negligence (willful omission in exercising the proper care of a person or property under the individual's responsibility, or the failure in providing a service as required by law under the circumstances). *Mens rea* is therefore the basis of legal accountability both in civil and criminal courts. In its absence, or if the offender's *mens rea* is diminished or impaired due to a mental disorder or another circumstance, the offender cannot be blamed or punished by his act or omission. In other words, the prosecution has to prove that the accused not only committed the offense, but also that the individual had the required state of mind to be legally responsible for the act.

Criminal responsibility is often questioned by defense lawyers on the grounds of temporary or chronic insanity. These grounds require the assessment of the defendant by forensic psychiatrists and the testimony of the psychiatrist in court. As a general rule, criminal offenders diagnosed as not responsible for their acts by reason of mental retardation or a psychiatric disorder, will be, at the court's discretion, subjected to compulsory confinement or hospitalization in a psychiatric institution for treatment. Legislation of each country regulates the extension, duration, termination, and supervision of treatment and reclusion of mentally ill offenders.

Because criminal responsibility implicates liability for punishment, the establishment of *mens rea* has been required in some countries for centuries. This legal principle has been known and required since the thirteenth century in some European countries such as Italy and Scotland. However, the admission of **expert witnesses** to assess mental capacity in criminal courts is a relatively recent practice that encountered much resistance during the last decades of the nineteenth century, when psychiatry was still in its infancy. In the United Kingdom, the Report of the Royal Commission on Capital Punishment stated that criminal responsibility should not be founded solely on legal principles, but also on the establishment of moral responsibility. The report defined moral responsibility as the ability of a person to know that their action was legally and morally wrong, according to the criminal law and the moral standards of the community. Much controversy existed about whether or not it was possible to establish such moral responsibility. The English physician and philosopher John Locke (1632–1704), for instance, argued that a person's actions are completely separated from his thoughts. Later the English Lady Wootton stated that not even science could provide any answers to the questions concerning the moral responsibility of an individual. In 1863, an English judge recommended jurors to "not be deprived of the exercise of your common sense because a gentlemen comes from London and tells you scientific sense."

The common law test to establish criminal responsibility, known as M'Naghten rule, originated in Great Britain in the nineteenth century and was later applied in the United States. Daniel M'Naghten was what is now defined as a paranoid schizophrenic who murdered the secretary to British Prime Minister Robert Peel in 1843. M'Naghten was acquitted under the grounds of delusion and lack of control over his actions, and sent to a mental institution instead of receiving the capital penalty. His case, in addition to other previous similar judicial decisions, established by common law the M'Naghten rule, which assumed that if an individual could distinguish right from wrong, he or she was not insane and therefore, was criminally responsible. Conversely, if the offender was not able to make such distinction, insanity was established and acquittal was required.

Some English jurists have criticized the ambiguities of the standards for insanity under the M'Naghten rules and have proposed three parameters for acquittal of criminal responsibility: the illegality standard, the subjective moral standard, and the objective moral standard. The illegality assumed that if the offender lacked the capacity to understand that his acts were against the law, he could not be held accountable for those actions. The second standard stated that those offenders suffering from a disease of the mind that caused a delusional belief of being morally justified in their actions or that God dictated their acts, should be considered mentally insane and not criminally responsible. The third standard assessed the capacity for understanding the social moral standards and the capacity to abide by them. The United States, Tasmania, and Queensland have added another parameter to these rules, that of partial insanity and irresistible impulse, which characterize diminished responsibility, implying that if a person was under a temporary delusion, even if not insane, mitigation of responsibility (and penalty) could be considered by the defense. In Great Britain, however, due to the many cases of acquittal and even release of offenders who made attempts against the lives of members of the royal family and other political personalities, such revisions of the test by the Atkin Committee on Insanity and Crime in 1923, and by the Royal Commission on Capital Punishment in 1953 were rejected by the Judiciary. Queen Victoria even tried to change the Trial of Lunatics Act of 1883 to an "insane but guilty" connotation. However, the common law was maintained, with the special verdict of insanity implying a qualified acquittal, although not an absolute acquittal. More recently, the American model penal code required the establishment of a lack of substantial capacity by the offender to conform his behavior to the law and admit insanity defense pleas.

Diminished responsibility due to partial insanity existed in Scottish penal law since the seventeenth century. It did not imply acquittal, but only penalty mitigation, by changing the charge from **murder** to **manslaughter**. Partial insanity was defined as an abnormality of the mind arising from a condition of arrested or retarded mental development, or a disease or injury that significantly impaired mental responsibility for acts or omissions in relation to a killing. Therefore, manslaughter opened a wide range of possibilities for courts, which ranged from conviction for life, or compulsory commitment to a mental institution, to absolute acquittal.

It is important to emphasize that all the above descriptions and definitions of insanity were non-scientific in nature and the tests were merely cognitive, as medical psychiatry was still in its infancy. The first attempts to assess criminal responsibility in courts used non-specialist physicians and even apothecaries as expert witnesses, during the late nineteenth and early twentieth centuries, both in England and the U.S., with convictions or acquittals due much more to lawyers' rhetorical skills than to sound scientific data. When psychiatrists began to serve as expert witnesses, a standardized psychiatric evaluation procedure was not still in use, often giving rise to allegations of inferential, inconclusive diagnoses from both the prosecution and the defense.

Forensic psychiatry is a relatively recent specialty that differs from clinical psychiatry in its objectives. While clinical psychiatry aims at diagnosing and treating neuropsychiatric disorders, forensic experts must establish to courts whether an offender was, at the time the offense was committed, mentally impaired or sane. In the first case, a precise diagnosis and the explanation of how the mental condition interferes with the cognitive, emotional, and behavioral capacities of the offender is necessary. Forensic psychiatry is a sub-field of psychiatry that requires special **training** in order to perform specific types of clinical assessments and diagnoses, such as retrospective, transversal, or prospective assessments to prosecutors, defense lawyers, probation boards, judges, and police investigators. The adoption of psychiatric diagnostic guidelines by several countries in the last 20 years gave the forensic experts a new level of credibility in courts, thanks to the advances in neurosciences and diagnostic resources and technologies.

A more clear description in the last 30 years of biological factors associated with each psychiatric disorder and the detailed description of related symptoms, led to the publication of the *Clinical Descriptions and Diagnostic Guidelines* and the *Diagnostic Criteria for Research* of psychiatric disorders by the World Health Organization (WHO), which is used by several countries around the world to establish forensic criminal responsibility. In the United States, the American Psychiatric Association (APA) is responsible for the guidelines used by forensic psychiatrists, published under the title *Diagnostic and Statistical Manual of Mental Disorders*. WHO and APA guidelines are regularly updated to incorporate new scientific information and diagnostic techniques. Such advances and improvements in science and law released the task of establishing *mens rea* from the realm of conjecture and philosophical arguments, and gave it the status of an objective evidence-based scientific field. In many countries, forensic psychiatry has become a field of expertise apart from clinical psychiatry, and a qualified psychiatrist is the only expert witness recognized in court to establish criminal responsibility.

SEE ALSO Criminal profiling; Expert witnesses; Federal Rules of Evidence; Psychiatry; Psychology; Psychopathic personality.

Metal detectors

Metal detectors use electromagnetic fields to detect the presence of metallic objects. They exist in a variety of walk-through, hand-held, and vehicle-mounted models and are used to search personnel for hidden metallic objects at entrances to airports, public schools, courthouses, and other guarded spaces; to hunt for landmines, archaeological artifacts, and miscellaneous valuables; and for the detection of hidden or unwanted metallic objects in industry and construction. Metal detectors detect metallic objects, but do not image them. An x-ray baggage scanner, for example, is not classed as a metal detector because it images metallic objects rather than merely detecting their presence.

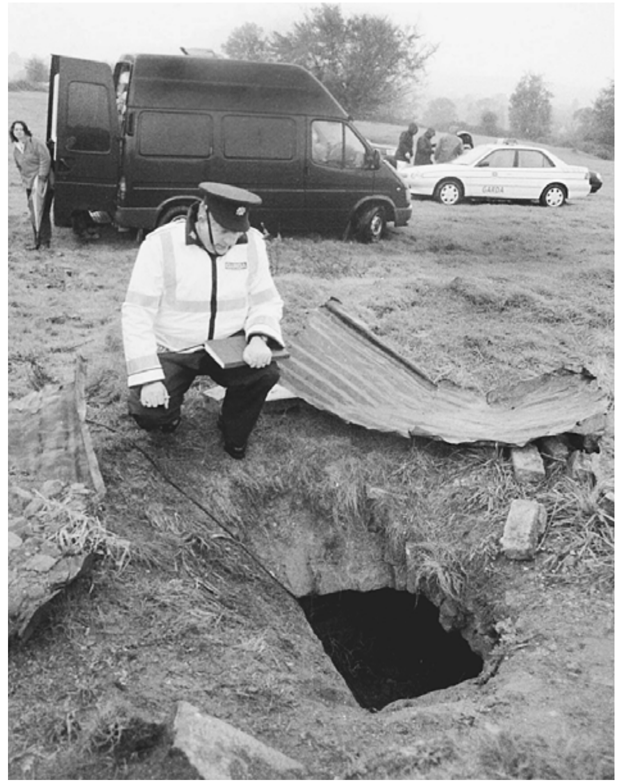
Metal detectors use electromagnetism in two fundamentally different ways, active and passive. Active detection methods illuminate some detection space—the opening of a walk-through portal, for example, or the space directly in front of a hand-held unit—with a time-varying electromagnetic field. Energy reflected from or passing through the detection space is affected by the presence of conductive material in that space; the detector detects metal by measuring these effects.

Passive detection methods do not illuminate the detection space, but take advantage of the fact that every unshielded detection space is already permeated by the Earth's natural magnetic field. Ferromagnetic objects moving through the detection space cause temporary, but detectable, changes in this natural field. (Ferromagnetic objects are made of metals, such as iron, that are capable of being magnetized; many metals, such as aluminum, are conducting but not ferromagnetic and cannot be detected by passive means.)

Walk-through or portal detectors are common in airports, public buildings, and military installations. They bracket their portal with two large coils or loop-type antennae, one a source and the other a detector. Electromagnetic waves (in this case, low-frequency radio waves) are emitted by the source coil into the detection space and interact with objects there. When the electromagnetic field of the transmitted wave impinges on a conducting object, it induces transient currents on the surface of the object; these currents, in turn, radiate electromagnetic waves. These secondary waves are sensed by the detector coil.

Metal detectors small enough to be hand-held are often used at security checkpoints to localize metal objects whose presence has been detected by a walk-through system. Forensic investigations can also utilize hand-held metal detectors. Some units are designed to be carried by a pedestrian scanning for metal objects in the ground (e.g., nails, loose change, landmines). All such devices operate on variations of the same physical principle as the walk-through metal detector, that is, they emit time-varying electromagnetic fields and listen for waves coming back from conducting objects. Some ground-search models further analyze the returned fields to distinguish various common metals from each other.

Gradiometer metal detectors are passive systems that exploit the effect of moving ferromagnetic objects on the Earth's magnetic field. A gradiometer is an instrument that measures a gradient—the difference in magnitude between two points—in a magnetic field. When a ferromagnetic object moves through a gradiometer metal detector's detection space, it causes a temporary disturbance in the Earth's magnetic field, and this disturbance (if large enough) is detected. Gradiometer metal detectors are usually walk-through devices, but can also be mounted on a vehicle such as police car, with the intent of detecting ferromagnetic weapons (e.g., guns) carried by persons approaching the vehicle. Gradiometer metal detectors are limited to the detection of ferromagnetic objects and so are not suitable for security situations where a would-be evader of the system is likely to have access to nonferromagnetic weapons.



Irish police officer examines the entrance to an underground bunker said to be a firing range for the Irish Republican Army in 1999. Police searched nearby fields with metal detectors after discovering a weapons cache in the bunker. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

The magnetic imaging portal is a relatively new technology. Like traditional walk-through metal detectors, it illuminates its detection space with radio-frequency electromagnetic waves; however, it does so using a number of small antennas arranged in a ring-like formation around its portal, pointing inward. Each of these antennas transmits in turn to the antennas on the far side of the array; each antenna acts as a receiver whenever it is not transmitting. A complete scan of the detection space can take place in the time it takes a person to walk through the portal. Using computational techniques adapted from computed axial tomography (CAT) scanning, a crude image of the person (or other object) inside the portal is calculated and displayed. The magnetic imaging portal may for some purposes be classed as a metal detector rather than as an imaging system because it does not produce a detailed image of the metal object detected, but only reveals its location and approximate size.

SEE ALSO Crime scene investigation.

Meteorology

Meteorology, the study of the atmosphere, is a related field of **geology** used by forensic investigators, lawyers, and prosecutors to look for specific information to be used in court when climate conditions are of relevance in explaining an event. The term meteorology originates from the Greek, *meteoros*, for airborne, and *logos*, for discourse or study.

Meteorologists may be requested by courts or by companies to give information necessary for reconstructing ship or airplane accidents, or on wind chills affecting outdoor workers, or to present a detailed weather reconstruction for a given area on a particular day. Meteorologists are sometimes requested to explain events associated with air pollution and airborne spread of dangerous substances, or to clarify whether a given meteorological event is abnormal or expected in a certain region and period of the year.

Forensic meteorologists may also help in crime investigations. For instance, they can calculate the wind and ocean currents in a particular body of water and thus indicate the most probable area where a disabled boat or even a corpse could be washed onshore.

Mankind has been intrigued since antiquity by meteorological phenomena such as sudden climate changes, the cycle of seasons, and the origins of winds, lightning bolts, storms, and tides. However, meteorology is a relatively young science whose importance and impact on the economic activities and military strategic planning became increasingly evident in the industrial era. Agricultural communities have regulated their activities for thousands of years through the empirical observation of local climatologic cycles. But weather prediction was a very imprecise and challenging task until the end of World War II (1939–1945). The date for the invasion of Normandy by the Allied forces, the famous D day, had to be changed several times because of such limitations. The field was able to remarkably advance after satellites, Doppler radar, and computer technologies allowed the development of more efficient research methods for the understanding and prediction of meteorological phenomena.

Climate variations are determined by the interchange between the atmosphere and terrestrial topography, with noticeable differences in temperature, moisture, and pressure between two localities of a given area due to such features. A large body of water, or the presence or absence of forests and mountains are topographic factors responsible for climate variations, known as local effects. For instance, a mountain chain running parallel to a coastal seashore functions as a dividing barrier, with different local effects on opposite sides of the mountains. Big cities also function as topographic factors, with their industrial and automotive emissions of carbon dioxide increasing the local temperature and changing the patterns of rain and snow precipitation compared with the surrounding countryside. Differences in air temperatures over the sea and coastal lands give rise to breezes and winds that circulate between the two surfaces. Breezes usually start blowing from the sea to the land in the morning, increasing speed until mid afternoon, and then reversing direction in late afternoon and during the night. The main reason for this event is that the air over land heats faster than over the ocean. Water absorbs a great amount of solar radiation and slows down the heating process of the air, whereas land surfaces reflect most of the radiation to the atmosphere. As air temperature rises, atmospheric pressure lowers over the land, allowing the air to move from the sea to land. At night, however, land surfaces loose heat faster than water, causing the wind direction to reverse.

The presence of a maritime current of cold or warm water flowing along a coastline also will interfere with wind patterns as well as the presence of a mountain chain nearby the coastline. Mountains create their own thermal circulations, even when atmospheric pressures are weak, because of the heating variations among different altitude gradients. Air over the valleys heats faster than over the mountain slopes, creating the anabatic air currents that move toward the mountaintop. At evening, the current reverses, and the katabatic winds move down from the mountaintops to the valleys. Anabatic winds are more frequent and stronger in summer and in tropical regions, whereas katabatic winds are more frequent in wintertime and in temperate latitudes. Mountain chains along the coastal line have anabatic, or upwardly moving, winds increased by the breeze blowing from the ocean. They also act as a partial barrier against sea wind propagation toward inland, and promote the formation of cumulus clouds on mountaintops because air is gradually cooled and water vapor condenses as it ascends. Late afternoon or evening precipitation is common in tropical coastlines with these topographic features.

Winds blowing perpendicular to mountain slopes create phenomena known as convergence, by forcing the air around the slopes to move upward, being

A researcher poses by blocks of ice, some as big as basketballs, in a lab in Spain. Chemical analysis helped determine meteorological condiitons that enabled the ice chunks to fall from Spanish skies over a 10-day period in 2000. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

continuously deflected by the wind as they rise. When the air reaches the top, a strong current is released and sinks on the other side, except when a temperature inversion is present near the mountain summits. Temperature inversion refers to a descending air mass that is warmer than the ascending air. When the ascending air encounters the warmer, less-dense air, it loses pressure and a wavelike turbulence pattern is formed, known as lee waves or orographic waves, which are felt as a "bumpy road" when airplanes fly through them. When a large front of cool high-pressure air descends from higher altitudes and encounters a large warm low-pressure front, complex interactions take place. These may lead to the onset of tropical storms, gusty winds, thunderstorms, or tornadoes, depending on the particular conditions of the resulting super cell.

SEE ALSO Accident investigations at sea; Accident reconstruction; Aircraft accident investigations; Careers in forensic science; Crime scene reconstruction; Geology; Satellites, non-governmental high resolution.

Method of operation (M.O.)

The concept of method of operation (M.O.) or *modus operandi*, as it has been historically termed, is a means of identifying a single perpetrator in a series of criminal events. Forensic **evidence** such as crime scene photographs, **physical evidence**, **autopsy** photographs and report, and an extremely detailed study of the characteristics of the criminal's behavior is compiled. Methodology, weapons, means of victim acquisition, location of crime, victim demographics, methods and types of ligatures or bindings, and crime-scene characteristics are also compiled and analyzed in order to create a picture of the unique perpetrator, as well as to link geographically or temporally remote crimes that were previously believed to be unrelated, but that actually encompass a serial pattern.

The offender's method of operation undergoes an evolutionary process, one that changes as he or she becomes more skilled at committing a particular act (or a series thereof). That is, the perpetrator learns to be more successful at achieving his or her particular aim in the commission of the crime over time (with practice, skills improve). Another aspect of the M.O. is referred to as the signature, consisting of those behaviors emitted but not actually required in the commission of the crime. Signature behaviors are suggestive of the personality of the offender and help to distinguish similar or copycat offenses. Some examples of signature behaviors are use of specific ligature or binding materials, type and order of knots used, repeated unusual injuries such as laceration pattern, bites, disfiguration, mutilation, amputation of specific regions, evidence of torture or sadistic injuries, location and type of crime scene, victim posture, body arrangement, and actual messages left at the crime scene or divulged to the media.

The study of criminal method of operation offers the forensic investigator a window into the psyche of the perpetrator; it is a means of identifying or characterizing a criminal by his or her behavior, motivation for commission of particular acts, victim choice, and crime scene characteristics. By diligent development of the specific perpetrator's M.O., it is possible to link crimes committed in different parts of the country (or the world), across time and across venues. Because people have become progressively more able to move rapidly from place to place, it is possible for a single perpetrator to commit crimes in multiple areas within short periods of time. Successful analysis and identification of an individual's M.O. can facilitate rapid identification of an offender, and markedly increase ease or rapidity of apprehension.

SEE ALSO Antemortem injuries; Autopsy; Bite analysis; Body marks; Cold case; Criminal profiling; Physical evidence; Psychological profile.

Micro-fourier transform infrared spectrometry

Spectrometry of various kinds is used in the laboratory analysis of **trace evidence**, because it can produce a chemical "fingerprint," which helps in **identification** and comparison. Fourier transform infrared spectrometry (**FTIR**) is a particularly useful tool for the forensic scientist because it allows the analysis of such a wide variety of trace **evidence** including paint, drugs, lubricants, cosmetics, and adhesives. Micro-fourier transform infrared spectrometry combines a microscope with an FTIR instrument, providing even more information because microscopic examination is always the first step in the examination of trace evidence.

The basic technique of micro-FTIR is infrared spectrometry. Fourier transformation is a mathematical process that improves the quality of the signal at the detector. Infrared spectrometry can provide chemical fingerprints for both organic and **inorganic compounds** that are components in trace evidence. It works on the principle of chemical bonds absorbing energy in the infrared region of the **electromagnetic spectrum**. The frequency at which a bond absorbs energy depends upon its polarity, that is, the nature of the constituent atoms making up a bond. A carbon-hydrogen bond absorbs energy at a different frequency from a carbon-carbon bond, for instance.

The sample is inserted into the FTIR machine and then exposed to a scan of different infrared frequencies over the whole of the infrared range. As each bond absorbs energy, a peak appears on the detector. The scan produces a fingerprint, or spectrum, that is characteristic of that compound. Mixtures of compounds also give characteristic fingerprints. Research has produced huge libraries of reference infrared fingerprints for known compounds and products. Therefore, the spectrum of the trace evidence can be compared, by rapid computer analysis, with reference samples that should provide an identification match. Micro-FTIR can also be used in comparison work—comparing a flake of paint from the scene of a crime to a **reference sample** taken from a suspect's car, for instance, which could be helpful in investigating a hit and run accident. The technique has also been found particularly useful in the analysis and comparison of hairs and **fibers**.

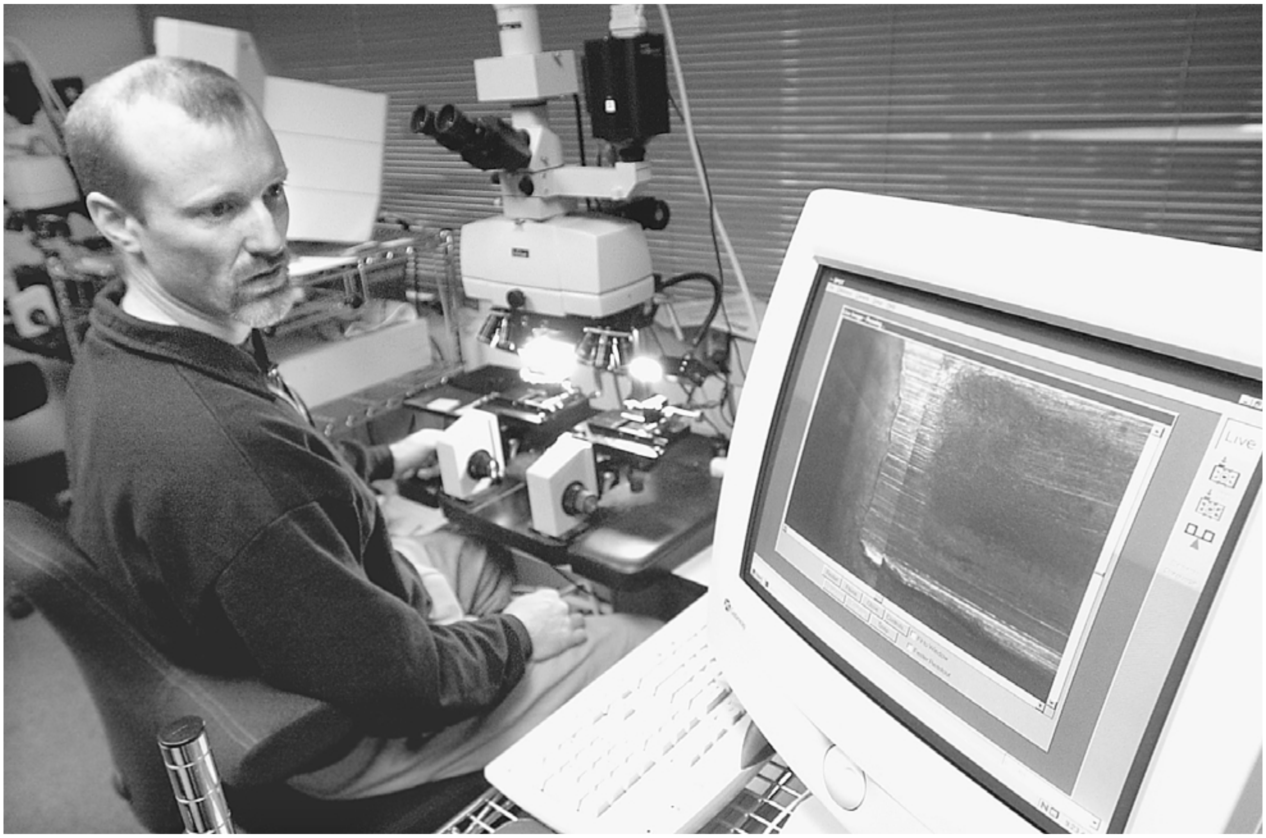
SEE ALSO Infrared detection devices; Microspectrophotometry.

Microphones SEE Bugs (microphones) and bug detectors

Microscope, comparison

A comparison microscope is a device used to observe side-by-side specimens. It consists of two **microscopes** connected to an optical bridge, which results in a split view window. The comparison microscope is used in forensic sciences to compare microscopic patterns and identify or deny their common origin. Without this device, the **identification** of **toolmarks** and **firearms** would be such a cumbersome process that it would be carried out on a very limited basis.

The idea behind the comparison microscope is simple. Two microscopes are placed next to each other and the optical paths of each microscope are connected together by the optical bridge. The optical bridge consists of a series of lenses and a mirror that brings the two images back together at the single eyepiece. The user looks through the eyepiece as with a regular microscope, except that a line in the middle separates the circular view field into two parts. The left side of the view field is the image produced by the left microscope, and the right side of the view field is the image produced by the right microscope. In some more modern or sophisticated comparison microscopes, it is also possible to superimpose the view fields generated by the two microscopes. This is particularly convenient when the forensic scientist compares impressed patterns rather than striated patterns. It is important that the two microscopes are identical. In order for a comparison to be valid, the two images produced in the circular view field needs to be at the same magnification and present the same lens distortion (if any). Comparison microscopes are mostly used in a reflected light setting, but a transmitted light setting is also available in some instances, and fluorescent light settings are found on higher-end models. This



An Oregon State Police forensic scientist uses a comparison microscope on two bullets for firearms identification at the crime lab in Portland, Oregon, 2003. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

allows for comparison of more than just bullets and toolmarks.

Use of a comparison microscope is straightforward. The incriminated impression, typically a bullet or casing found at a crime scene or a toolmark's cast from a crime scene, is placed under the left microscope and thus, appears in the left part of the circular view field. A comparison impression, such as a bullet fired from a revolver found on a suspect, is placed under the right microscope and thus, appears in the right part of the view field. When comparing striations, the forensic scientist moves the comparison object until the striations match the ones present on the incriminated object. If the striations do not present similarities, then the two objects cannot be associated with a common origin. If the striations match, then a common source between the two objects is established. When comparing impression marks, the forensic scientist can use the superimposition option and, again, by moving the comparison object on the right, try to find common characteristics between the two objects.

The comparison microscope is used to compare **impression evidence** that requires a magnification ranging from 5× to approximately 100×. Items that are commonly observed under the comparison microscope are fired bullets, fired casings, and toolmarks. These items are observed under a reflected light setting. Other **evidence**, including impressions of serial numbers or characters from a typewriter, can also be compared using the comparison microscope. These are compared using a reflected light setting. This comparison might allow for the link between a stamped serial number and a die or between a sheet of paper bearing characters and the typewriter that was used to write it. The comparison microscope is also used to compare layers of a paint chip. This might allow for the identification of the vehicle from which the paint originated. Finally, when used in a transmitted light setting, hair, **fibers**, or the extruding striations of plastic bags can be compared. This allows the comparison of fibers found on a seat with the clothing of a suspect, for example. Plastic bag striations might establish links between different plastic bags and to demonstrate that they originate from the same batch. This is particularly useful with the small bags used to sell drugs. When dealing with fibers and plastic bags, the comparison microscope can also be used in an ultraviolet light setting or a polarized light setting.

The comparison microscope was invented in the 1920s by American Army Colonel Calvin Goddard (1891–1955) who was working for the Bureau of Forensic **Ballistics** of the City of New York. Goddard also benefited from the help of Colonel Charles Waite, Philip Gravelle, and John Fisher. At that time, the comparison microscope was used to compare fired bullets and casings. In the late 1920s, Swedish criminalist **Harry Söderman** (1902–1956) drastically improved the comparison microscope by inventing a system for rotating the bullets under the objectives. This allowed for a much faster comparison of lands of grooves of bullets by simultaneous rotation of both the suspect and comparison bullets. Söderman gave the name Hastoscope to his invention.

SEE ALSO Criminalistics; Drugfire; Integrated Ballistics Identification System (IBIS).

Microscopes

A microscope is the instrument that produces the high magnification image of an object that is otherwise difficult or impossible to see with the unaided eye. A microscope's resolving power allows the user to differentiate two objects from one another that could not be distinguished with the naked eye.

Microscopes assume a central role in **forensic science**. Forensic **evidence**, particularly **trace evidence**, is often so tiny as to escape detection with the naked eye. But the magnified examination of samples can reveal a great deal of detail. For example, examination of **gunshot residue** using a scanning electron microscope can allow an investigator to determine the shape of the spent residue and even its elemental composition, both of which are critical to the **identification** of the gunpowder used. The microscope can aid in matching the residue on a victim to residue present on a suspect. As another example, examination and identification of **fibers** would be impossible without the use of light microscopy.

Microscopic examination of documents can reveal information that cannot otherwise be seen. The high magnification and analysis possible using specialized techniques of scanning and transmission electron microscopy can reveal the presence of material that is otherwise undetectable in the elements that make up a sample.

Today's sophisticated use of microscopes in forensic analysis had its beginnings hundreds of years ago. In ancient and classical civilizations, people recognized the magnifying power of curved pieces of glass. By the year 1300, these early crude lenses were being used as corrective eyeglasses.

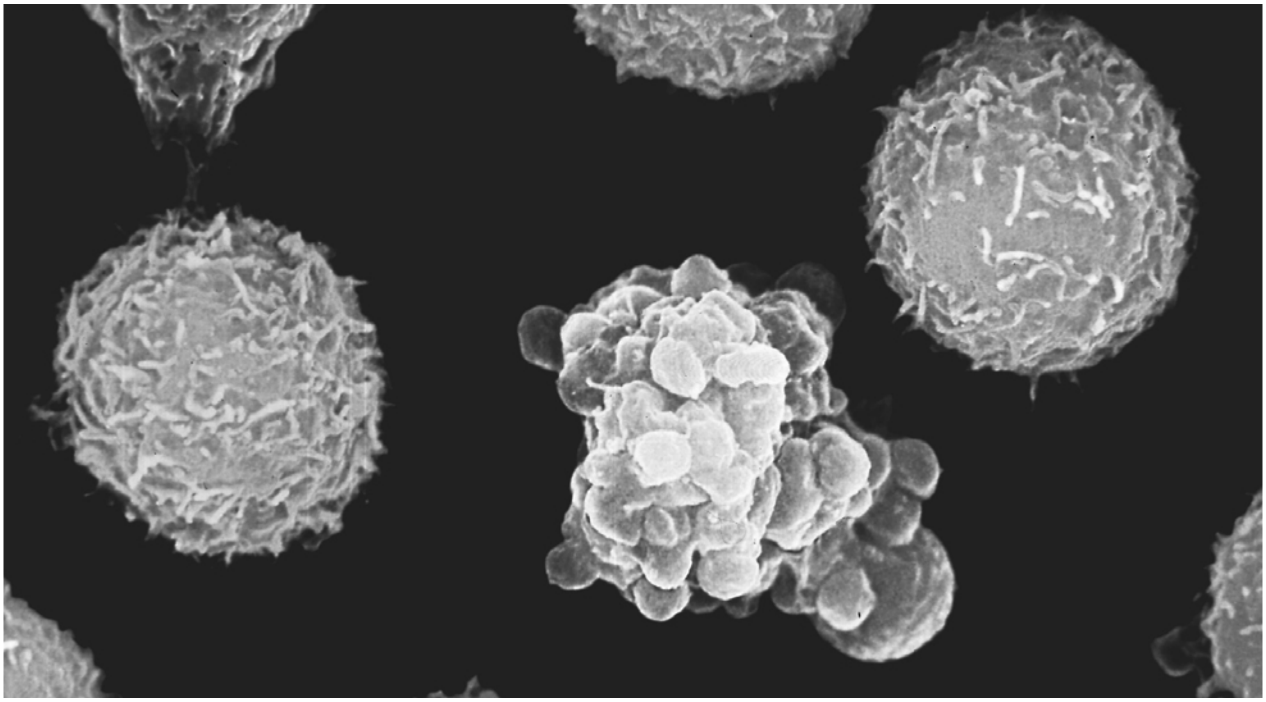
In the seventeenth century Robert Hooke published his observations of the microscopic examination of plant and animal tissues. Using a simple two-lens compound microscope, he was able to discern the cells in a thin section of cork. The most famous microbiologist of this century was Antony van Leeuwenhoek (1632–1723). Using a single lens microscope that he designed, Leeuwenhoek described microorganisms in environments such as pond water. His were the first descriptions of bacteria and red **blood** cells.

By the mid-nineteenth century, refinements in lens grinding techniques had improved the design of light microscopes. Still, advancement was mostly by trial and error, rather than by a deliberate crafting of a specific design of lens. It was Ernst Abbe who first applied physical principles to lens design. Abbe combined glasses that bent light beams to different extents into a single lens, reducing the distortion of the image.

The resolution of the light microscope is limited by the wavelength of visible light. To resolve objects that are closer together, the illuminating wavelength needs to be smaller. The adaptation of electrons for use in microscopes provided the increased resolution.

In the mid-1920s, Louis de Broglie suggested that electrons, as well as other particles, should exhibit wavelike properties similar to light. Experiments on electron beams a few years later confirmed this hypothesis. This was utilized in the 1930s in the development of the electron microscope.

There are two types of electron microscope: the transmission electron microscope (TEM) and the scanning electron microscope (SEM). The TEM transmits electrons through a sample that has been cut so that it is only a few molecules thin. Indeed, the sample is so thin that the electrons have enough energy to pass right through some regions of the sample. In other regions, where metals that were added to the sample have bound to sample molecules, the electrons either do not pass through as easily, or are restricted from passing through altogether. The different behaviors of the electrons are detected on



Scanning electromicrograph of apoptosis (center) showing cell death due to normal cellular processes rather than injury.

special film that is positioned on the opposite side of the sample from the electron source.

The combination of the resolving power of the electrons, and the image magnification that can be subsequently obtained in the darkroom during the development of the film, produces a total magnification that can be in the millions.

Because TEM uses slices of a sample, it reveals internal details of a sample. In SEM, the electrons do not penetrate the sample. Rather, the sample is coated with gold, which causes the electrons to bounce off of the surface of the sample. The electron beam is scanned in a back and forth motion parallel to the sample surface. A detector captures the electrons that have bounced off the surface, and the pattern of deflection is used to assemble a three dimensional image of the sample surface.

In the early 1980s, the technique called scanning tunneling microscopy (STM) was invented. STM does not use visible light or electrons to produce a magnified image. Instead, a small metal tip is scanned very close to the surface of a sample and a tiny electric current is measured as the tip passes over the atoms on the surface. When a metal tip is brought close to the sample surface, the electrons that surround the atoms on the surface can actually “tunnel through” the air gap and produce a current through the tip. The current of electrons that tunnel through the air gap is dependent on the width of the gap. Thus, the current will rise and fall as the tip encounters different atoms on the surface. This current is then amplified and fed into a computer to produce a three dimensional image of the atoms on the surface.

Without the need for complicated magnetic lenses and electron beams, the STM is far less complex than the electron microscope. The tiny tunneling current can be simply amplified through electronic circuitry similar to circuitry that is used in other electronic equipment, such as a stereo. In addition, the sample preparation is usually less tedious. Many samples can be imaged in air with essentially no preparation. For more sensitive samples that react with air, imaging is done in vacuum. A requirement for the STM is that the samples be electrically conducting, such as a metal.

Scanning tunneling microscopes can be used as tools to physically manipulate atoms on a surface. This holds out the possibility that specific areas of a sample surface can be changed.

Other forces have been adapted for use as magnifying sources. These include acoustic microscopy, which involves the reflection of sound waves off a specimen; x-ray microscopy, which involves the transmission of x rays through the specimen; near field optical microscopy, which involves shining light through a small opening smaller than the wavelength of light; and atomic force microscopy, which is similar to scanning tunneling microscopy but can be applied to materials that are not electrically conducting, such as quartz.

SEE ALSO Fibers; Fluorescence; Microscope, comparison; Polarized light microscopy; Scanning electron microscopy; Scanning electron microscopy; Trace evidence.

Microscopy, confocal SEE Confocal microscopy

Micro-spectrophotometry

Micro-spectrophotometry (MSP) is an essential tool in the forensic analysis of many kinds of **trace evidence**. It uses either visible or infrared light to determine the light transmission, absorption, or reflectance properties of a material. MSP is particularly valuable in the investigation of hair, textile **fibers**, and paint.

The chemical bonds within the molecular components of trace **evidence** interact with light in a characteristic way. They will absorb, transmit, or reflect specific frequencies of visible and infrared light. When we see a piece of cloth as red, for example, this means that although white light falls upon the material, all the color frequencies making it up except red are absorbed by the dye molecules in the material. It is therefore the red frequencies of light that are reflected back. A blue cloth contains different dye molecules, which reflect back only blue frequencies. MSP is a more sophisticated and highly accurate way of recording exactly what color an object is.

When an opaque or translucent specimen is inserted into an MSP instrument, it is exposed to a range of visible or infrared frequencies. The frequencies where it reflects, absorbs, or transmits, depending on the mode of the instrument, are recorded at a detector as a spectrum or fingerprint of that material. Comparisons can be made with materials whose spectra are held in databases. It is also possible to compare a piece of trace evidence with a control sample. A fiber found at the scene of the crime can be compared with one found on a suspect's clothing, for instance. If the two fibers' MSP spectra are identical, then they come from the same source. The same is true of hairs and paint flakes. Indeed, MSP can reveal whether someone's hair has been dyed, bleached, or treated in some way, as well as when the person last visited the hairdresser. This could be useful, for example, in linking hair found on a suspect to that taken from the victim and so place the suspect at the scene of the crime, or eliminate them as a suspect.

SEE ALSO Micro-fourier transform infrared spectrometry; Spectroscopy.

Military police, United States

Forensic science is not the exclusive domain of civilian law enforcement agencies. Various branches of the military also undertake investigations into accidents and deaths and must utilize the same forensic techniques and skills as those used by local, state, and federal police. Military police are also concerned with crimes and accidents that call for forensic analyses, albeit of a more specialized nature than their civilian counterparts.

The United States military police, whose establishment dates back to the early twentieth century, are the law enforcement corps within each of the major services. The Army has the Military Police Corps (the largest of the armed forces police services), the Navy has the Shore Patrol, the Air Force has the Air Force Security Police, and the Marine Corps has the Military Police. These forces are staffed almost entirely by military personnel, and are responsible for all the ordinary civilian-analogous functions of a police force, as well as additional military duties.

Military police personnel are involved in law enforcement operations ranging from protecting school crossings and writing parking tickets to **murder** investigations and undercover drug stings. Personnel at U.S. bases around the country and the world provide temporary confinement of service members charged under the uniform code of military justice (UCMJ). Assuming the individual is found guilty after trial in a military court, where he or she is represented by a member of the judge advocate general (JAG) corps, if the sentence warrants, the convicted will serve time at a federal facility such as Fort Leavenworth in Kansas.

In addition to the regular military police activities, several branches have special undercover contingents—for example, the forensically-relevant Army Central Investigation Division (CID)—as well as corrections officers.

SEE ALSO Careers in forensic science; Navy Criminal Investigative Service (NCIS); United States Army Medical Research Institute of Infectious Diseases (USAMRIID).

Minerals

Minerals have played many important roles in the world of **forensic science**, from forensic **geology** used in criminal **identification** and crime scene investigations, to forensic **toxicology** and the study of poisons.

Historically, metal-based mineral poisons were commonly used as murder weapons, with arsenic a favorite. In fact, arsenic was often referred to as "inheritance powder" for its efficacy in hastening the demise of wealthy relatives. In the eighteenth century, the Dutch physician Hermann Boerhaave (1668–1738) was the first expert witness to use basic forensic toxicological methods as the basis for testimony at a **murder** trial. In this case, Mary Blandy was encouraged by her fiancé to use a powdered preparation in order to get the money from her father's estate (he was very much alive at the time). She dutifully put the white substance into her father's food; he became ill. The servants became suspicious. One of the servants found the white powder and took it to a local apothecary for examination, where the hypothesis was arsenic. The servant relayed her concerns to her employer, who dismissed them, and not long after, was dead. Mary was tried for murder, and four medical toxicologists served as **expert witnesses**. They noted that the appearance of Mr. Blandy's organs at **autopsy** was suggestive of arsenic poisoning. Boerhaave reported that he had taken some of the white powder saved by the servant, treated it with a hot iron and smelled it (not a safe test for poisons, by any means). The smell was that of arsenic. Equally important was the testimony of the servant, who was able to describe the white powder that she had observed Mary putting into her father's food. Mary Blandy was found guilty of murder, sentenced to death, and hanged shortly thereafter. This trial set the stage for development of forensic toxicological methods for detection of metal-based (and other) poisons.

In 1911, a forensic method for determining the quantity of metal-based poisons in internal organs was developed by the English physician William Willcox, who was particularly interested in arsenic poisoning. He ran several tests for arsenic, and then used this method to determine how much arsenic was in each of the internal organs of Elizabeth Barrow, a victim of murder by poisoning. His method was used as the basis for far more sophisticated toxicological testing, which can now determine the amount of arsenic down to the microgram (one one-millionth of a gram) in both the human body and in soil.

After the middle of the twentieth century, thallium, a new metal-based poison, was popular for use in rat poison. Although it was banned from commercial use in 1984, it remained readily available in rat poison for at least another decade. In August 1991, Robert Curley developed a barrage of confusing symptoms and was repeatedly hospitalized. The cluster of symptoms included uncontrollable vomiting, abrupt hair loss, numbness of the extremities, general weakness, and burning skin. Shortly before his death in September 1991, he became combative, agitated, and aggressive; at that point, heavy metal exposure was hypothesized. A battery of tests revealed markedly increased thallium levels in his system.

Curley worked in a chemistry laboratory at Wilkes University in Wilkes-Barre, Pennsylvania. Five bottles of thallium salts were found in a stockroom there, although none of his coworkers became ill or evidenced any signs of accidental thallium exposure. Upon Curley's death, an autopsy was performed; it revealed extremely high thallium levels, confirming intentional poisoning, and leading to a ruling of homicide. During the investigation, the Curley home was examined, and several thermoses tested positive for thallium. Curley's widow reported that her husband brought iced tea to work in the thermoses daily. Curley's widow and her daughter by a previous marriage were found to have slightly elevated thallium levels, but they were well below the toxic range. Curley's widow sued the university for wrongful death. Upon further investigation, it was found that she had collected more than one million dollars from a car accident involving her first husband, and had also gained nearly three hundred thousand dollars in life insurance proceeds after Curley's death. At that point, she became a suspect, and the local criminal authorities requested **exhumation** of the body in order to perform more sophisticated testing.

Frederic Reiders, of National Medical Services, agreed to run forensic toxicology tests on Curley's hair shafts, toenails, fingernails, and skin. From the length of the victim's hair, Reiders was able to create a timeline extending 329 days before Curley's death. He used atomic absorption spectrophotometry to record thallium levels at different times. The surprising conclusion was that Robert Curley had been systematically exposed to thallium, through ingestion, for a period of nine months before his death. There was a sharp spike several days before his death, indicating intentional poisoning. Hair from other parts of his body, as well as the skin, fingernail, and toenail samples, all supported the conclusions reached by Reiders after testing the head hair. It was further determined that the valleys, corresponding to drops in thallium level, occurred whenever Curley was away from home (or in the hospital). When confronted with conclusive **evidence**, Curley's widow plea-bargained and confessed to poisoning her husband in an effort to gain his life insurance proceeds.

As testing for metal-based poisons has become progressively more conclusively detectable, the criminal use of these substances as a "murder weapon" has dramatically decreased in favor of plant-based **toxins**.

SEE ALSO Chemical and biological detection technologies; Energy dispersive spectroscopy; Food poisoning; Gas chromatograph-mass spectrometer.

Misdemeanor

A misdemeanor, when applied to criminal law, is defined as any offense other than a **felony** or treason. Being the least serious of these three classifications of crimes, a misdemeanor usually covers all minor offenses. In the United States, criminal codes vary among the fifty states but generally include such offenses as libel, slander, assault in the third or fourth degrees, conspiracy in the third and fourth degrees, and criminal tampering; along with more minor infractions such as violations of driving, fishing, hunting, and boating laws.

A misdemeanor is generally prosecuted by means of information (or prosecutor's information) rather than by indictment, which is how a felony is prosecuted. Both are accusatory documents that must supply information about the alleged illegal act such as time, place, and nature of the crime. However, when a misdemeanor is involved, the prosecutor's information is used to formally file a charge with the court based on the information gathered during the investigation. When a felony is involved, an indictment must be given to the court and presented to a grand jury because of the more serious nature of the crime. Persons found guilty of a misdemeanor are usually punished by probation, fine, or imprisonment in a jail (such as a county jail) or prison (excluding a federal or state penitentiary). The maximum penalty for a misdemeanor could likely be imprisonment in a county jail for less than one year, while a more minor penalty could be a fine of $100 for violating, for example, a municipal code.

Through the use of high-tech devices and modern laboratory techniques, **forensic science** is often used to prove that misdemeanors have occurred by detecting the presence of various substances in a victim or suspected criminal at a crime scene. For example, most DUI (driving under the influence) and driving while intoxicated/impaired (DWI) cases are misdemeanor offenses. Police officers who have stopped drivers suspected of driving under the influence of such intoxicates as alcohol and illegal drugs will often use a breath test (such as a **Breathalyzer®**) to ascertain whether the reasonable cause of the suspect's erratic behavior is due to such a substance.

A breath test—originating within the field of forensic science—which is given to an alleged intoxicated driver by a police officer involves collecting an exhaled sample of a suspect's breath at the scene of the incident. The police officer then analyzes the sample at the scene in order to measure the concentration of alcohol consumption; that is, to measure the amount of alcohol as a percentage of blood (0.08, for example, indicates that alcohol makes up 0.08 percent of the total amount of blood in a person's blood stream). Using such forensic analysis, the police officer can make a determination, based on specific state law, as to whether or not a person should be arrested. Today, alcohol breath-testing instruments are so accurate that their results are regularly used as **evidence** to prosecute misdemeanor cases involving drunk driving.

SEE ALSO Breathalyzer®; Felony.

Missing children

Children can disappear inadvertently or as a result of deliberate abduction, or **murder**. Typically, an investigation will assume that the child is still alive, and so will be geared to locating the child. While much of this effort involves police work that is not forensically-oriented, **forensic science** plays an important role.

The nature of the forensic activities can change with the length of time a child is missing. For example, as will be dealt with in more detail subsequently, computerized techniques can alter the photographic image of a child to approximate the child's appearance through adolescence and into adulthood. Such a visual cue can prove valuable in recognizing a children years after they have been reported missing.

Forensic science plays a grimmer role when a child is discovered dead, or when an unidentified body or skeleton that may potentially be the missing child is discovered. In this case the focus naturally shifts from a happy reunion of the child with loved ones, to the **identification** of the body.

As sad as the latter task may be, this aspect of forensic science can help grieving family members to begin to deal with the reality of what has transpired. Finally, forensic science is invaluable in establishing the **cause of death** of a missing child, especially when foul play is suspected.

In age progression, a forensic artist uses a facial photograph of the missing child to render an image of how the child might look as a pre-adolescent, adolescent or even an adult.

An image can be created the old-fashioned way, using a pencil and sketchpad. This type of image recreation actually has become quite sophisticated. In the 1950s a facial identification kit was developed that consisted of a series of clear stackable sheets ("foils") that allowed a myriad of different hand-drawn facial features to be laid on top of one another on different-shaped faces. The thousands of possible combinations made it possible to produce a final image that proved to be very similar to a person's true appearance.

Today, computer programs enable the forensic artist to digitally scan the child's image into a program and then digitally manipulate the image to approximate the effects of aging. Forensic age progression is a combination of science and art. It relies on the rendering skill of the artist and knowledge of the development of facial muscles, features such as the eyes and nose, and the change in shape of the **skull** with age.

Predictably, faces broaden and lengthen during the transition from the childhood years to adolescence. Primary teeth are lost and secondary teeth appear. The bridge of the nose will tend to rise. As the skull expands, the eyes tend to narrow, the mouth becomes wider and the nose lengthens. Hair that is lighter colored tends to darken.

By about the age of 12, the facial features that are present will persist throughout life, unless surgically altered. Some subtle changes can occur; eyebrows can become more extensive and the cheekbones more prominent. However, other changes may occur that may need to be factored into an image. As examples, hairstyles will change, a hairline can recede, and changing optics of the eyes may necessitate the use of glasses.

In an age progressed image that is within a few years of the child at the time she/he went missing, these age-related changes will be kept to a minimum. However, if the child has been missing for an extended number of years, then a series of images can be made, to give a better overall portrayal of the person's possible appearance.

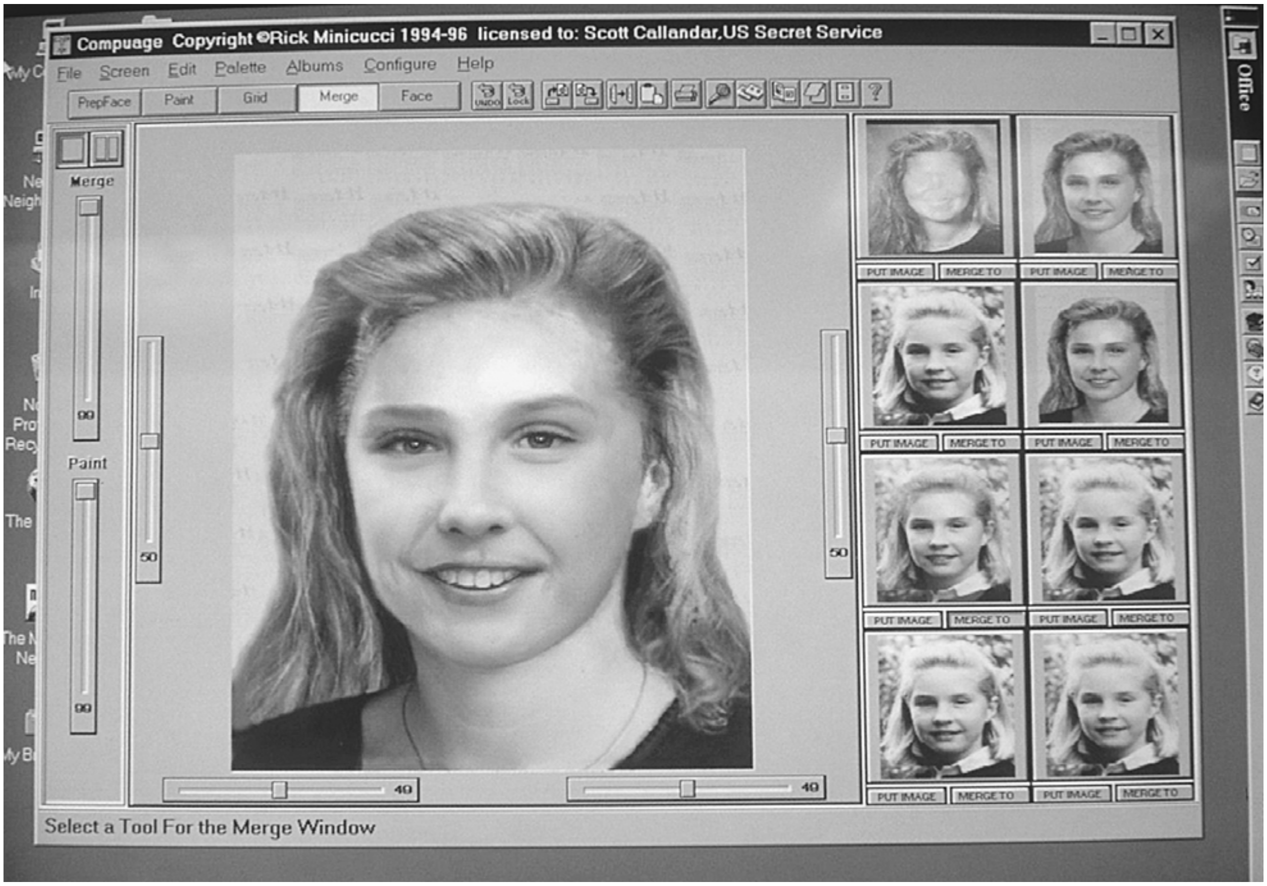
If the missing child has older biological siblings, then their appearance will be scrutinized, as will parental features, since some of their facial features acquired by the siblings from their biological parents will likely have been acquired by the missing child.

Medical records of the missing child can provide useful information in image reconstruction. For example, the presence of a facial scar from a childhood accident, moles, and even tattoos can remain with the child for life, and will be a feature of the age progressed image.

In a related area, image rendering is also done if the missing child is suspected of being abducted and the identity of the kidnapper is unknown. In this case, since the abductor may well try to disguise their appearance, different images may be produced, based on information gleaned from witnesses, surveillance **cameras** or other means. For example, a man can be shown clean shaven, with various styles of facial hair, and with a face that reflects a weight gain or loss.

Particularly in the case of an abduction of a child by an unknown person, the need for eyewitness information is pressing. Such information can be valuable in producing an image of the suspect, and for trying to piece together the events of the abduction.

Obtaining information from eyewitnesses calls for tact and special skills on the part of the forensic investigator. Eyewitnesses, who themselves may be traumatized by what they have witnessed and whose memory can be subject to manipulation, need to be given the time and emotional encouragement that unlocks accurate recollections of the event.



Software available at the National Center for Missing Children in Arlington, Virginia, provides a digital image "aged" to the current chronological age of the missing child. © RICHARD ELLIS/CORBIS SYGMA

A forensic investigator will assess the information provided by a witness while considering the person's involvement with the event. For example, the information provided by someone who had only a brief glimpse of the missing child and/or suspect may not be as reliable as the information from someone who had a more prolonged view. As another example, if the eyewitness normally wears glasses but was not at the time, then the quality of the information, while not necessarily suspect, needs to be considered cautiously.

Other forms of eyewitness information are available. Surveillance cameras that are an ever-present facet of daily life can provide a picture of the child and an abductor, for example.

Fingerprints are unique identifiers that are invaluable in the identification of a missing child and, in the case of an abduction, the suspect. For fingerprints to be useful, a child's fingerprints need to be already recorded and on file. Programs such as ID Me Now, sponsored by the Child Protection Education Foundation of America, incorporate on a card high quality images of **fingerprint** patterns with a digital facial photograph, dental records, contact numbers and personal information, and even information on how to collect a cell sample for deoxyribonucleic acid (**DNA**) extraction.

Fingerprint patterns can also be submitted to a databank that is administered by the Federal Bureau of Investigation. The fingerprint patterns obtained from a missing child (or recovered corpse) can be compared to the hundreds of thousands of digitized patterns resident in the database to determine an identity match.

Such child fingerprint collection is, however, more the exception than the norm. In this case, a forensic investigator may instead be able to obtain a fingerprint of a missing child from an object known to be handled by the child.

The conclusion of a missing child case can be tragic with the discovery of a corpse or skeleton. Identification of the body or remains as that of the missing child becomes the priority. If an intact skull is found, it can be used to create a three-dimensional reconstruction of the facial appearance of the person. The shape of the skull, combined with knowledge of the typical thickness and arrangement of facial and head muscles and tissue can be used to physically create a face.

For this task, modeling clay is applied to the skull. The clay mimics the muscles and tissues that underlie the skin. The shape of the nose can be deduced from measurements of the nasal aperture; the hole in the skull where the nose once was. Typically, the width of the nasal aperture is increased by five millimeters on either side. Other measurements of the nasal aperture are used to calculate the approximate length of the nose. Appropriate facial hair and prosthetic eyes are inserted, and the reconstruction is photographed. The final image can be very similar to the actual image of the deceased.

Skin, tissue, muscle and even bone that can be recovered can be used as a source of DNA or a related genetic material known as ribonucleic acid (RNA). Through various sophisticated means, the genetic material can be amplified in number, and the sequence of nucleotide building blocks that comprise the DNA or RNA can be determined. These genetic sequences can be as unique to an individual as is a fingerprint pattern. People inherit genetic material from their parents; indeed, this is the basis of paternity testing that is used to establish if a man is the biological father of a child.

The genetic identification utilizes specialized DNA that is known as mitochondrial DNA. The pattern of mitochondrial DNA between mother and child can be identical. This generational similarity of genetic material has been used in El Salvador to identify the remains of children who were abducted and murdered by the Salvadoran military in the 1980s and, more happily, to reunite children who were abducted but not killed, with their biological parents.

SEE ALSO Anthropometry; Autopsy; DNA profiling; Integrated automated fingerprint identification system; International Association for Identification; Mitochondrial DNA typing; Paternity evidence; STR (short tandem repeat) analysis.

Mitochondrial DNA analysis

In human cells, **DNA** is found in both the nucleus and the mitochondria. The mitochondrion is an organelle responsible for the molecular products that provide the energy to the cell. There is a single nucleus in human cells and it contains two copies of DNA, one originating from the father and one from the mother. In contrast, there may be hundreds or thousands of mitochondria in human cells and the DNA in a single mitochondrion may be copied numerous times. Nuclear DNA is much longer than mitochondrial DNA, also written mtDNA, however the fact that there are so many more copies of mtDNA makes it extremely useful in cases in which there is only a small sample or the sample has been degraded. In addition, some biological materials such as hair shafts, teeth, and bones do not contain any cell nuclei, but mitochondria may be present and mitochondrial DNA analyses can be performed.

When a **sperm** fertilizes an egg, the DNA-containing head of the sperm fuses with the egg, but the tail and midsection are left on the outside of the egg. The mitochondria of a sperm are found in the tail and midsection as these parts require energy in order to propel the sperm. Because the mitochondria of the sperm never reach the inside of the egg, all the mitochondria in the embryo come from the egg. As a result the mitochondrial DNA in a child is identical to that of the mother. Mitochondrial DNA is therefore useful for proving maternal relationships in forensic investigations.

The DNA molecule is made up of a sequence of four different smaller molecules called nucleotides: adenine (A), guanine (G), cytosine (C) and thymine (T). DNA is a double stranded molecule and its nucleotides always associate themselves with a complementary nucleotide; if adenine is on one of the strands, thymine is across from it on the other strand. Similarly, if cytosine is on one strand, guanine will be found across from it on the other strand. Because the nucleotides of DNA are found in pairs on the two strands, the nucleotide sequence is also called a sequence of base pairs (bp).

Mitochondrial DNA is approximately 16,569 base pairs long and the genome is usually found in a ring-like conformation. There are two major parts of the molecule. A coding region accounts for the majority of the molecule and the DNA from this section codes for biochemical products related to providing energy to the cell. The other section of the mtDNA is called the control region and it is responsible for regulating the production of the **gene** products from the coding region. Within the control region there are two regions that have been found to contain a disproportionate number of variations in humans. These regions are called Hypervariable Region 1 and Hypervariable Region 2, or HV1 and HV2. HV1 is approximately 342 bp and HV2 is approximately 268 bp.

There are five major steps to mtDNA analysis. First, the sample is visually examined, cleaned, and prepared. Cleaning is extremely important because extraneous cells from handling can easily contaminate a sample. Usually the sample is immersed in detergent and an ultrasonic bath. Teeth and bones are sanded and cross-sectioned. In teeth, the dentin and pulp are used in the analysis. In all cases, the sample is ground to a powder and then placed in an extraction solution to release the cellular material, including the mtDNA, from the cells.

The second step involves extracting the mtDNA from the cellular material. This is accomplished by adding to the solution a mixture of chemicals that separate DNA from other organic molecules and then spinning the mixture in an ultracentrifuge. The mtDNA is concentrated in the top layer and then purified. The third step involves a technique called **PCR**, **polymerase chain reaction**, which uses carefully regulated cycles of heating and cooling to produce many copies of the mtDNA. This process is called amplification. After amplification, the mtDNA product is purified and quantified to ensure that the PCR yielded the expected quantity of mtDNA. The final step in mtDNA analysis is **sequencing** the amplified mtDNA. This is done using a technique similar to PCR, but special fluorescently labeled nucleotides that terminate the growth of a strand are added to the solution. This technique is referred to as Sanger's method and the result is many strands of DNA that vary in length by one nucleotide. This collection of DNA is then sorted by length, using a technique called gel **electrophoresis**. A **fluorescence** detector then reads the labels at the end of each strand of DNA and computer software reconstructs the mtDNA sequence. Finally, a DNA examiner edits and verifies the sequence.

When performing mitochondrial DNA analysis, about 610 bp are sequenced and compared to a standard. Any nucleotides in the sample sequence that differ from this standard are listed by location and nucleotide. For example, if a sample contained cytosine at position 263 while the standard contained adenine in this location, then the results would be presented 263 C.

The **FBI** has been using mtDNA to solve crimes since 1996. By 2002, they had processed more than 500 cases using mtDNA analysis and had established the National Missing Persons DNA Database to gather information on missing persons for the law enforcement community. A database of mitochondrial DNA can also be accessed through the FBI's **CODIS** (Combined DNA Index System) software. Mitochondrial DNA has been used successfully in a broad range of instances such as solving missing persons cases and identifying human remains and disaster victims. In 2005, the FBI decided to expand its mitochondrial DNA work and planned to open four new facilities focusing directly on mitochondrial DNA analysis.

SEE ALSO Human migration patterns; Identification of the son of Louis XVI and Marie Antoinette; Mitochondrial DNA typing.

Mitochondrial DNA typing

The field of **forensic science** has benefited significantly from the identification, characterization, and basic understanding of the mitochondria. The mitochondrion is a subcellular organelle that is located within the cell and functions to produce energy for various tissues of the body. It contains its own genome distinct from the genome found in the nucleus (nuclear **DNA**) due to many features, including: how it is inherited; how it is replicated; its copy number; and its size. Mitochondrial DNA is circular, double stranded, and inherited maternally.

Mitochondrial DNA typing is a method used by forensics scientists to match DNA from an unknown sample to a sample collected at a crime scene. It is ideally used in special cases where the DNA is degraded or the source of the sample doesn't contain enough genomic nuclear DNA for analysis. As it is maternally inherited, the DNA from siblings and all maternal relatives should be identical (in the absence of spontaneous mutations). For this reason, the remains of missing persons can be rapidly identified by using **mitochondrial DNA analysis** of relatives. Additionally, there is generally a lack of recombination, an event that takes place during nuclear DNA cell division in which two stands of DNA cross over and exchange information, thereby creating greater sequence diversity. Therefore, even matriarchal relatives separated by several generations can serve as reference samples. Nuclear DNA samples cannot provide this function, due to multiple recombination events that take place throughout the nuclear DNA genome.

The two genomes are not mutually exclusive, instead they rely on each other for survival. The nuclear DNA can encode roughly 1,000 proteins that are targeted for the mitochondria and play a role in oxidative phosphorylation, or energy production, while the mitochondrial DNA produces energy by producing

ATP as well as several other functions. All other **DNA typing systems** use nuclear DNA analysis.

There are several advantages to studying the mitochondrial DNA of a sample. The application of mitochondrial DNA analysis in forensic sciences stems from characteristics of the mitochondrial DNA genome, including its copy number within the cell, its hypervariable region, its size, and its sequence variations. The mitochondrial genome is roughly 16,569 base pairs in size (compared to the 3 billion base pairs in the nuclear DNA). Whereas nuclear DNA has only two copies of each **gene**, tightly woven into chromosomes, mitochondrial DNA can be copied 2–10 times per mitochondrion and there can be hundreds to even thousands of mitochondria per cell. With the mitochondria's role as an energy provider, different tissues contain different amounts of mitochondrial DNA, depending on the energy requirements of the cell. A higher copy number equates to greater sensitivity. This is particularly important if the DNA sample is significantly degraded, or the DNA is present only in a very small quantity. The likelihood of recovering mitochondrial DNA from a small or degraded sample is, therefore, greater in mitochondrial DNA samples compared to nuclear DNA samples since the mitochondrial DNA has a larger copy number.

The low fidelity of DNA repair mechanisms to correct specific mitochondrial DNA mutations has lead to a 5–10 fold higher mutation rate, and, in turn, a higher rate of evolution. Human identity testing employs these regions where there is hypervariability as a consequence of a higher mutation rate. Two hypervariable (HV1 and HV2) regions are part of a control region. On average, there are roughly 8 nucleotide differences between Caucasians and 15 differences between individuals with African decent in these two hypervariable regions. Mitochondrial DNA typing using HV1 and HV2 can be readily performed by using a mitochondrial DNA-specific **polymerase chain reaction** and amplification of genomic mitochondrial DNA. This is followed by direct DNA **sequencing** and identification of sequence variations.

The sample source can often determine which DNA typing system represents the ideal approach. For example, if a hair is left at the scene of the crime, nuclear DNA can only be analyzed if the root is intact. However, mitochondrial DNA can be analyzed from anywhere along the hair follicle, including the shaft. Bones and teeth also contain mitochondrial DNA and can be used in mitochondrial DNA analysis.

There are several disadvantages of using mitochondrial DNA typing in forensics in lieu of nuclear DNA markers. As all individuals of the same maternal lineage are virtually indistinguishable by mitochondrial DNA analysis, identification of the remains of an individual would not be possible without comparing it to maternally-related relatives. Additionally, using mitochondrial DNA analysis to match a suspect to a sample by comparing different genomic locations might reveal a similar profile. Mitochondrial DNA should not be viewed as a unique identifier, since seemingly unrelated individuals might have an unknown shared maternal relative in their distant past. If this is the case, a mistaken match might be suggested. Finally, using a more sophisticated (multi-locus) nuclear DNA analysis will provide far greater discriminatory power.

SEE ALSO DNA fingerprint; DNA profiling; DNA sequences, unique; DNA typing systems.

Andre A. Moenssens J.D., LL.M.

BELGIAN
FORENSIC CONSULTANT

Andre Moenssens did both his pre-legal studies and his early forensic studies in his native Belgium. In 1950, he began a formal study of fingerprints and **fingerprint** analysis under the mentorship of Major Georges E. Defawe. In 1953, Moenssens joined the **International Association for Identification** (IAI); in 1956 he immigrated to the United States. He studied law at the Illinois Institute of Technology-Kent College of Law, where he received his J.D. cum laude in 1966. He completed his Master of Laws degree (LL.M.) at Northwestern University in 1967.

Moenssens continued to pursue his **forensic science** interests as head instructor in fingerprint **identification** at the Institute of Applied Science in Chicago (1960–1967). He was also the associate editor of the *Fingerprint and Identification* magazine from 1960 to 1968.

After completing his academic legal studies, Moenssens began his professional tenure as a law professor at Chicago-Kent College of Law (1967–1973), the University of Richmond in Virginia (1973–1995), and the University of Missouri at Kansas City (1996–2002), where he was on the doctoral faculty and held the Douglas Stripp Professorship in Law. From 1993 to 1995, and again in 2004, Moenssens was Visiting Professor of Law, holding the William J. Mayer Chair, at West Virginia University. After retirement from teaching, he again turned his attention to the world of forensic science.

Moenssens has been the editor of the *Illinois Law Enforcement Officers Law Bulletin* since 1972; he was elected to membership in the prestigious Scientific Working Group on Friction Ridge Analysis, Study, and Technology (SWGFAST). He has been a fellow of the **American Academy of Forensic Sciences** since 1966, where he has served two terms as secretary-treasurer (among other leadership positions). Moenssens is also a member of the Canadian Identification Society, The United Kingdom's Forensic Science Society, and the Indiana Division of the IAI (formerly a member of the Virginia Division of the IAI as well).

Andre Moenssens authored *Fingerprints and the Law* (1969) and *Fingerprint Techniques* (1971), was the senior co-author of *Scientific Evidence in Civil and Criminal Cases* (5th edition, 2005), and *Cases and Comments on Criminal Law* (7th edition, 2003). He has also written dozens of articles, presentation and position papers, books and book chapters, and commentaries on criminal justice and the forensic **evidence**. He remains a sought-after forensic consultant and public speaker, and has also made consistent contributions to the field of forensic science via both the Computer Forensics International Web site and his evolving Forensic Evidence Web site and database.

SEE ALSO Criminal responsibility, historical concepts; Criminology; Fingerprint; Friction ridge skin and personal identification: a history of latent fingerprint analysis.

Monochromatic light

Technologies using monochromatic light have a wide range of application, from astrophysics and astronomy to **forensic science**. The term monochromatic derives from the Greek words *monos*, meaning one or sole, and *chromos*, meaning color. Monochromatic light, or one-color light, is essentially electromagnetic radiation derived from photon emissions from atoms. Photons propagate, or travel, as energy wave fronts of different lengths and levels of energy. Energy levels determine the frequency of light, and the length of a wave determines its color. The bands of light wavelengths that humans can see are called visible light.

Visible light includes red light (in the lower energy level of the **electromagnetic spectrum**) and violet light in the higher visible energy level of the electromagnetic spectrum. As light propagates through different media, it interacts with atoms present in molecules, such as atmospheric gases, water, and organic matter. These interactions are known as atomic transitions, and consist of emission or absorption of specific wavelengths (or energy packages). The particular structure of isotopes (atoms or molecules of one element of the periodic table) as well as the structure of complex molecules (containing more than one element) defines their physical-chemical properties. Such properties will determine which wavelengths are absorbed and which ones are emitted. Absorption and emission of light by atoms occur in energy packages known as quanta. Absorption occurs when light excites atoms, making electrons suddenly jump to specific outer orbits. This is not a progressive movement between orbits, but a sudden change of energy state by which a given energy quanta is absorbed.

Emissions occur in the inverse manner, resulting in the release of the absorbed quanta. Monochromatic light and **laser** technologies take advantage of these atomic transitions as well as another atomic property known as ground state energy. Ground state energy refers to the tendency of electrons to return to the lowest energy level, therefore undergoing spontaneous emission of the energy quanta.

A monochromatic light beam is characterized by its brightness or light intensity, direction of propagation, and color (all visible characteristics) and by its state of polarization (an invisible characteristic). Light waves oscillate, or swing back and forth, perpendicularly to the direction of propagation. For example, if a light wave is propagating horizontally, it is oscillating vertically. The best example of monochromatic light is a laser beam. A laser light results from one atomic transition with a specific single wavelength, which results in a monochromatic light beam.

When a monochromatic light is directed to a substance or material, it induces transitions which are characteristic to the chemical properties of the constituent elements of such material. Optical **spectroscopy** instruments record the peaks and troughs of the resulting wave lights in a spectrometer that measures the changes in frequency and intensity of these transitions. The resulting wave patterns indicate the chemical composition of the sample. Scanning monochromators are optical instruments that disperse light, permitting the scanning of forensic samples or **evidence**, using one wavelength (or light color) at a time, and scan for the entire spectral range. Battery powered ultraviolet monochromatic devices are used to scan for evidence not easily detected by the naked eye at crime scenes. They allow hidden bloodstains, **fibers**, fingerprints, and lesions that are just beneath the skin on corpses to be visualized by the examiner.

Credit cards, currency, and important documentation are often marked with imprinted holograms on security stamping foils, which are created by monochromatic laser beams. Security standard holography represents the first generation of a security technology known as optically variable devices (OVDs). Other non-holographic OVDs technologies exist, and are detectable in marked materials with ultraviolet light devices.

SEE ALSO Alternate light source analysis; Isotopic analysis; Laser.

Arthur Ernest Mourant

4/11/1904–8/29/1994
ENGLISH
SEROLOGIST, GEOLOGIST

A. E. Mourant was born in the city of Jersey in the United Kingdom. He graduated from Exeter College Oxford, where he studied chemistry, with a specialization in crystallography. He obtained a doctorate (PhD) in **geology** from Leeds University in 1931. In 1933, Mourant founded the Jersey Chemical Pathology Laboratory, which he ran until 1938. At that point, he decided to become a psychoanalyst and moved to London to undergo his own preparatory psychoanalysis training; he began medical studies at St. Bartholomew's Hospital Medical College in London in 1939. During the course of his medical studies, he developed a strong interest in hematology and changed the direction of his career. Mourant completed his coursework in 1943 and was appointed to the position of Medical Officer in the National Blood Transfusion Service in 1944.

Mourant began researching blood **serum**; this led to his discovery of the **antibody** anti-e and his work on the Rhesus system, the Lewis factor in blood grouping, his co-discovery of the Kell factor, and his work on the creation of the antiglobulin test with Race and Coombs. Mourant's discovery of the antibody anti-e was of forensic importance in establishing the three-factor system of Rh blood typing. As a result of his finding of an antibody that reacted with the Lewis system, he was credited with the first publication documenting the Lewis blood grouping system in 1946. There are two genes associated with the Lewis Blood Grouping system: the Lewis **gene** and the **secretor** gene. Mourant also shared in the discovery of the Kell system, which has been found to be comprised of twenty-two different blood group antigens, some of which are associated with allelic genes. An important forensic aspect of the Kell system is its relationship to certain specific racial groups: the more specifically biological **evidence** is able to point to (or exclude) a suspect, the more likely it will be to successfully identify an individual perpetrator, to link crimes, and to achieve successful (and accurate) criminal prosecution.

Mourant authored numerous forensically important hematology texts, the most well-known of which are: *The Distribution of Human Blood Groups and Other Biochemical Polymorphisms* (1953), *The ABO Blood Groups and Maps of World Distribution* (1958), *Blood Group and Disease* (1978) and *Blood Relations, Blood Groups and Anthropology* (1985).

In 1945, Mourant became the Medical Officer at the Galton Laboratory Serum Unit; in 1946 he accepted the Directorship of the Medical Research Council's Blood Group Reference Laboratory at the Lister Institute of Preventive Medicine in London, where he remained until 1965. In 1952, the World Health Organization named the Laboratory as their International Blood Group Reference Laboratory.

Over time, Mourant's interests turned progressively more to **anthropology**. He published two forensically important books about human blood group distribution worldwide: in 1953 he published *The Distribution of Human Blood Groups and Other Biochemical Polymorphisms*, and in 1958 he published *The ABO Blood Groups and Maps of World Distribution.* Of particular forensic significance is the suggestion by Mourant that specific geographic areas and their populations could be associated with particular blood groups and blood types. By so stating, he was indicating that it might be possible to pinpoint the race or geographic origin of an unknown suspect by means of blood typing and blood group analysis. This is of scientific significance because the more specifically it is possible to define an unknown suspect, the more likely it will be to identify (or rule out) an individual.

SEE ALSO Antibody; Anthropology; Blood; Serology; Serum.

M.P. SEE Military Police, United States

Robert S. Mueller III

8/7/1944–
AMERICAN
DIRECTOR, FEDERAL BUREAU OF INVESTIGATION

Robert S. Mueller, III assumed his current position as sixth Director of the Federal Bureau of Investigation on September 4, 2001, exactly one week before the September 11, 2001, terrorist attacks against the United States.

Mueller was born in New York City and raised near Philadelphia, Pennsylvania. He graduated from Princeton University in 1966 and completed a master's degree in International Relations at New York University in 1967. After completing his education, Mueller spent three years as an officer in the Marine Corps. He served in Vietnam, earning the Vietnamese Cross of Gallantry, a Bronze Star, two Navy Commendation Medals, and a Purple Heart. After returning to the United States, Mueller attended Virginia Law School, graduating with a J.D. in 1973. He worked as a litigator with a San Francisco law firm until 1976, and then spent 12 years working in the United States Attorney's Offices. While at the Northern District of California in San Francisco, he achieved the position of criminal division chief. In 1982, he assumed the Boston-based position of Assistant United States' Attorney. His primary areas of investigation and prosecution were terrorist and public corruption cases, major financial fraud, international money laundering, and narcotics conspiracies. He spent a brief period as a partner in a Boston law firm before accepting the position of Assistant to Attorney General Richard L. Thornburgh at the United States Department of Justice (USDOJ) in 1989.

In 1990, Mueller took over responsibility for the criminal division. There, he oversaw the John Gotti crime boss prosecution, the case surrounding the bombing of Pan Am Lockerbie Flight 103, and the conviction of Panamanian leader Manuel Noriega. He was elected a fellow of the American College of Trial Lawyers in 1991. In 1993, he joined the Boston Law Firm of Hale and Dorr as a partner, specializing in white-collar crime. In 1995, he resumed public service as a senior litigator in the homicide division of the District of Columbia United States Attorney's Office. From 1998 until 2001, Mueller was posted in San Francisco as the United States Attorney. Before becoming the sixth Director of the Federal Bureau of Investigation on September 4, 2001, Mueller spent several months as the Acting Deputy Attorney General of the U.S. Department of Justice.

Mueller has stated his conviction that the **FBI** must be responsive to the changing face of American security in the post-9/11 era. Since 9/11, there has been increasing emphasis on field work, due to efforts at improving homeland security as well as an increased need for mobile response to criminal activity and suspected or threatened acts of terrorism. Mueller maintains that in order to remain effective, the FBI must improve core competencies, increase workforce skills specificity, significantly improve ability to gather and protect the security of confidential information, become better able to collaborate with partner agencies, develop and expand its proficiency with emerging technologies, and use that technological acumen to buttress investigations, analyses, and operations.

Historically, the FBI's method of operations has been reactive; it responded to potential or actual events. It is Mueller's plan to fully shift the Bureau to a proactive stance, reshaping the philosophy of the FBI for increased compatibility with current world events. His proactive emphasis involves broadening the working relationship between American and international intelligence and law enforcement communities, particularly in three areas: counterterrorism, cybercrime and infrastructure protection, and counterintelligence.

As of March 2005, Mueller has outlined three major tenets underlying the FBI management shifts: the mission and the priorities of the FBI must be refocused in accordance with the changing face of terrorism and threats to national security; the FBI workforce must be realigned in order to address its new priorities; and the operational culture and philosophical stance of FBI management must support enhanced agility, flexibility, effectiveness, and accountability.

SEE ALSO FBI (United States Federal Bureau of Investigation); FBI crime laboratory; September 11, 2001, terrorist attacks (forensic investigations of).

Kary Banks Mullis

12/28/1944–
AMERICAN
BIOCHEMIST

American biochemist Kary Banks Mullis is famous in **forensic science** circles as the designer of the **polymerase chain reaction** (**PCR**). PCR is a fast and effective technique for reproducing specific genes or deoxyribonucleic acid (**DNA**) fragments that is able to create billions of copies in a few hours. Widely available because it is now relatively inexpensive, PCR has revolutionized not only the biotechnology industry, but also many other scientific fields and it has important applications in forensic science and law enforcement.

Mullis was born in Lenoir, North Carolina, on December 28, 1944. He entered Georgia Institute of Technology in 1962 and studied chemistry. As an undergraduate, he created a laboratory for manufacturing poisons and **explosives**. He also invented an electronic device stimulated by brain waves that could control a light switch.

Upon graduation from Georgia Tech in 1966 with a B.S. degree in chemistry, Mullis entered the doctoral program in biochemistry at the University of California, Berkeley. At the age of 24, he wrote a paper on the structure of the universe that was published by *Nature* magazine. He was awarded his Ph.D. in 1973 and he accepted a teaching position at the University of Kansas Medical School in Kansas City. In 1977, he assumed a postdoctoral fellowship at the University of California, San Francisco. In 1979, he accepted a position as a research scientist with a growing biotech firm, Cetus Corporation, that was in the business of synthesizing chemicals used by other scientists in genetic cloning.

In the late 1970s, the most effective way to reproduce DNA was by cloning. The cloning process is not only time-consuming, but it replicates the whole DNA strand, increasing the complexity. The revolutionary advantage of PCR is its selectivity; it is a process that reproduces specific genes on the DNA strand millions or billions of times, effectively amplifying or enlarging parts of the DNA molecule for further study.

A commercial version of PCR and a machine called the Thermal Cycler have been developed. With the addition of the chemical building blocks of DNA, called nucleotides, and a biochemical catalyst called polymerase, the machine would perform the process automatically on a target piece of DNA. The machine is so economical that even a small laboratory can afford it.

In the field of genetics, the PCR process has been particularly important to the Human Genome Project, a huge undertaking to map human DNA. The ability of this process to reproduce specific genes has made it possible for virologists to develop extremely sensitive tests for acquired immunodeficiency syndrome (AIDS), capable of detecting the virus at early stages of infection. PCR has been particularly useful for diagnosing genetic predispositions to diseases such as sickle cell anemia and cystic fibrosis.

PCR has also revolutionized evolutionary biology, making it possible to examine the DNA of woolly mammoths and the remains of ancient humans. PCR has been used to identify the bones of Czar Nicholas II of Russia. Scientists are preparing to use PCR to amplify DNA from the hair of Abraham Lincoln, as well as bloodstains and bone fragments, in an effort to determine whether he suffered from Marfan's syndrome.

In law enforcement, PCR has made genetic fingerprinting more accurate and effective. It has been used to identify murder victims, and to overturn the sentences of men wrongly convicted of rape.

In 1988, Mullis became a private biochemical research consultant. In 1993, he won the Nobel Prize in chemistry.

SEE ALSO DNA; Fingerprint; PCR (polymerase chain reaction).

Multisystem method

Serologists (scientists who study **blood serum**, and immune factors in blood serum) **Brian Wraxall** and **Mark Stolorow** pioneered the "multisystem method" for the simultaneous separation of three isoenzymes (glyoxalase I, esterase D, and phosphoglucomutase) from bloodstains in 1978. They also created and developed a multisystem method involving the use of **electrophoresis** analysis and an immunoelectrophoretic technique for use in forensic **identification** of bloodstains. The goal of the multisystem method is to carry out several different procedures simultaneously, thereby vastly reducing the amount of bloodstain needed for the analysis (cutting it by two-thirds), multiplying accuracy, markedly reducing the time previously involved in the sequential analysis of all three isoenzyme components, and accomplishing all of this without any loss in sensitivity or resolution.

Blood remains the single most important type of **evidence** in the world of **forensic science** and of criminal investigation. It can link perpetrator to act of violence, to victim, to crime scene, and to other evidence. A bloodstain is first typed for blood group. While quite useful, this is considered only class evidence (evidence that links to a specific group), as it can exclude suspects, but cannot conclusively identify a specific individual. At a slightly higher level of sophistication, the sample can then be typed for Rh factor, and sub-grouped beyond this.

In order to type the stain to the greatest possible level of specificity, with the goal of accurately linking a sample or bloodstain to a single individual, the typing of proteins and enzymes is utilized. Blood proteins and enzymes share the characteristics of isoenzymes, or polymorphisms; that is, they exist in multiple molecular forms that have the same or very nearly identical enzyme activities and therefore, they have subtypes. Among the more common isoenzymes found in blood (and in bloodstains) are: transferrin, glucose-6-phosphate dehydrogenase, 6-phosphogluconate dehydrogenase, esterase D, adenyl kinase, glutamic pyruvate transaminase, glyoxalase I, erythrocyte acid phosphatase, adenosine deaminase, and phosphoglucomutase. Each isoenzyme, as well as every blood group subtype, has a known population distribution. By breaking the blood sample down to the level of maximum specificity, it is possible to progressively exclude the population of suspects until only one individual is left who could possibly match the set of specific blood group, type, and polymorphism markers. For example: the sample and the suspected perpetrator both have blood type A (42% of the population), and basic subtype A2 (25%), protein adenyl kinase (15%), and enzyme phosphoglucomutase (6%). The probability that there could be two individuals with this exact blood type is: (0.42 x 0.25 x 0.15 x 0.06), or less than 0.000945 percent.

By creating multisystem methods for bloodstain typing, Wraxall and Stolorow revolutionized the field of individualized blood typing, and made lasting contributions to the accuracy, validity, and reliability of forensic science, by dramatically decreasing required sample size, increasing efficiency and saving considerable cost by allowing for the simultaneous testing of three isoenzymes, and doing so without sacrificing either resolution or accuracy.

SEE ALSO Antibody; Antigen; Bloodstain evidence.

Mummies

For legal **medicine** purposes, the state of conservation of a corpse is crucial to determining the cause and **time of death**. Conservative-transformative phenomena, also called spontaneous mummification, can occur when a body is exposed to favorable conditions, such as dehydration combined with heat, or dehydration combined with freezing temperatures. Mummification may occur naturally or may be achieved through artificial methods. Ancient Egyptians, Incas, and the natives of the Canary Islands used different methods to embalm and conserve the bodies of their dead. In modern societies, embalming is also practiced when requested by the family of the deceased or to preserve corpses for academic teaching and research.

Forensic scientists, forensic anthropologists, and forensic archeologists work together to unwrap the mysteries surrounding both preserved and naturally occurring mummies. **DNA** fingerprinting and **skull** reconstruction, techniques originally developed to solve crimes, are useful in investigating mummified human remains. Investigators may also use CT scans to help determine the **cause of death**, radiocarbon dating to help determine the time of death, and knowledge of forensic **entomology** (insect **evidence**) to determine what happened to the mummy at different stages after death.

The natural mummification process usually happens in extremely dry environments that allow the fast dehydration of tissues, simultaneously slowing down or inhibiting the **decomposition** by bacteria and other microorganisms. Bodies buried in the sands of the Takla Makan Desert in Asia and the Atacama Desert in the north of Chile have been found mummified even thousands of years after death. Mummification also happens to the bodies of people who die on the desert surface, where direct exposure to sunlight and the highly dry atmosphere favor rapid dehydration. Stone crypts sometimes house conditions favorable for natural mummification, such as occurred in the catacombs of the Franciscan Brotherhood in Tolosa, Spain, and in the crypt of Saint Boumet-le-Chatêau, where more than 30 mummies exist in a perfect state of conservation. These two locations share in common a dry climate, crypts that have a natural constant temperature of about 59°F (15°C), and enough air movement to prevent vapor from the bodies to build up in the crypts.

Natural mummification is also favored by some other factors, such as age (it is more common in newborns), gender (occurs more often in female corpses), and cause of death (large hemorrhages, ante-mortem prolonged administration of **antibiotics**, and poisoning by arsenic and potassium cyanide). The external aspect of both natural and man-made mummies includes drastic body-weight reduction, dried leather-like shrunken and darkened skin, reduced volume of the head, and well-conserved teeth and nails. Facial features are in a measure preserved, but tendons and muscles are very fragile and

Scientists discuss the x ray of a 3,000-year-old Egyptian mummy at the National Taiwan University Hospital in Taipei, 2003.

disintegrate at touch. Another environment that favors mummification is freezing temperatures associated with dry climates such as those found in upper altitudes in the Himalayas, Alps, as well as in the Artic and Antarctic caps. The famous Otzi mummy, also known as "Iceman," was found in the Tyrolean Alps in 1991, after approximately 5,000 years, in highly conserved conditions and still bearing the wounds of the weapon that killed him. From the position of his fallen body and his wounds, it was possible to make a **crime scene reconstruction**, 5,300 years after the **murder**.

Peat bogs, the soft moist soil formed by the partial decay of vegetation, are very acidic due to high kevels of tannin, one of the compounds used in leather conservation. Marshes and other peat bogs in Scandinavia, Ireland, and Scotland have yielded from time to time well-preserved mummies from the Bronze and Iron Ages. Perhaps the first peat bog mummy to draw the attention of anthropologists was the one known as Tollund Man, found in a peat bog on Denmark in 1950. An **autopsy** revealed even his last meal and estimated the time of death as having occurred 12 hours after that meal, through the analysis of the well-conserved partially digested grains in his stomach. The mummy was dated as having died around 350 B.C., at the approximate age of 40. Among the seeds present in his stomach were found barley, knotweed, bristle grass, chamomile, and some other wild seeds, suggesting that such a meal was a soup. Since those seeds were only cropped in the spring in those latitudes, researchers could conclude that he died during a spring season. As he had a rope with a knot and noose around the neck and clear marks of the knot in the skin of his neck, they concluded that he had been hung (cause of death), although his bones were very deteriorated to allow the verification of a neck fracture. These and other lines of analysis are what a forensic anthropologist considers when investigating a "cold case."

Calcification is a conservative-transformative phenomenon by which a corpse is "petrified" due to the rapid absorption of calcium salts by the skeleton in the presence of bacterial decomposition of internal organs. Fetuses that die in the womb are more likely to undergo calcification than other bodies. However, most fetuses undergo maceration (softening of the tissues) and not calcification when death occurs in the womb, due to the presence of the amniotic fluid in the mother's uterus. Colorification is a very rare mummification phenomenon, described in 1985 by Della Volta, occurring in cadavers kept in perfectly sealed zinc urns. The mummies' skin has the appearance of rawhide, with a flattened and depressed abdomen, muscles, and subcutaneous tissues well preserved, and internal organs softened and generally conserved. A small quantity of a viscous liquid of a brown-yellowish tonality is usually found at the bottom of such urns. The exact process underlying this type of mummification is not yet understood.

SEE ALSO Anthropology; Autopsy; Body marks; Coroner; Crime scene reconstruction; Death, cause of; Entomology; Hanging (signs of); Medical examiner.

Murder vs. manslaughter

Killing another person is commonly referred to as murder. However, the precise term for the killing of one person by another is homicide. Murder is a form of criminal homicide that has a precise legal meaning. Murder is usually defined as the "unlawful killing of another with malice aforethought (or "an abandoned and malignant heart"). Malice aforethought refers to the perpetrator's intention of doing harm.

There are different legal variations of murder, known as degrees. Degrees of murder vary by the gravity (seriousness) of the offense (usually measured by the intent of the perpetrator) and the sentence assigned to that offense. For example, murder in the first degree, or first-degree murder, carries the sternest sentences and is usually reserved for murders committed with premeditation or extreme cruelty.

Manslaughter is also a form of criminal homicide. The difference between murder and manslaughter is in the element of intent. In order to commit voluntary manslaughter, a person must have committed a homicide, but have acted in the "heat of passion." This mental state must have been caused by legally sufficient provocation that would cause a reasonable person of ordinary temperament to lose self-control. To convict a person of manslaughter, it must be proved that the person who committed the homicide had adequate provocation (this cannot involve words alone), acted in the heat of passion, and lacked the opportunity to cool that passion. There must also be a connection between the incident of provocation, the heat of passion, and the act that caused the homicide.

Involuntary manslaughter is manslaughter resulting from a failure to perform a legal duty expressly required to safeguard human life, from the commission of an unlawful act not amounting to a **felony**, or from the commission of an act involving a risk of injury or death that is done in an unlawful, reckless, or grossly negligent manner. Involuntary manslaughter is a relatively new legal concept. Its exact definition varies greatly by jurisdiction, and is sometimes known as second- or third-degree manslaughter.

In order to convict someone of either murder or manslaughter, the distinct elements of each crime must be proved beyond a reasonable doubt, and the actions of the perpetrator cannot be explained or excused by any legal defense, excuse, or justification. Murder and manslaughter also differ in the sentences imposed for each crime. As the perpetrator of manslaughter is assumed to have evidenced less mental culpability, the sentence for manslaughter is usually less than that for murder.

SEE ALSO Assassination; Criminal responsibility, historical concepts; Death, cause of; Death, mechanism of; Serial killers.

Murders, serial SEE Serial killers

Raymond C. Murray

7/2/1929–
AMERICAN
FORENSIC GEOLOGIST

Over the course of his career, Raymond C. Murray turned his knowledge of **geology** into a critical tool for crime investigators. He worked for several years as a geology professor before also becoming a forensic geologist, aiding law enforcement officers and testifying in criminal cases. Murray has written numerous books on the subject, including *Forensic Geology*, the first textbook of its kind.

Murray had an early interest in geology. He attended the University of Wisconsin, Madison, earning a master's degree in geology in 1952 and a doctorate in geology in 1955. After graduation, he was hired by Shell Development Company in Houston, Texas, to work as a manager of geology research, a position he held for the next eleven years. But ultimately, Murray decided to move into academia, taking an associate professor position at the University of New Mexico in 1966.

In 1967, Murray was offered a job at Rutgers University, and became the chairman of the geology department there. It was at Rutgers where Murray first became involved in forensic geology. A Bureau of Alcohol, Tobacco, and Firearms agent had come to Murray with soil involved in a crime investigation, and asked Murray for help. From that point forward, Murray continued his work as a professor, but also expanded his knowledge and expertise into the world of forensic geology. In 1975, along with fellow Rutgers professor John Tedrow, Murray published *Forensic Geology: Earth Sciences and Criminal Investigation.* It was the first textbook written on the science. A revised edition was published in 1991.

Murray left Rutgers in 1977 to take a position at the University of Montana. There he continued his work in forensic geology, often testifying as an expert witness and lecturing at crime laboratories around the world. He retired from the University of Montana in 1996, devoting more time and attention to his private forensic geology practice. In 2004, Murray wrote and published his latest book on the subject, *Evidence from the Earth: Forensic Geology and Criminal Investigation.* In this text he details the many ways geologists have been able to analyze forensic data and reveal soil and rock **evidence**.

SEE ALSO Careers in forensic science; Soils.

Mustard gas

Among the toxic agents that can injure or kill people are noxious gases. One example is mustard gas. Its use as an offensive chemical weapon makes mustard gas of particular relevance for military forensic scientists. Mustard gas is the popular name for the compound with the chemical designation 1,1-thiobis(2-chloroethane) (chemical formula: Cl-CH2-CH2-S-CH2-CH2-Cl). Mustard gas has also been called H, yprite, sulfur mustard and Kampstoff Lost.

The name mustard gas arose because the odor of the impure substance is similar to mustard, garlic, or horseradish. However, in the pure form, mustard gas is odorless and colorless.

The gas was used for the first time as an agent of **chemical warfare** during World War I, when it was distributed with devastating effect near Ypres in Flanders on July 12, 1917.

In 1860, Frederick Guthrie observed that when ethylene reacted with chlorine a substance was produced which, in small quantities, could produce toxic effects on the skin. Exposure to low concentrations of mustard gas classically causes the reddening and blistering of skin and epithelial tissue. On inhalation, the gas causes the lining of the lungs to blister and leads to chronic respiratory impairment. Higher concentrations of mustard gas will attack the corneas of the eyes and can cause blindness.

Exposure to mustard gas can lead to a slow and painful death and any moist area of the body is especially susceptible to its effects. The compound is only slightly soluble in water, but it undergoes a hydrolysis reaction, liberating highly corrosive hydrochloric acid and several other vesicant intermediates, which are able to blister epithelial surfaces.

Despite the ease of hydrolysis, mustard gas may be preserved underground in a solid form for up to ten years. The reason for this is that in an environment where the concentration of water is relatively low, the reaction pathway proceeds to form an intermediate known as thiodiglycol. In a low moisture environment, most of the water available at the solid surface is used in this reaction. Subsequently, another intermediate in the reaction pathway, a sulfonium ion, reacts with the thiodiglycol in the place of water. This reaction then creates stable, non-reactive sulfonium salts, which can act as a protective layer around the bulk of the solid mustard and prevent further degradation.

Mustard gas as a chemical weapon is a particularly deadly and debilitating poison and when it was first used in 1917, it could penetrate all the masks and protective materials that were available at that time. In more recent years, urethane was found to be resistant to mustard gas, and also has several other advantages for use in combat; urethane is tough, resistant to cuts, and is stable at a wide range of temperatures.

Detoxification procedures from mustard gas are difficult because of its insolubility and also because of the drastic effects it can have on lung epithelial tissue following inhalation. During World War I, physicians had no curative means of treating the victims of mustard gas exposure. The only method of detoxification that was known involved a rather extreme oxidation procedure using superchlorinated bleaches, such as 5% sodium hypochlorite. Today, several novel methods of detoxification have been developed to counter the effects of mustard gas and these include the use of sulfur-amine solutions and magnesium monoperoxyphthalate. The most effective method to date employs peroxy acids, because they are able to react quickly with the mustard gas. Furthermore, the addition of a catalyst can speed up the detoxification reaction even more effectively.

Although mustard gas has been shown to have long-term carcinogenic properties, it can also be used as an agent in the treatment of cancer. In 1919, it was observed that victims of mustard gas attack had a low white blood cell count and bone marrow aplasia (tissue growth failure). More detailed research in the years following 1946 showed that nitrogen mustards, which differ from traditional mustard gas by the substitution of a sulfur atom by a nitrogen, could reduce tumor growth in experimental mice by cross linking **DNA** strands. It had been shown previously that the sensitivity of mouse bone marrow to mustard gas was similar to that of humans and more detailed research eventually led to successful clinical trials. Today, nitrogen mustards are also part of the spectrum of substances used in modern anti-cancer chemotherapy. They are primarily used in the treatment of conditions such as Hodgkin's disease and cancers of the lymph glands.

SEE ALSO Chemical warfare; Chemical Biological Incident Response Force, United States; Nerve gas; Sarin gas; Tabun.

N

Narcotic

The detection of narcotics and other drugs of abuse in the **blood**, body **fluids**, and tissues of drug abusers and corpses where the suspected **cause of death** is related to drug overdose is routine procedure in forensic laboratories. The National Institute on Drug Abuse (NIDA), the Federal Bureau of Investigation (**FBI**), the Drug Enforcement Administration (**DEA**), and the Department of Justice are the agencies responsible for drug research and preventive programs, regulatory control, classification of drugs of abuse, and law enforcement.

Narcotics are opium (a substance naturally occurring in poppy seeds) and semi-synthetic opioid substances used to relieve intense pain. These drugs block specific receptors that processes pain information in the central nervous system (CNS), such as the brainstem, medial thalamus, spinal cord, hypothalamus, and limbic system, along with peripheral nerve fibers. Narcotics are addictive substances due to the euphoric effect they have on mood and general disposition. Morphine, codeine, and heroin are the main drugs of abuse in the narcotic category.

Morphine is a controlled medication prescribed for the treatment of intense chronic pain and for post-surgery pain due to its strong analgesic (pain-relieving) properties. However, morphine is highly addictive and can present dangerous side effects. Ordinary doses of morphine may lead to respiratory depression, or the slowing or cessation of breathing, through the reduction of sensitivity of the brain cells that regulate breathing. A study funded by the National Institute on Drug Abuse has shown that the chronic administration of morphine to rats reduced the size of nerve cells that produce dopamine by 25%. Dopamine is a natural brain chemical messenger (neurotransmitter) that causes sensations of pleasure, joy, and reward. The euphoric effects of morphine and other opiates indicate that they act upon the dopamine receptors. It is also known that cells decrease sensitivity to a given medication when frequently exposed to it. Therefore, such observed cell size reductions may be the result of cell desensitization to the drug. This explains the tolerance effect that morphine and other drugs of abuse cause in the CNS, leading addicts to intake increased doses to obtain the same initial effects of euphoria. It also explains the deep depressive episodes that take place when the effect of the drug ceases, or when abusers are under detoxification treatment. Besides addiction, the other side effects of morphine chronic intake are sedation, constipation, nausea and vomiting, urinary retention, and respiratory depression. Withdrawal causes acute depression, tremors, emotional instability, and irritability.

Heroin is an illegal and highly addictive narcotic with the fastest action on brain receptors. Heroin is a semi-synthetic derivate of morphine, sold on the black market either as a black gluey substance known as “black tar” or in a more “purified” form, mixed with sugar, starch, powdered milk, or quinine. The purification process is done by reacting heroin with other drugs or poisons, such as strychnine, which increases the risk of death or irreversible brain

Tattoos on a heroin addict's arm, done for the purpose of covering up needle marks. © TED STRESHINSKY/CORBIS

damage. Since abusers usually inject heroin in an intravenous or intramuscular solution, often while sharing needles, the risk for abusers contracting hepatitis C and HIV is a large concern among public health authorities. Other forms of heroin consumption involve inhaling it through the nose (snorting) or smoking the drug. As tolerance develops, abusers may inject heroin three or four times per day. After the initial rush of euphoria, users become drowsy, respiratory depression sets in, and higher mental functions are clouded. Heroin is converted into morphine in the brain, so the withdrawal symptoms are the same as with morphine, although more severe with heroin. Another risk imposed by heroin is that its illegal manufacture is accomplished by criminals who use toxic compounds and poisons in the process. The product can also be mixed with other dangerous drugs. In addition, the user does not know exactly how much heroin is in the purchased drug; it may have enough to induce an accidental overdose. It can also be contaminated with fungus and other **pathogens**, leading to infections. Lung complications, such as tuberculosis and pneumonia, are common among drug abusers. Inflamed veins or arteries are also common, due to the poor solubility (dissolvability) of substances mixed with the abused drugs.

Law enforcement against international drug traffickers who illegally bring narcotics and other **illicit drugs** of abuse into the United States requires a continuous effort and strategic planning from the FBI and DEA. It also involves collaboration with other international agencies, such as **Interpol** and the police of other countries where these drugs are originally produced, as well as those that are used as routes for drug dealers.

Forensic **identification** of addicts involves the examination of physical indicators such as needle marks in the veins of arms and legs, bluish bruises due to collapsed veins in these areas, and pinpoint pupils. Frequent snorting of cocaine or heroin leads to the destruction of nasal cartilages and nosebleeds. To determine what drugs a suspect is using, laboratory tests are performed on blood or urine samples that allow for the detection of both classes of drugs and specific drugs of abuse. **Interrogation** of arrested addicts helps local investigators to identify and arrest street drug dealers. The use of trained dogs in ports and airports is also a useful resource for the rapid identification of packages and luggage containing drugs. In the past, “mules,” or people hired to carry drugs between countries, hid drugs wrapped in plastic inside their own body cavities. After the installation of x-ray scanners in airports, mules were more easily detected and arrested.

SEE ALSO DEA (Drug Enforcement Administration); FBI (United States Federal Bureau of Investigation); Homogeneous enzyme immunoassay (EMIT); Illicit drugs; Immune system; Interpol; Nervous system overview; Neurotransmitters; Psychotropic drugs.

National Institute of Justice

Various branches of the federal government in the United States are concerned with the forensic investigations of accidents, deaths, and crimes, and in determining both the cause of a particular incident and in taking steps to lessen the likelihood of a recurrence.

The National Institute of Justice (NIJ) serves the United States Department of Justice in the areas of research, development, and evaluation. Established under the authority of the Omnibus Crime Control and Safe Streets Act of 1968, its purpose is to provide independent, evidence-based tools to assist state and local law enforcement. Its programs address a variety of law-enforcement issues, including use of **DNA evidence**, drug abuse, and domestic violence.

Appointed by the President and confirmed by the Senate, the director of the NIJ is responsible for establishing objectives in alignment with Justice Department priorities, as well as the current needs of the field. It works to take account of views from professionals in all areas of criminal justice and related fields in its search for knowledge and tools to guide the policy and practice of law enforcement nationwide. On January 12, 2003, it reorganized, streamlining its structure from three offices to two, the Office of Development and Communications and the Office of Research and Evaluation.

NIJ has set research priorities in a number of fields, including law enforcement/policing; justice systems (sentencing, courts, prosecution, defense); corrections; investigative and forensic sciences (including DNA); counterterrorism/critical incidents; crime prevention/causes of crime; violence and victimization (including violent crimes); drugs, alcohol, and crime; interoperability, spatial information, and automated systems; and program evaluation. Among its programs are the Arrestee Drug Abuse Monitoring Program (ADAM); Community Mapping, Planning, and Analysis for Safety Strategies (COMPASS); National Commission on the Future of DNA Evidence; and the Violence Against Women and Family Violence Research and Evaluation Program.

SEE ALSO FBI (United States Federal Bureau of Investigation); Law Enforcement Training Center (FLETC), United States Federal.

Navy Criminal Investigative Service (NCIS)

In addition to civilian law enforcement agencies, various branches of the military conduct forensic investigations into accidents and deaths. One of these branches is the Navy Criminal Investigative Service (NCIS). NCIS is responsible for providing law enforcement on behalf of United States Navy and Marine Corps personnel and their families. Originally part of the Office of Naval Intelligence (ONI), the organization was staffed primarily by military personnel, whereas today it is largely staffed with civilians. NCIS has been involved in **murder** investigations and drug sweeps, and since September 11, 2001, it has also taken on a homeland security role. All these activities can involve forensic analyses.

NCIS began as part of ONI, which was deployed during World War II to detect potential spies and saboteurs on the domestic front. Through the end of World War II, the investigative branch of ONI was composed mainly of military personnel. In the postwar era, however, the Secretary of the Navy developed a coterie of civilian agents responsible for conducting criminal investigations, counterintelligence, and security background investigations on naval and marine personnel and civilians associated with the U.S. Navy and Marine Corps.

Only on February 4, 1966, did the Naval Investigative Service (NIS), as NCIS’s predecessor was called, gain an identity separate from that of ONI. Nonetheless, it remained a part of the naval intelligence office. In 1972, the newly formed Defense Investigative Service took over responsibility for background checks, leaving NIS free to concentrate on counterintelligence and criminal investigations. During the 1980s, the organization went through a number of name changes until, in December 1992, it gained its present identity.

NCIS has received numerous accolades for its efficiency, not least for the work of its "cold-case squad," which attempts to solve old, previously unsolved crimes. The latter has reopened scores of previously unsolved homicide cases, and successfully solved dozens. This work is not possible without the application of modern **forensic science** techniques.

Working with the cold-case squad of the Fairfax County, Virginia, law-enforcement authorities, for instance, NCIS helped solve a homicide case that was extremely "cold"—so much so that the accused had finished high school, had a full career in the Navy, and retired—all in the quarter-century between the murder and his arrest.

The case involved Paul S. Sorensen, who was 16 years old in 1975, when he allegedly stabbed to death a convenience store clerk while robbing a 7-Eleven. Sorensen entered the Navy after graduating high school in 1976, and in 1999, having attained the rank of chief petty officer, retired to Corpus Christi, Texas. Three years later, and five years after NCIS and Fairfax County reopened the **cold case**, Sorensen—knowing that he would soon be arrested anyway—turned himself in to authorities.

Another example of NCIS at work was the drug sweep that in July 2002 netted 84 marines and sailors at Camp Lejeune, North Carolina. Code-named Operation Xterminator, the sweep took two years and yielded $1.4 million in narcotics.

SEE ALSO Careers in forensic science; Cold case; Military police, United States; United States Army Medical Research Institute of Infectious Diseases (USAMRIID).

NCIC (National Crime Information Center)

As part of the Federal Bureau of Investigation (**FBI**), the National Crime Information Center (NCIC) is a national computerized repository system of criminal justice data used by local, state, and federal law enforcement agencies throughout the United States, Canada, Puerto Rico, and the U.S. Virgin Islands. Now under the direction of the FBI's Criminal Justice Information Services (CJIS) division, located in the city of Clarksburg, West Virginia, the NCIC provides North American **forensic science** departments with search information for such data involving convicted sex offenders, **fingerprint** impressions, and missing persons.

The NCIC was created by the FBI in January 1967 in response to an alarming increase in crime within the United States. Recognizing that law enforcement agencies throughout the country needed instantaneous access to standardized criminal data, the FBI established a computer system and a telecommunications network to initially assist fifteen metropolitan and state regions with about 95,000 records in five databases (Wanted Persons, Stolen License Plates, Stolen or Missing Guns, Stolen Autos, and Other Identifiable Stolen Articles). By 1971, all of the U.S. states and the District of Columbia were part of the NCIC system. Then, in February 1992, the CJIS was created by the FBI in order to serve as the primary information repository for criminal justice data. The NCIC was consolidated under the jurisdiction of the CJIS, along with other relevant federal programs such as Fingerprint Identification and Uniform Crime Reporting.

Open around the clock, the NCIC is well equipped to search for a wide range of forensic data due to the use of its expanding number of databases that contain a growing amount of historical and current data. For example, by using the New York State Identification and Intelligence System, NCIC personnel are able to search for phonetically similar names (such as Clark and Clarke) or derivatives (such as William, Willy, and Billy). In addition, fingerprint searches of wanted and missing persons are made using stored images of the right index fingerprint. NCIC personnel can also search records within the Convicted Persons or Supervised Release File for suspects under probation and parole.

Photographs, commonly called mugshots, can be searched through a signature, fingerprint, or other identifying images (such as scars and tattoos). NCIC personnel can also search for digital images of physical possessions (such as automobiles and boats) associated with a suspect. Records of convicted sexual offenders and violent sexual predators can also be searched through a Convicted Sex Offender Registry. Convicts currently held in the U.S. federal prison system can be identified through the NCIC's Sentry file.

As of March 2005, the NCIC possesses more than ten million records in around seventeen database files (some recently added ones include Foreign Fugitive, Missing Persons, Violent Gang/Terrorist, Unidentified Persons, and U.S. Secret Service Protective) and about 24 million criminal history records contained in the Interstate Identification Index. In the business of law enforcement, the NCIC deals with more than 80 thousand law enforcement and criminal justice agencies.

SEE ALSO DNA databanks; DNA profiling; FBI (United States Federal Bureau of Investigation); Tattoo identification.

NDIS, FBI database

The National DNA Index System, or NDIS, is a United States Federal Bureau of Investigation (**FBI**) DNA database that facilities the electronic comparison and exchange of DNA profiles between participating local, county, state, and federal law enforcement agencies and forensic laboratories. First made operational in 1998, the NDIS is a highly valued instrument that is used by law enforcement professionals in order to better coordinate and communicate information related to serial violent crimes committed across the United States. Authorization to establish the NDIS came about from the DNA Identification Act of 1994.

The NDIS is a critical component of the Combined DNA Index System (**CODIS**), an FBI software support program developed in 1990, which uses DNA (deoxyribonucleic acid) technology to generate leads in crimes where forensic **evidence** is recovered from crime scenes. In its role, the NDIS enables participating organizations to compare DNA profiles on a national level in order to more efficiently investigate crimes. Managed by the FBI as the nation's DNA database, DNA profiles typically are generated at the local level, transferred to state and national levels, and uploaded electronically through the Internet at the state level to the NDIS. At this point, the data is compared to determine if a convicted offender can be associated with a previous or current crime, or if two or more crimes can be joined together.

An actual example that shows how the NDIS works involves the unsolved (and previously unconnected) rape and **murder** cases of a college professor in Flint, Michigan, in 1986; and of a flight attendant in Romulus, Michigan, in 1991. With access to CODIS in 2001, Michigan State Police submitted DNA from the 1986 case to the NDIS. When the sample was matched with DNA from the 1991 case, latent fingerprints from the 1986 case were sent to the FBI's Latent Fingerprint Unit. While searching through the FBI's **Integrated Automated Fingerprint Identification System** (IAFIS), one of the prints was identified. Based on this information, the Flint Police Department followed the suspect, recovered a restaurant napkin used by the suspect, and after the material found on the napkin was forensically matched with evidence left at both homicide scenes, the suspect was arrested and charged with murder.

From its beginnings on October 13, 1998, to today, the NDIS has gained participants and now includes over 130 federal, state, and local laboratories representing all fifty states, the District of Columbia (the FBI Laboratory), Puerto Rico, and the U.S. Army. On June 12, 2002, the NDIS achieved a major milestone when the Florida Department of Law Enforcement contributed the one millionth DNA profile to the program. As of December 2004, the total number of DNA profiles within the NDIS is 2,132,470; the total number of convicted offender profiles is 2,038,470; and the total number of forensic profiles is 93,956.

SEE ALSO CODIS: Combined DNA Index System; DNA; DNA databanks; DNA profiling; FBI (United States Federal Bureau of Investigation); FBI crime laboratory; Integrated automated fingerprint identification system; Serial killers.

Nerve gas

Noxious gases can injure or kill people, and so can be of significance in a forensic investigation. One example is nerve gas. Its offensive military use makes nerve gas of particular relevance for military forensic scientists. As well, the specter of the use of agents like **sarin gas** by rogue organizations and extremists has made the forensic detection of nerve gas a national security issue.

Nerve gases, or nerve agents, are mostly odorless compounds belonging to the organophosphate family of chemicals. Nerve gasses are either colorless or yellow-brown liquids under standard conditions. Two examples of nerve gases that have gained some notoriety through their powerful physiological effects are sarin and VX.

Even in small quantities, nerve gases inhibit the enzyme acetylcholinesterase and disrupt the transmission of nerve impulses in the body. Acetylcholinesterase is a serine hydrolase belonging to the esterase enzyme family, which acts on different types of carboxylic esters in higher eukaryotes. Its role in biology is to terminate nerve impulse transmissions at cholinergic synapses. It does this by rapidly hydrolyzing the neurotransmitter, acetylcholine, which is released at the nerve synapses. Inhibition of the acetylcholinesterase results in the excessive build up of acetylcholine in, for example, the parasympathetic nerves leading to a number of important locations in the body, such as the smooth muscle of the iris, ciliary body, the bronchial tree, gastrointestinal tract, bladder and blood vessels; also the salivary glands and secretory glands of the gastrointestinal tract and respiratory tract; and the cardiac muscle and endings of sympathetic nerves to the sweat glands. An accumulation of acetylcholine at parasympathetic sites gives rise to characteristic muscarinic signs, such as emptying of bowels and bladder, blurring of vision, excessive sweating, profuse salivation, and stimulation of smooth muscles. The accumulation of acetylcholine at the endings of motor nerves leading to voluntary muscles ultimately results in paralysis.

Nerve gases are highly toxic, stable, and easily dispersed. They produce rapid physiological effects both when absorbed through the skin or through the respiratory tract. They are also fairly easy to synthesize and the raw materials required for their manufacture are inexpensive and readily available. This means that anyone with a basic laboratory can produce them. Nerve gases are, therefore, a significant concern for authorities as they are an easily available weapon for terrorist groups.

In 1936 the German chemist Gerhard Schrader of the I. G. Farbenindustrie Laboratory in Leverkusen first prepared the agent **tabun** (ethyl-dimethylphosphoramidocyanidate). At the time, Schrader was leading a program to develop new types of insecticides, working first with fluorine-containing compounds such as acyl fluorides, sulfonyl fluorides, fluoroethanol derivatives, and fluoroacetic acid derivatives. Schrader's research eventually led to the synthesis of tabun as an extremely powerful agent against insects. Schrader found that as little as 5 parts per million (ppm) of tabun killed all the leaf lice used in his experiments. Soon after Schrader's experiments, the potential use of this substance as an agent of war was realized.

In 1939, a pilot plant for tabun production was set up at Munster-Lager, on Luneberg heath near the German Army training grounds at Raubkammer. In January 1940, Germany began the construction of a full-scale plant, code named Hochwerk, at Dyernfurth-am-Oder (now Brzeg Dolny in Poland). A total of 12,000 tons of tabun was produced during the ensuing three years (1942–1945) and at the end of WWII, large quantities were seized by the Allied Forces. In addition to tabun, Schrader and his colleagues produced some 2,000 new organophosphates, including sarin in 1938 and the third of the "classic" nerve agents, soman, in 1944. These three nerve agents, tabun, sarin, and soban, are known as G agents. The manufacture of sarin was never fully developed in Germany and only about 0.5 tons were produced in a pilot plant before the end of WWII in 1945.

After 1945, a great deal of research began to focus on understanding the physiological mechanisms of nerve gas action, so that more effective means of protection could be devised against them. However, these efforts also allowed for the development of new and more powerful agents, closely related to the earlier ones. The first official publications on these compounds appeared in 1955. The authors, British chemists Ranajit Ghosh and J. F. Newman, described amiton, one of the newly developed nerve agents, as being particularly effective against mites. At this time, researchers were devoting a great deal of energy to studying organophosphate insecticides both in Europe and in the United States. At least three chemical firms independently studied and quantified the intense toxic properties of these compounds during the years 1952–53 and some of them became available on the market as pesticides. By the mid-1950's, following in the wake of the intensive research activity, a new group of highly stable nerve agents had been developed. These were known as the V-agents and were approximately ten-fold more poisonous than sarin. The V-agents can be numbered among the most toxic substances ever synthesized. VX, a persistent nerve gas, was discovered by Ghosh and was touted as being more toxic than any previously synthesized compound. Since the discovery of VX, there have been only minor advancements in the development of new nerve agents.

A contemporary use of nerve gas occurred during the Iran-Iraq war of 1984–1988. In this conflict, the United Nations confirmed that Iraq used tabun and other nerve gases against Iran. This incident is a prime example of how the technology of chemical weapons was shared during the Cold War. The Soviets armed their allies while the U.S. did the same for its allies. Iraq was a benefactor and implemented its chemical stockpiles during this period.

Another contemporary incident of nerve gas use occurred in Japan in 1995. Members of the Aum Shinrikyo cult introduced sarin gas into Tokyo's subway system. This incident gives an example of the possible new roles that nerve gases may play in the future, as tools of insurrection rather than the weapons of powerful nations.

SEE ALSO Chemical warfare; Chemical Biological Incident Response Force, United States; Mustard gas; Sarin gas; Tabun.

Nervous system overview

The knowledge of the structure and functioning of the nervous system can be very relevant to a forensic examination that seeks to determine the cause of an illness or death. For example, in cases where suspected drugs or **toxins** may have been used, a forensic scientist may be able to determine what compounds were used by the symptoms produced. Drugs including **barbiturates** can slow or cripple the transmission of nerve impulses, while **amphetamines** stimulate the nervous system by causing the excessive release of norepinephrine, which is involved in the transmission of the nerve impulses. The toxin produced by the bacterium *Clostridium botulinum* inhibits nerve transmission by binding to sites at the junction between adjacent nerves.

The nervous system is responsible for short-term immediate control of the human body and for communication between various body systems. Although the endocrine system achieves long-term communication and control via chemical (hormonal) mechanisms, the nervous system relies on a faster method of alternating chemical and electrical transmission of signals and commands through a network of specialized neural cells (neurons).

There are three differing types of neurons, including sensory neurons, neurons associated with transmission of impulses, and effecter neurons such as motor neurons that transmit nerve impulses to specialized tissues (e.g., motor neurons to muscle tissue) and glands. In addition to neurons, there are a number of cell types that play a supportive role in the nervous system. Principal among these neuron-supporting cells are Schwann cells, which are associated with an insulating myelin sheath that wraps around specific types of neural fibers or tracts.

Neurons contain key common components. At one end, the dendrite end, specialized cell processes and molecular receptor sites bind **neurotransmitters** released by other neurons and sensory organs across a gap known as the neural synapse. At the dendrite, the nerve impulse within a particular neuron is generated by a series of chemical and electrical events associated with the binding of specific neurotransmitters. The nerve impulse then travels down the neuron cell body, the axon, via an electrical action potential that results from rapid ion movements across the neuron's outer cell membrane. Ultimately, the action potential reaches the presynaptic terminus region where the electrical action potential causes the release of cell specific neurotransmitters that diffuse across the synapse (the gap between neurons) to start the impulse generation and conduction sequence in the next neuron in the neural pathway. The major chemical neurotransmitters include acetylcholine, norepinephrine, dopamine, and serotonin.

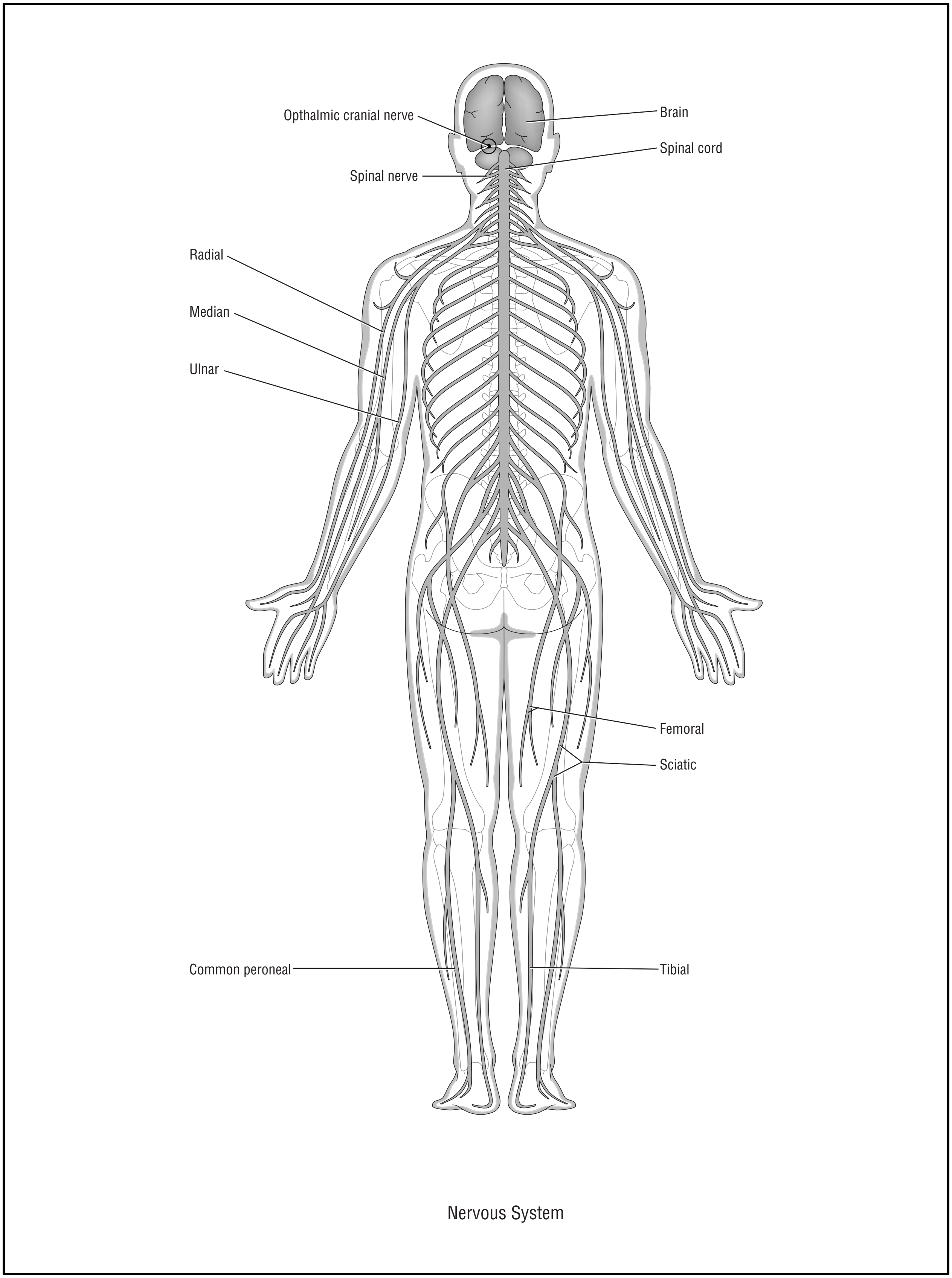
Neural transmission and the diffusion of neurotransmitters across the synapse do not always produce a subsequent action potential without the combined input of other neurons in a process termed summation. Depending on the specific neurotransmitters, receptor binding can produce either excitation or inhibition of action potential production. Subject to a refractory period, during which a neuron returns to its normal state following the production of an earlier action potential, once the neuron reaches a properly timed threshold stimulus, it will produce an action potential. The production of action potentials is an "all or none" process and once produced the axon potential (nerve impulse) sweeps down the axon.

The nervous system is organized along morphological (structural) and functional lines. Structurally, the nervous system can be divided into the central nervous system (CNS) that includes the brain and spinal cord, and the peripheral nervous system (PNS) that contains all other nerves (e.g., sensory and motor neurons), ganglia, and associated cells.

The CNS is protected by a tri-fold layer of specialized membranes, termed the meninges. The brain and spine are organizationally reversed. The spinal cord contains gray matter tracts surrounded by white matter. In contrast, the brain contains centralized white matter.

Functionally, the nervous system can be divided into the somatic or voluntary nervous system (VNS), which coordinates voluntary muscles and reflexes, and the autonomic nervous system (ANS), which is associated with the regulation of viscera, smooth muscle, and cardiac muscle. The autonomic nervous system is further subdivided into sympathetic and parasympathetic systems.

The sympathetic nervous system (SNS), when related to the classic "fight or flight" response,



Nervous system overview. ILLUSTRATION CREATED BY ARGOSY heightens activity in bodily organs or systems (e.g., the respiratory system) and the metabolic rate (the rate at which energy is consumed by bodily processes such as respiration). In contrast, the parasympathetic nervous system (PNS) lowers response and decreases the metabolic rate. The sympathetic and parasympathetic systems work in opposition to control bodily systems.

The brain is divided into various areas or lobes. The large left and right anterior lobes represent the convoluted (wrinkled) cerebral cortex or cerebrum. Posterior lobes represent the cerebellum. At the top of the spinal cord lie the pons and medulla. The cerebellum, pons, and medulla together are referred to as the hindbrain and are associated with many basic process involved in body maintenance, metabolism (e.g., breathing and heart rate), and homeostasis. In general, the forebrain (the cerebrum and some related areas) is the area responsible for higher intellectual functions involved in sensory interpretations, memory, language, and learning. The midbrain tract acts as a switching system that directs, coordinates, and integrates impulses among various regions of the brain.

Within the peripheral nervous system, mechanoreceptors, most of which are located in the skin (integumentary system), respond to physical stimuli such as pressure and motion. Thermoreceptors are specialized to respond to changes in temperature. Chemoreceptors associated with taste and smell senses respond to specific molecules. Highly developed complex sensory structure such as the eyes and ears respond to light (electromagnetic radiation) and sound.

In addition to a complex network of nerves throughout the body that act as a transmission system, the PNS contains specialized nerve cells to interface and transmit signals to muscles and glands.

Nerves usually contain neuron cell bodies that lie in tracts or fibers. Unmyelinated axons form gray matter. When Schwann cells wrap around the axon they create a myelin sheath around neurons (in the peripheral nervous system) that in tracts or fibers are termed white matter. Because the myelin sheath disrupts the normal transmission of the electrical action potential down the neuron, a specialized form of conduction of the nerve impulse or action potential occurs between spaces in the myelin sheath termed the nodes of Ranvier. Accordingly, diseases that disrupt or destroy the myelin sheath (demyelinating diseases) can impair or destroy normal nerve function.

Schwann cells are only one form of neuroglia or glial cells that are required to support normal neural function. Other glial cells include astrocytes, microglia, ependymal cells, oligodendrocytes, and satellite cells. Astrocytes are necessary for the proper vascularization of nerve cells and for the transport of nutrients and the removal of cellular waste products across the blood brain barrier. Microglia cells engage in phagcytosis and are capable of helping defend neural cells from attacks by a range of pathogenic agents. Ependymal cells line brain and spinal ventricles (fluid filled cavities in the brain and spine) and produce and maintain cerebrospinal fluid. Oligodendrocytes are responsible for the production of the myelin sheath in the CNS. Satellite cells protect neurons in ganglia.

SEE ALSO Amphetamines; Barbiturates; Botulinum toxin; Epilepsy; Neurotransmitters; Psychotropic drugs; Toxicology.

Neurotransmitters

The forensic investigation of an accident or death is not always aided by the presence of physically obvious signs, such as a stab wound or gunshot wound. Injury or death inflicted by toxic agents may have less subtle physical effects. **Toxins** can interfere with the normal physiological functions of the body. Then, their presence is forensically evident by a physiological change in the norm. One example is agents that disrupt the action of neurotransmitters.

Neurotransmitters are chemicals released in minute amounts from the terminals of nerve cells in response to the arrival of an action potential. There are now more than 300 known neurotransmitters and they act either locally in point-to-point signal transmission (e.g., the motor nerve of a neuromuscular junction) or at a distal site (e.g., the hypothalamic releasing hormones acting on the anterior pituitary). Locally acting neurotransmitters relay the electrical signal traveling along a neuron as chemical information across the neuronal junction, or synapse, that separates one neuron from another neuron or a muscle. Neurons communicate with peripheral tissues, such as muscles, glands etc., or with each other, largely by this chemical means rather than by direct electrical transmission.

Neurotransmitters are stored in the bulbous end of the nerve cell's axon. When an electrical impulse traveling along an axon reaches the junction, the neurotransmitter is released and diffuses across the synaptic gap, a distance of as little as 25 nanometers (nm) or as great as 100 micrometers (μm). The interaction of the neurotransmitter with the postsynaptic receptor of the target cell generates either an excitatory postsynaptic potential (EPSP) or an inhibitory postsynaptic potential (IPSP). Transmitters that lead to EPSPs appear to open large, non-specific membrane channels, permitting the simultaneous movement of Na^+, K^+ and Cl^-. IPSPs are caused by Cl^- flux only.

Neurotransmitters include such diverse molecules as acetylcholine, noradrenalin, serotonin, dopamine, γ-aminobutyric acid, glutamate, glycine and numerous other small monoamines and amino acids. There are also small peptides, which appear to act as chemical messengers in the nervous system. They include substance P, vasopressin, oxytocin, endorphins, angiotensin, and many others. A rather unusual but interesting neurotransmitter is the gas nitric oxide. This diverse range of chemical neurotransmitters may suggest that chemical coding could play as important a part in communication between neurons as do the strict point-to-point connections of neural circuitry.

Acetylcholine is one of the neurotransmitters functioning in the peripheral nervous system. It is released by all motor nerves to control skeletal muscles and also by autonomic nerves controlling the activity of smooth muscle and glandular functions in many parts of the body. Norepinephrine is released by sympathetic nerves controlling smooth muscle, cardiac muscle, and glandular tissues. In these tissues acetylcholine and norepinephrine often exert diametrically opposed actions.

The neurotransmitters used by the majority of fast, point-to-point neural circuits in the central nervous system (CNS) are amino acids. Of these, the inhibitory substance γ-aminobutyric acid (GABA) is well characterized and it is present in all regions of the brain and spinal cord. GABA rapidly inhibits virtually all CNS neurons when applied locally by increasing cell permeability to chloride ions, thus stabilizing resting membrane potential near the chloride equilibrium level. Although GABAergic (GABA-producing) neurons also exist in the spinal cord, another inhibitory amino acid, glycine, predominates in this region of the CNS. Glycine is present in small inhibitory interneurons in the spinal cord gray matter and mediates the inhibition of most spinal neurons. The amino acids L-glutamate and L-asparagine depolarize neurons by activating membrane sodium channels and are ubiquitously distributed, appearing as the most common excitatory transmitters for interneurons in the CNS.

In contrast to the point-to-point signaling in which amino acids are involved, the monoamines are mainly associated with the more diffuse neural pathways in the CNS. The monoamines are present in small groups of neurons, primarily located in the brain stem, with elongated and highly branched axons. These diffuse ascending and descending monoaminergic innervations impinge on very large terminal fields and there is evidence that the monoamines may be released from many points along the varicose terminal networks of monoaminergic neurons. Most monoamines released in this way occur at nonsynaptic sites and a very large number of target cells may be affected by the diffuse release of these substances, which are therefore thought to perform modulatory functions of various types.

One of the most remarkable developments was the realization that most peptide hormones of the endocrine and neuroendocrine systems also exist in neurons. These are by far the largest group of potential chemical messengers. For example, the opioid peptides (endorphins) have attracted enormous interest because of their morphine-like properties. They are consequently of considerable interest in the understanding of pain. Endorphins represent a family of chemical messengers found in all regions of the CNS including the pituitary (e.g., beta-endorphin and dynorphin) and the peripheral enteric nervous system. Their presence in regions such as the basal ganglia and the eye's retina, where it is unlikely that they have any connection with pain pathways, suggests that they may also have other diverse functions. There is still much to be learned about the possible functions of neuropeptides in the CNS. In all cases so far examined the peptides seem to be capable of being released by a specialized secretory mechanism from stimulated CNS neurons. They can exert powerful effects on the CNS. For example, the direct administration of small amounts of peptide to the brain can elicit a variety of behavioral responses, including locomotor activity (substance P), analgesia (endorphins), drinking behavior (angiotensisn II), female sexual behavior (LHRH), and improved retention of learned tasks (vasopressin).

An interesting and novel neurotransmitter identified in the 1980s is nitric oxide (NO). This is a highly reactive naturally occurring gas generated in the body from arginine and has the alternative name "epithelium-derived-relaxing factor." Synthesis of NO in blood vessel epithelia occurs in response to the distortion of blood vessels by blood flow. The gas then rapidly diffuses into the surrounding muscle layers, causing them to relax. It, therefore, has vasodilatory (dilation of blood vessels) properties and as a neurotransmitter occurs in a number of nerve networks. For example, it is known to be active in the dilation of arteries supporting the penis and in the relaxation of muscles of the corpora cavernosa (the two chambers filled with spongy tissue which run the length of the penis). NO released from stomach nerves causes the stomach to relax in order to accommodate food. Intestinal nerves also induce the relaxation of the intestinal muscle by releasing NO. In addition, nervous activity in the cerebellum is increased by NO and it appears that NO is an important neurotransmitter associated with memory. Despite its usefulness, nitric oxide can have a toxic effect on body cells and has been implicated in Huntington's disease and Alzheimer's disease.

SEE ALSO Death, cause of; Nervous system overview; Toxicology.

William Nicol

1768–1851
SCOTTISH
MINEROLOGIST, PHYSICIST

William Nicol (aka William Nichol) was born, lived his entire life, and died in Edinburgh, Scotland. He was considered a quiet and unassuming professor at the University at Edinburgh who had a profound effect on the forensic sciences by pioneering the production of polarized light and the creation of the Nicol prism.

Nicol used the double refraction properties of Iceland spar to produce polarized light in 1825 and in 1829 created an optical device called the Nicol prism, a precursor to the polarizing light microscope. Essentially, the Nicol prism consists of a crystal of calcite or Iceland spar that is cut into two equal pieces at an angle; the pieces are then rejoined with Canada balsam. When a beam of light enters the crystal, it undergoes double refraction (birefraction). That is, the beam is split into two parts, each of which is differentially affected. The first part, called the ordinary ray, undergoes total reflection at the Canada balsam joint and is shifted off course to pass out of one side of the Iceland spar crystal. The other part, called the extraordinary ray, continues on through the crystal. By means of the Nicol prism, a beam of light could be polarized or a beam of already polarized light can be subjected to analysis. William Nicol utilized his prism to investigate the optical properties of **minerals** and other substances. He created lenses by grinding semiprecious stones, and used those to investigate fossilized wood and fluid-filled cavities in crystals.

Nicol prisms were first used to measure the polarization angle of birefringent compounds, which led to new developments in the scientific understanding of interactions between polarized light and crystalline substances. (Optical birefringence is when light enters a nonequivalent axis in an anisotropic crystal and is refracted into two rays, each of which are polarized with the vibration directions oriented at right angles to one another, and traveling at different velocities. Anisotropic crystals have crystallographically different axes that interact with light differently, depending on the angle in which the incident light reaches the surface of the crystal.)

Nicol's work set the stage for development of the polarizing light microscope, an important forensic tool. The purpose of the polarizing light microscope is to view and photograph specimens visible due to their anisotropic characteristics. Polarized light is scientifically and forensically useful because it enhances contrast and improves the image quality of birefringent materials when compared to other techniques such as darkfield and brightfield illumination, phase contrast, and **fluorescence**. As a forensic investigative tool, **polarized light microscopy** permits access to a great deal of information not obtainable with any other optical microscopy technique: because it exploits optical properties of anisotropy, it can reveal minutely detailed information about the structure and composition of materials. This is of critical importance for crime scene/criminal **identification**, as well as for forensic diagnostic purposes.

SEE ALSO Alternate light source analysis; Identification; Microscopes; Minerals.

Night vision devices

Forensic investigations are not always conducted in well-lit settings or during daylight. When lighting conditions are diminished, assistance in maximizing the available light using night vision technology can be important in inspecting the scene of an accident or death. Night vision devices have also proved useful in conjunction with lasers to identify altered, obliterated, or over-written documents.

Night vision technology can also be part of surveillance systems. Analyzing the recordings from surveillance **cameras** can reveal aspects of a crime or accident scene before and during the incident that would otherwise not be available.

Night vision scopes are devices that enable machines or people to "see in the dark," that is, to form images when illumination in the visible band of the **electromagnetic spectrum** is inadequate. Although it is not possible to form images in absolute darkness (in the absence of any electromagnetic radiation), it is possible to form images from radiation wavelengths to which the human eye is insensitive, or to amplify visible-light levels so low that they appear dark to the human eye.

There are two basic approaches to imaging scenes in which visible light is inadequate for human vision:

In the first approach, low-level visible light that is naturally present may be amplified and presented directly to the viewer's eye. (Light in the near-infrared part of the electromagnetic spectrum [$\cong$.77–1.0 microns], either naturally present or supplied as illumination, may also be amplified and its pattern translated into a visible-light pattern for the viewer's benefit.) This technique is termed image intensification.

In the second approach, light in the infrared part of the spectrum (>.8 microns) that is emitted by all warm objects may be sensed by electronic devices. A visible-light image can then produced on a video screen. This technique is termed thermal imaging.

Image intensification is the method used for the devices termed night-vision scopes, which exist in a variety of forms that can be mounted on weapons or vehicles or worn as goggles by an individual. Image-intensification devices have been used by technologically advanced military organizations since the 1950s. In a modern, high-performance light amplifier, light from the scene is collimated—forced to become a mass of parallel rays—by being passed through a thin disk comprised of thousands of short, narrow glass cylinders (optical fibers) packed side by side. The parallel rays of light emerging from these optical fibers are directed at a second disk of equal size, the microchannel plate. The microchannel plate is also comprised of thousands of short, narrow cylinders (.0125–mm diameter, about one fourth the diameter of a human hair), but these microchannels are composed of semiconducting crystal rather than optical fiber. A voltage difference is applied between the ends of each microchannel. When a photon (the minimal unit of light, considered as a particle) strikes the end of a microchannel, it knocks electrons free from the atoms in the semiconducting crystal. These are pulled toward the voltage at the far end of the microchannel, knocking more electrons loose as they move through the crystal matrix. Thousands of electrons can be produced in a microchannel by the arrival of a single photon. At the far end of the microchannel, these electrons strike a phosphor screen that is of the same size and shape as the microchannel disk.

The phosphor screen contains phosphor compounds that emit photons in the green part of the visible spectrum when struck by electrons; thus, that part of the phosphor disk affected by a single microchannel glows visibly, the brightness of its glow being in proportion to the intensity of the electron output of the microchannel. (Green is chosen because the human eye can distinguish brightness variations in green more efficiently than in any other color.) The phosphor-disk image is comprised of millions of closely packed dots of light, each corresponding to the electron output of a single microchannel. The light from the phosphor disk is collimated (made parallel) by a second fiber-optic disk and presented to the viewer's eye through a lens. The function of the lens is to allow the user's eye to relax (i.e., focus at infinity), rather than straining to focus on an image only an inch or so away. Alternatively, the phosphor-disk image can be filmed by a camera.

Either a pair of night-vision goggles may contain two such systems, one for each eye, or, as in the case of the U.S. Army's AN/PVS-7B night vision goggles, a single image may be split into identical copies and presented to both the user's eyes simultaneously.

A "third generation" image intensifier has been described above; several other image-intensification technologies remain in the field. All, however, operate by using photons to liberating electrons, amplifying the resulting electron current, and using the amplified electron current to liberate visible photons.

Infrared imaging systems are bulkier and more expensive than image intensification systems. However, they work even in a complete absence of illumination (since all scenes "glow" in infrared) and can detect otherwise invisible phenomena, such as hot, nonsmoky exhaust plumes, that may be of forensic interest. Infrared imagers are also used for a wide variety of forensic and industrial purposes, as they can reveal chemical compositional differences not evident in visible light.

SEE ALSO Alternate light source analysis; Crime scene investigation.

NIST Computer Security Division, United States

A phenomenal amount of information is computerized. Whether isolated or connected to the global computerized community via the Internet, computers house countless pages of text, graphics, and other forms of information. Without safeguards, this information is vulnerable to misuse or theft.

Forensic computing is concerned with **computer security**, particularly when a breach has occurred. This aspect of **forensic science** is a national priority. The Computer Security Division (CSD) is one of eight divisions within the Information Technology Laboratory of the National Institute of Standards and Technology (NIST), itself a bureau of the Chamber of Commerce. CSD is concerned with raising awareness of information technology (IT) risks, vulnerabilities, and protection requirements, especially for new and emerging forms of technology.

In addition to its support and security role with regard to new technologies, CSD is involved in researching IT vulnerabilities, advising federal and state agencies of these, and developing means to provide cost-effective protection. Also, in line with its mission as a part of NIST, it helps develop standards, tests, validation programs, and metrics in computer systems and services with an eye toward security.

NIST involvement in "digital sleuthing," or the use of computers in detective work, often allows the division to team up with a consortium of law-enforcement agencies to develop **computer forensics** technology. NIST and CSD scientists worked with agents from the Federal Bureau of Investigation, United States Customs Service, and other agencies, along with software vendors, to create the National Software Reference Library (NSRL), which allows easier review of the contents of a computer, especially with regard to material potentially relevant to a criminal investigation. By examining file tag attachments, NIST CSD programs can easily identify certain types of files (e.g., picture files that may be hidden in other programs).

Presidential Decision Directive 63, signed by President William J. Clinton in 1998, earmarked $5 million to NIST and CSD (far less than the $50 million Clinton had requested from Congress) to encourage the development of secure information systems for support of the telecommunications, transportation, and government service infrastructures. In the heightened security environment of the post-September 2001 United States, the work of CSD has become—like that of most agencies either within or at the periphery of the security and intelligence apparatus of the federal government—critical to national defense. Among the forensically-relevant areas of focus for CSD are development of cryptographic standards and applications, security testing, and research in the interests of emerging technologies.

SEE ALSO Computer forensics; Computer hackers; Computer hardware security; Computer software security; Computer virus.

NTSB (National Transportation Safety Board)

The investigation in the aftermath of a transportation accident is a federal responsibility in most countries, including the United States and Canada. The investigations are entirely forensic in scope, from the physical piecing together of the shattered train or aircraft to the **identification** of victims based on genetic material, dental samples, or bone and tissue samples.

The United States National Transportation Safety Board (NTSB) is an independent national agency responsible for investigating transportation accidents within the United States. The agency has custody of all debris and wreckage from accidents that it investigates, and thorough investigations sometimes take years to complete. The primary focus of NTSB operations is the investigation of civil aviation accidents, however the agency is also required to report on railroad, pipeline, and significant marine and highway accidents. For the NTSB to be involved in an accident investigation, the accident must involve a national transportation infrastructure, a public vessel, or hazardous materials.

The NTSB was established on April 1, 1967. In its early days, the agency worked closely with the Department of Transportation. Concerned with the NTSB's ties to the nation's transportation regulatory agency and the transportation industry, Congress sought to make the NTSB an independent, and impartial, entity. In 1975, the agency became independent, receiving funding in its own right through the Independent Safety Board Act.

In addition to accident investigation, the NTSB maintains the government database of civil aviation accidents. The database permits NTSB researchers to search for patterns in accident occurrence, as well

Aerial view of the wreckage of the Amtrak Sunset Limited that plunged into a bayou north of Mobile, Alabama, in 1993, killing 47 people when a barge rammed the bridge and caused the derailment. Coast Guard rules on towing vessels changed because of the accident. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

as publish safety statistics for carriers and airports. The NTSB conducts regular studies of transportation safety procedures, making improvement suggestions to transportation officials and Congress when necessary. Since its inception in 1967, the NTSB has issued nearly 12,000 recommendations. Though the NTSB does not have the power to act as a regulatory authority, most of its recommendations have been adopted by the national transportation industry.

Although the investigative jurisdiction of the NTSB does not extend beyond national borders, the agency provides investigators to international accidents involving United States registered aircraft or maritime vessels. United States NTSB investigators, or foreign NTSB Accredited Representatives, have occasionally been welcomed by foreign governments that do not have their own investigative services to report on accidents.

While in the wake of September 11, 2001, the NTSB's mandate shifted to reflect increased concern with airline safety and screening procedures, forensic investigations remain the heart of the board's work.

SEE ALSO Accident investigations at sea; Aircraft accident investigations.

Nuclear detection devices

In the Gulf Wars of 1991 and 2003, much effort was spent on the detection of nuclear and biological weapons that were suspected to be stockpiled by the government of Iraq. One aspect of this forensic sleuthing was the use of devices to detect nuclear weapons and their radioactive payloads. Nuclear detection devices, also termed radiation detectors, are systems designed to detect the presence of radioactive materials. These materials may take the form of gases, particles suspended in air, or solid metals (often alloys of uranium or plutonium).

Although radioactive materials can be (and, in the laboratory, often are) detected by direct chemical assay, or analysis, it is far easier in practice to detect them at second hand by measuring the radiation they emit. Nuclear materials emit two kinds of radiation as the nuclei of their atoms spontaneously break apart: fast particles (i.e., neutrons, electrons, and ions) and electromagnetic radiation (i.e., x rays and gamma rays). Different nuclear materials emit different blends of these radiation types. This radiation, unless blocked by layers of matter (shielding), reveals the presence of the nuclear material. The use of nuclear detection devices or radiation detectors is thus, key to monitoring for the presence of radioactive substances. The arms-control monitoring programs of the International Atomic Energy Agency, for example, depend heavily on both automated and hand-carried detection devices that seek to measure the telltale radiations emitted by nuclear materials.

Radiation can cause illness, injury, or death. A single fast particle, x ray, or gamma ray can damage a **DNA** molecule so that a healthy cell is converted to a cancer cell, and sufficiently large numbers of particles or rays can disturb enough of a cell's molecules to kill it. Therefore, nuclear detection devices are also used to alert to releases of radioactive material, whether deliberate (e.g., caused by a "dirty bomb") or accidental (e.g., material escaping from a nuclear power plant, waste-storage facility, or fuel-reprocessing plant).

To be detectable, radiation must be partly or wholly absorbed by ordinary matter. Radiation is said to have been absorbed by a mass of material when it has given up most or all of its energy to that material; radiation that is difficult to absorb (e.g., neutrino flow) is correspondingly difficult to detect. There are several different radiation-absorption phenomena, each of which is exploited in the design of a different class of detection devices. The most important form of absorption is ionization, that is, the separation of neutral atoms in the absorbing medium into free electrons (negatively charged) and free ions (positively charged atoms lacking one or more electrons). All forms of radiation mentioned above can cause ionization. Ionization, in turn, can be detected in numerous ways. One way is chemical; because ions lack electrons they readily combine with other atoms to form new molecules. In a photographic film, this recombination appears as the chemical change known as exposure. Film-badge dosimeters measure radiation by accumulating chemical changes in response to ionizing radiation.

Researcher holding uranium at the Oak Ridge, Tennessee Y-12 plant, where uranium-235 powder is converted to metal discs or "buttons," which then are manufactured into nuclear weapon components. © CORBIS

A more precise and continuous measure of ionizing radiation is obtained by electronic amplification of individual ionization events. The best known of the tools that measures radiation in this way is the Geiger counter. In a Geiger counter, a voltage is placed across a chamber filled with gas (usually argon or xenon); this causes an electric field to exist between one end of the chamber and the other. When a fast particle or high-energy ray passes through the chamber, it ionizes neutral atoms, that is, splits them up into free electrons and positively charged ions. Under the influence of the electric field, the electrons accelerate toward one end of the chamber and the ions toward the other. If the electrical field is strong enough, it accelerates them enough so that when they strike other atoms in the gas they ionize them as well. The electrons and ions thus produced may also be accelerated enough to cause ionization, and so on. The resulting brief avalanche of charged particles constitutes a pulse of electrical current that can be detected, amplified, and counted by appropriate circuitry. In the audio output circuit of a Geiger counter, a single ionization event is amplified to produce the device's trademark "click." Although the arrival of any one ray or particle is a randomly timed event, the average rate of such arrivals, smoothed over time, gives an accurate idea of how much radiation is present.

Another type of radiation-detection device is the scintillation detector. Certain crystals, when struck by a single high-energy photon or particle, produce a scintillation, that is, a flash of light consisting of thousands or tens of thousands of visible photons.

U.N. weapons inspectors search inside a storage tank at Tikrit University in Iraq for evidence of alleged nuclear weapons programs, 2003.

In the early twentieth century, one method of measuring radiation was to count scintillation rates under a microscope; modern detectors use electronic circuits for the same purpose.

The interactions of radiation with semiconducting crystals such as silicon can also be measured. Semiconducting radiation detectors have the advantages of small size, high sensitivity, and high accuracy.

SEE ALSO War forensics.

Nuclear spectroscopy

Nuclear **spectroscopy** is a powerful tool in the arsenal of scientists and forensic investigators because it allows detailed study of the structure of matter based upon the reactions that take place in excited atomic nuclei.

Nuclear spectroscopy is a widely used technique to determine the composition of substances because it is more sensitive than other spectroscopic methods and can detect the trace presence of elements in an unknown substance that may only be present on the order of parts per billion.

Nuclear spectroscopy analysis techniques provided forensic investigators with **evidence** that linked several of what were eventually to be known as the Washington, D.C.-area "sniper shootings" in late 2002.

A number of methods can be used to excite atomic nuclei and then measure their decaying gamma ray emissions as the atoms return to normal energy levels (i.e., their ground state). The emissions are then analyzed and separated into an emission spectrum that is characteristic for each element. Excitation can be accomplished by colliding nuclei, heavy ion beams, and a number of other methods, but the fundamental purpose remains to measure the spectral properties of a sample as a tool to learn something about the quantum structure of the atoms in the sample.

Like other forms of spectroscopy, the fundamental measurements of nuclear spectroscopy involve recording the emissions or absorption of photons by atoms. The specific emissions or absorptions reflect the energy levels, spin states, parity, and other properties of an atom's structure (e.g., quantized energy levels).

A qualitative analysis identifies the components of a substance or mixture. Quantitative analysis measures the amounts or proportions of the components in a reaction or substance.

Because each element—and each nuclide (i.e., an atomic nucleus with a unique combination of protons and neutrons)—emits or absorbs only specific frequencies and wavelengths of electromagnetic radiation, nuclear spectroscopy is a qualitative test (i.e., a test designed to identify the components of a substance or mixture) to determine the presence of an element or isotope in an unknown sample.

In addition, the strength of emissions and absorption for each element and nuclide can allow for a quantitative measurement of the amount or proportion of the element in an unknown. To perform quantitative tests, that is, to measure amounts of an element present, the measured spectrum needs to be narrowed down to analysis of photons with specific energies (i.e., electromagnetic radiation of specific wavelength or frequency). Quantitative computation using Beer's Law is then applied to the measured intensities of photon emission or absorption. Many other spectroscopic methods use this technique (e.g., atomic absorption spectroscopy and UV-visible light spectroscopy) to determine the amount of a element present.

One of most widely used methods of nuclear spectroscopy used to determine the elemental composition of substances is nuclear activation analysis (NAA).

In neutron activation analysis the goal is to determine the composition of an unknown substance by measuring the energies and intensities of the gamma rays emitted after excitation and the subsequent matching of those measurements to the emissions of gamma rays from standardized (known) samples. In this regard, neutron activation analysis is similar to other spectroscopic measurements that utilize other portions of the **electromagnetic spectrum**. Infrared photons, x-ray florescence, and spectral analysis of visible light are all used to identify elements and compounds. In each of these spectroscopic methods, a measurement of electromagnetic radiation is compared with some known quantum characteristic of an atomic nucleus, atom, or molecule. With NAA, of course, high energy gamma ray photons are measured.

Neutron activation analysis involves a comparison of measurements from an unknown sample with values obtained from tests with known samples. Depending on which elements are being tested for, the samples are irradiated with energetic neutrons. The process of radioactivity results in the emission of products of nuclear reactions (in this case, gamma rays) that are measurable by instruments designed for that purpose. After a time (dependent of the length of radiation) the gamma rays are counted by gamma ray sensitive spectrometers. Because the products of the nuclear reactions are characteristic of the elements present in the sample and a measure of amounts of the amounts present, neutron activation analysis is both a qualitative and quantitative tool.

Although NAA usually involves the measurement of gamma rays emitted from the radioactive sample, more complex techniques also measure beta and positron emissions.

Nuclear magnetic resonance (NMR) is another form of nuclear spectroscopy that is widely used in **medicine** and in forensic analysis.

NMR is based on the fact that a proton in a magnetic field had two quantized spin states. The actual magnetic field experienced by most protons is, however, slightly different from the external applied field because neighboring atoms alter the field. As a result, however, a picture of complex structures of molecules and compounds can be obtained by measuring differences between the expected and measured photons absorbed. NMR spectroscopy as an important tool used to determine the structure of organic molecules.

When a group of nuclei are brought into resonance—that is, when they are absorbing and emitting photons of similar energy (electromagnetic radiation, e.g., radio waves, of similar wavelengths)—and then small changes are made in the photon energy, the resonance must change. How quickly and to what form the resonance changes allows for the non-destructive (because of the use of low energy photons) determination of complex structures. This form of NMR is used by physicians as the physical and chemical basis of a powerful diagnostic technique termed magnetic resonance **imaging** (MRI). MRI can also be used for non-invasive examination for concealed substances or implanted objects.

SEE ALSO Nucleic acid analyzer (HANAA).

Nucleic acid analyzer (HANAA)

Forensic analysis often involves the analysis of samples for the presence of disease-causing microorganisms (**pathogens**). In the past, this analysis required the specialized media, incubators and other equipment housed in a laboratory. However, miniaturization of equipment has enabled some of the pathogen technology to be taken into the field in a portable form.

In the months preceding the 2003 war in Iraq, United Nations inspectors conducted forensic analyses throughout the country, searching for **evidence** of chemical, nuclear, and biological weapons. One of the portable devices utilized enabled detection of some bacterial pathogens based on the detection of target regions of nucleic acid.

The device used is a hand-held advanced nucleic acid analyzer (HANAA). It was developed by the Lawrence Livermore National Laboratory in 1999 based on a previous model of the nucleic acid analyzer ANAA produced in 1997.

HANAA is a real-time **polymerase chain reaction** (PCR)-based system for detecting pathogens. It is highly sensitive as it can detect 200 organisms per milliliter. Typical lab-based tests that require the growth of bacteria require the presence of millions of living bacteria.

The instrument takes advantage of real-time **PCR** technology that was developed in recent years. PCR amplification of **DNA** (deoxyribonucleic acid) requires repetitive sample heating (to approximately 203°F [95°C]) and cooling to a lower temperature specific for the sample (usually 122–161°F, or 50–72°C). Traditional instruments require two to three hours to complete a PCR run and additional time to run the products on a gel to detect positive samples. New real-time PCR instruments have heating and cooling systems allowing a reduction of the running time to less than 30 minutes. The same instruments also allow observation of product formation during the run. This is achieved by incorporation of fluorescent detection methods to visualize product formation.

The main part of the instrument is a sample module containing a miniaturized silicon thermal cycle of high heating and cooling efficiency. These small thermal units are a major breakthrough in technology, as batteries can efficiently support them. In comparison, most of the existing real-time systems are comparatively larger and heavier and cannot be operated in a field with ease, despite the similarly good technology for detection or time of analysis. HANAA also has an advantage over its predecessor ANAA, which was as big as a small suitcase. HANAA fits into the palm of a hand and weighs around two pounds (1 kg). It can operate 1.4–5.5 hours depending on the battery used. A run on the instrument is approximately 7–20 minutes depending on the program used for detection.

The PCR process used by HANAA is based on using TaqMan-type probes, which rely on a short DNA oligonucleotide being labeled by two fluorescent molecules, a quencher and a reporter. When a probe anneals to DNA, there is no signal as the short distance between the quencher and the reporter results in the reporter's **fluorescence** being quenched. However, during amplification, the reporter molecule is released and an increase in fluorescence is observed.

HANAA has four chambers for analysis and can perform two independent identifications in each chamber, therefore is able to test for up to eight pathogens at one time. Each of the sample units can be run independently, which makes the instrument highly flexible in use. The unit is operated by a keypad, with all the menu options and results displayed on a LCD (liquid crystal display) screen as text or bar charts. A positive sample is announced by an audible alarm.

The instrument and technology are still dependent on the quality of the sample and lack of any possible PCR inhibitors in the sample. However, sample preparation is relatively simple. A template for PCR is prepared by placing sample in a liquid buffer in a small (0.020 ml) test tube and reagents are added directly to the same tube.

SEE ALSO Biological weapons, genetic identification; DNA fingerprinting; DNA recognition instruments; DNA sequences, unique; PCR (polymerase chain reaction).

Odontology

Forensic odontology is the application of dentistry to the investigation of crime. It has its main applications in **identification** of corpses and human remains and in **bite analysis**. Although each person is born with the same number and type of teeth, the dental pattern of each individual is unique. Most people have dental records, or these can be created through making a dental impression from a suspect. These can then be compared to either teeth found on a corpse or bite marks found at the scene of a crime. However, the interpretation of dental **evidence** is a specialist task, undertaken by a forensic odontologist who may be called as an expert witness in a case.

One day, **DNA** analysis may become the "gold standard" for identifying an individual. However, if skeletal remains or fragmented corpses from mass disasters are involved, recovery of DNA is by no means certain. Identification by dental records remains the most reliable source of identification under such circumstances. Dental enamel is the hardest substance in the human body, so it does not decay alongside other tissue and will be found alongside skeletal remains.

Although everyone starts out with the same number of teeth, these differ naturally in length, width, and shape. During life, people sustain damage to their teeth; there may be missing teeth, chips, dental work, or misalignments. Taken together, these individual features create a unique pattern. If the person visited a dentist, then there will be a dental record that can be used to establish identity. Even if only a few teeth are available with a set of human remains, the forensic odontologist can still offer an opinion as to the age and habits of that person. This opinion can be set into context with other identifying information.

Bite marks are a valuable type of **impression evidence** that can be used to identify or eliminate a suspect. They sometimes appear as characteristic curved bruises on the flesh of victims of sexual assault or child abuse. The odontologist will study a dental cast of such bite marks and compare them with dental impressions made from suspects. Bite marks may also be found in soft materials at the scene of crime such as cheese, chocolate, pencils, or apples. They can be an important form of individualizing evidence in the hands of the forensic odontologist. Bitemark evidence has been used to in the trials of many criminals, including the serial killer Ted Bundy.

SEE ALSO Casting; Odontology, historical cases.

Odontology, historical cases

Odontology is the study of teeth for the investigation of identity and crime. One of its main applications is in the **identification** of corpses and human remains, especially in mass disasters where other forms of identification may not be available because

A forensic expert examines a human jaw with gold teeth found in a mass grave near the Bosnian town of Miljevina in 2004.

the bodies have been burned or otherwise destroyed. Teeth are the most enduring part of the human body, apart from bone. Odontology is also used in the analysis of bite marks left at the scene of a crime. Although we are all born with the same number and type of teeth, the dental pattern of each individual is unique. Most people have dental records, or these can be created through making a dental impression from a suspect. These can then be compared to either teeth found on a corpse or to bite marks. Odontology has been used in many historical cases of identification and crime.

The use of teeth for identification goes back to Roman times. In the first century A.D., the Roman Emperor Claudius had his mistress, Lollia Paulina, beheaded and then demanded to examine the teeth on the body to ensure the right woman had been put to death. He knew she had a discolored front tooth. In another early example of dental identification, William the Conqueror, King of England in the eleventh century, would bite into wax used to seal official documents. His teeth were misaligned, so his bite mark guaranteed the documents' authenticity. In 1775, Paul Revere, famous for alerting American colonists to the approach of British forces, made a set of dentures for a friend, Dr. Joseph Warren, who was killed at the Battle of Bunker Hill that year. Warren was buried in a mass grave, but his family wanted the body for a private burial. Revere was able to identify Warren's body through the dentures he had made. In a similar case in 1914, a dentist in Scotland helped to identify a corpse in a grave-robbing case. Such crimes were not uncommon at the time as the bodies were furnished to medical schools. The victim had recently been fitted with a denture and this was presented in court as **evidence** of her identity.

In United States courts, dental evidence was first presented in court in 1849 when the incinerated remains of a George Parkman were identified by Nathan Cooley Keep through a partial denture he had made for this patient. He proved identity by fitting the prosthesis onto the cast that had been used in its manufacture. The evidence led to the conviction and execution of a J.W. Webster for the **murder**.

The first use of dental records in the identification of victims of mass disaster was probably the fire at the Vienna Opera House in 1878. Dental remains were also used to identify some of the 126 dead in a fire in Paris in 1897, which prompted the writing of the first textbook on forensic dentistry by the pioneering figure Oscar Amoedo. Since then, forensic odontology has been used to identify the victims of many other major incidents such as plane crashes, fires, and terrorist attacks. For instance, in the year 2000, Alaska Airlines Flight 261 crashed in California, killing 88 passengers and crew. A team of forensic dentists summoned to the scene found few intact jawbones and worked with partial post-mortem records, comparing these with the full ante-mortem dental charts which were sent to them from the victims' dentists. Over 100 dental remains were studied and compared with 68 complete dental records. In total, 22 of the victims were identified through their dental records. In the attacks on the World Trade Canter on September 11, 2001, only around half of the estimated 2,749 victims were ever identified, through a mixture of **DNA**, jewelry, and dental records.

Forensic dentistry has also been used to identify some notorious figures from the Nazi era, including Adolf Hitler, Martin Bormann, Eva Braun, and Joseph Mengele. The identity of John F. Kennedy's assassin, Lee Harvey Oswald, was confirmed through dental records. The remains of Czar Nicholas II and his family, who were shot during the 1917 Russian Revolution, were also initially identified from their teeth.

The first time bite marks were ever used as evidence in a criminal trial was in the 1954 case *Doyle v. State of Texas*. This involved an assailant who left his bite mark in a lump of cheese at the scene. A more

Arrest of notorious serial killer Nikolai Dzhurmongaliev in Russia in 1992 (shown handcuffed, center). Dental evidence helped link Dzhurmongaliev to over 100 murders, in part due to his false metal teeth. © PATRICK ROBERT/SYGMA/CORBIS

famous case is that of serial killer Ted Bundy who left a bite mark on the buttock of a victim, which helped secure his conviction in 1978.

SEE ALSO Bite analysis; Bundy (serial murderer) case; Casting.

O. J. Simpson trial SEE Simpson (O. J.) murder trial

Oklahoma bombing (1995 bombing of Alfred P. Murrah building)

At 9:02 a.m. on April 19, 1995, a powerful truck bomb exploded on the street in front of the Alfred P. Murrah Federal Building, a U.S. government complex in Oklahoma City, Oklahoma. The explosion caused enormous damage, completely destroying a third of the seven-story building, including a day care center on the first floor near the front, and damaging more than three hundred buildings in the vicinity. The bomb killed 168 people, including 19 children and one rescue worker. It injured over 800 others, some of them blocks away, as the explosion turned street signs, shards of **glass**, and other debris into missiles and blew pedestrians off their feet. It was the largest domestic terror attack in U.S. history and the largest terrorist attack on U.S. soil until the attacks of September 11, 2001.

Less than an hour later, an Oklahoma highway patrolman stopped and arrested Gulf War veteran Timothy McVeigh for driving without a license plate and carrying a concealed weapon, a 9 mm Glock handgun. While McVeigh was being taken to the jail in Perry, Oklahoma, he left behind in the police cruiser a business card for Paulson's Military Supply. On the back McVeigh had written "TNT $5/stick need more" and "Call after 01 May, see if I can get some more." This would be the first piece of **physical**

evidence that would implicate McVeigh in the bombing.

While McVeigh awaited his bail hearing for the traffic and concealed weapon charges, the investigation of the bombing in Oklahoma proceeded. Many experts and members of the public initially assumed that the bombing was the work of foreign terrorists, but at the FBI's behavioral sciences unit in Virginia, psychological profiler Clinton R. Van Zandt arrived at a different conclusion. Noting that the bombing occurred on the two-year anniversary of the Branch Davidian siege in Waco, Texas—a day of infamy among right-wing militia and antigovernment groups—he concluded that the bomber was probably a white male in his twenties, a military veteran, and a member of a militia group.

As events turned out, this profile closely fit Timothy McVeigh. From an early age he had been fascinated with weapons. In 1988, he joined the U.S. Army, and he served with distinction as a gunner in the Gulf War in Iraq, earning a Bronze Star. When he failed in his effort to become a Green Beret, he left the army and became increasingly paranoid about what he saw as the oppressiveness of the U.S. government, particularly its efforts to curb the spread of guns, which McVeigh saw as a violation of the "right to bear arms" guaranteed by the Second Amendment of the Constitution. His antigovernment rage reached a boiling point in 1993 with the events in Waco. That siege, based on the government's belief that the cult's leader, David Koresh, had a cache of illegal weapons, had begun on February 28, 1993. It ended on April 19 when federal agents stormed Koresh's compound, a fire erupted, and seventy-five people inside were killed.

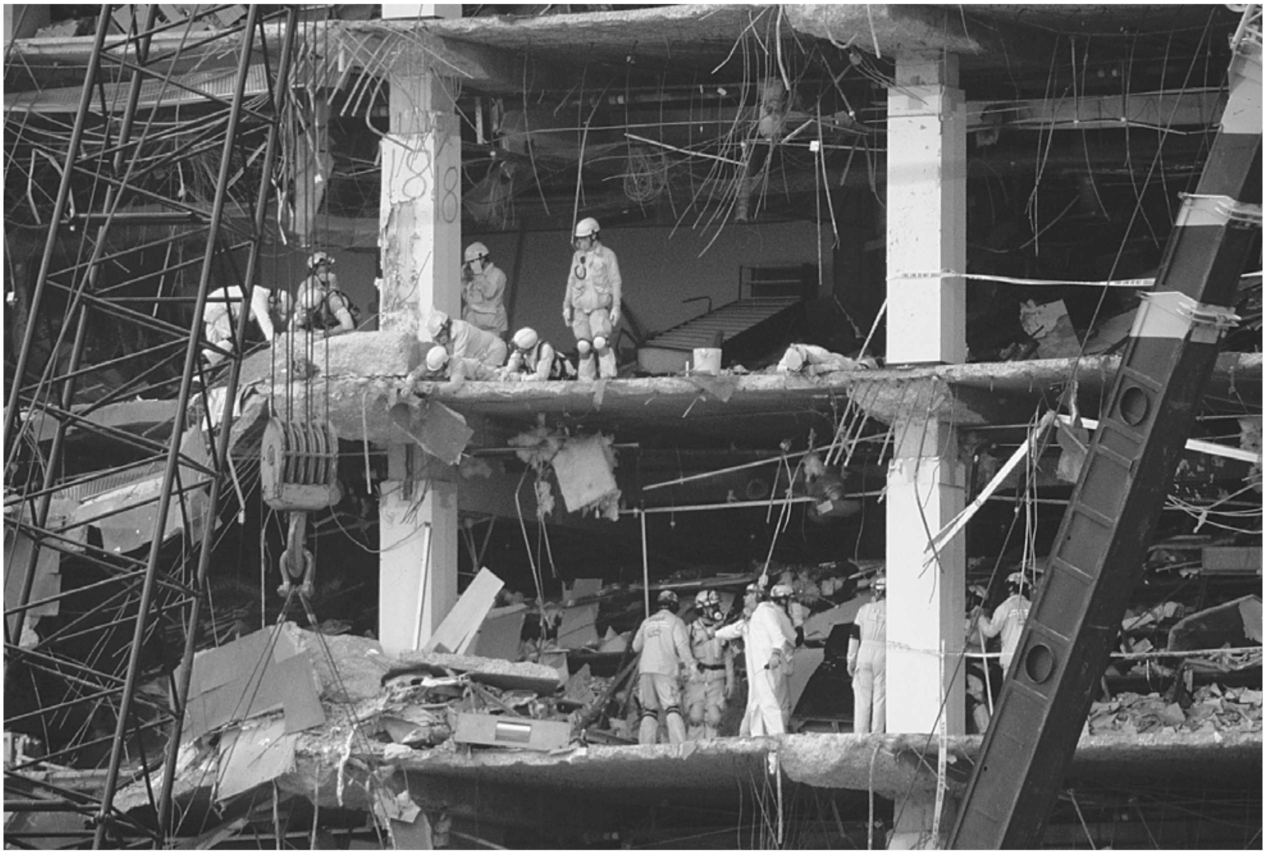
Enlisting the aid of army companions Terry Nichols and Michael Fortier, McVeigh decided to take action against the government. He had long admired the book *The Turner Diaries*, written by American Nazi leader and white supremacist William L. Pierce under the name Andrew Macdonald. In this book, the protagonist Earl Turner blows up an **FBI** building in Washington, D.C., with a truck bomb. McVeigh's goal was to wreak vengeance in similar fashion against the Bureau of Alcohol, Tobacco, and Firearms (**ATF**) for its role in the events in Waco. As it turned out, McVeigh's choice of target was a mistake, for the ATF did not maintain an office in the Murrah building.

Evidence that McVeigh was behind the bombing quickly accumulated. The bomb was contained in a yellow Ryder rental truck. The truck's 250-pound rear axle, which had landed on a car near the scene of the bombing, had an identifying number, and the rear bumper, license plate intact and legible, was found nearby. The truck was traced to a Ryder rental agency in Junction City, where the rental agreement had been signed by a "Robert Kling." Employees at the agency helped an FBI artist create a sketch of Kling, referred to as John Doe #1; they also created a sketch of another man who was in the agency at the same time, John Doe #2, although this person was never found or identified. Investigators showed the pictures throughout the area. That evening, the manager of a local motel told investigators that she recognized John Doe #1 and that he had registered at the motel under the name Timothy McVeigh. Additionally, McVeigh had parked a yellow Ryder truck in the motel's parking lot two nights before the bombing.

Later investigation would piece together the actions of McVeigh and Nichols in the weeks and months before the bombing. Following the advice of various bomb-building manuals, they gathered and stored their materials. Forensic examination of the bombsite showed the bomb consisted primarily of ammonium nitrate, an agricultural fertilizer, and nitromethane, a volatile motor-racing fuel. Experts estimate that the size of the bomb ranged from 4,000–5,000 pounds and detonated with an initial explosive force of 500,000 pounds per square inch. Traces of these chemicals were found on McVeigh's clothing, as well as on the victims. Shortly before 9:00 on the morning of April 19, McVeigh drove the truck to the street outside the Murrah building and walked away. Minutes later, the bomb detonated. Some experts argued that the pattern of the bomb blast and the amount of damage suggest more than one bomb, but these views were not widely accepted.

McVeigh was arrested for the bombing while still in jail on the traffic and gun charges. His trial began in Denver, Colorado, on April 24, 1997. Damaging testimony was offered by Fortier, as well as by Fortier's wife, Lori, and McVeigh's sister Jennifer, all of whom knew details of the plot. Physical evidence included not only the Ryder truck parts and the bomb residue on McVeigh's clothing but also his fingerprints on receipts from his purchase of the bomb's materials and calling-card records that tracked his movements. McVeigh was found guilty and executed on June 11, 2001. Nichols was later sentenced to life in prison, and Michael Fortier was sentenced to twelve years in prison for failing to warn authorities of the attack.

Although **forensic science** played a role in the investigation of the bombing, its chief role was in



Rescue workers and investigators sift through the rubble after a planted fuel and fertilizer truck bomb exploded in 1995 in front of the Alfred P. Murrah Federal Building in Oklahoma City, killing 168 people. © RALF-FINN HESTOFT/CORBIS

victim **identification**. Some of the bodies were complete enough to allow for **fingerprint** identification, but many were fragmented, making the work of identification painstaking and arduous. The forensic investigators' first step was to gather antemortem information, including lists of people who were believed to be at or near the bombsite. Families and funeral directors provided demographic information, and potential victims' dentists were contacted to provide records. As each body was brought to a temporary morgue across the street from the Murrah building, the task of postmortem information gathering began. A prominent role was played by forensic odontologists, who faced the grim task of identifying the remains of the victims from teeth. They estimated the age of children based on patterns of primary and permanent teeth. Many of these children had pieces of wallboard embedded in their teeth, suggesting that the explosion had blown them through the wall of the day care center.

Radiologists also played a key role. After a body was discovered, an average of fifteen x rays of it were taken. Pathologists, anthropologists, and FBI bomb specialists examined these x rays to identify the victims as well as to uncover crime scene evidence. In many cases, the x rays revealed either healed fractures or degenerative conditions. One victim, for example, was identified from degenerative changes in the spine; another was identified from healed fractures in the tibia and fibula. X rays of missing persons who were thought to be victims of the bombing were compared with these postmortem x rays for possible matches. X rays also revealed the presence of foreign objects in the bodies, including evidence of the bomb itself, and they were used to distinguish bomb evidence from leaded-glass shards from the building's windows.

Finally, forensic anthropologists also played a key role in victim identification. In many instances, only a single disembodied body part was found, and body parts were often commingled. Forensic anthropologists could, for example, measure a limb, then use a computer program that determines age and race from bone measurements to pin down the demographics of the victim, which could then be compared with antemortem information to provide a possible match. This procedure sometimes had to be used in tandem with other methods. In one instance, a forensic anthropologist identified a lower leg as belonging to a white male about 30 years of age. Because the leg had two pairs of socks, a military boot, and blousing straps, the question arose as to whether a second bomber may have been present and killed in the explosion. The leg, however, underwent **DNA** testing, which contradicted the earlier results, showing that it came from a twenty-one-year-old African American woman. This instance showed that forensic anthropologists often cannot rely on a single method of identification, but may have to use two or more methods to achieve a positive identification.

By the time all of the victims had been identified three weeks after the explosion, forty-four had been identified through teeth alone; twenty-five through fingerprints alone; seventy-seven through a combination of teeth and fingerprints; one through teeth and palm prints; one through teeth, fingerprints, and DNA; six through x rays alone; four through palm prints; three through DNA alone; one through footprints; one through a toe print; one through marks and scars; and four through visual identification.

SEE ALSO Anthropology; Bomb (explosion) investigations; Explosives; Odontology; Osteology and skeletal radiology; Profiling; Psychological profile.

Mathieu Joseph Bonaventure Orfila

4/24/1787–3/12/1853
SPANISH, NATURALIZED FRENCH
CHEMIST, PHYSIOLOGIST

Mathieu Orfila helped initiate the study of **toxicology**. His massive treatise on poisons appeared in three languages in the second decade of the nineteenth century and immediately propelled the medical, biological, chemical, physiological, and legal sciences in new directions.

Born as Mateu José Bonaventura Orfila i Rotger in Maó, Minorca, Spain, he eschewed his family's traditional career of merchant seafaring when he was fifteen in order to study **medicine**. From 1804 to 1807, he attended courses in medicine at the University of Valencia and chemistry at the University of Barcelona. He won a scholarship to the University of Madrid to study chemistry and mineralogy, but went instead to Paris in June 1807 to study medicine and pharmacy. There Orfila became the protégé of pharmacist and chemist Louis-Nicolas Vauquelin and chemist Louis-Jacques Thénard. As hostilities brewed that led to the 1808–1814 Peninsular War, Napoleonic France threatened Orfila with expulsion, but Vauquelin interceded on his behalf and Orfila was allowed to remain in Paris.

Orfila continued working with Vauquelin and Thénard after receiving his medical degree from the Faculté de Médecine de Paris in 1811. He married Anne Gabrielle Lesueur in 1815, succeeded Thénard as professor of chemistry at L'Athénée in 1817, became a naturalized French citizen in 1818, was named professor of legal medicine at the Faculté de Médecine in 1819, and succeeded Vauquelin there as professor of medical chemistry in 1823. He became dean of the Faculté de Médecine in 1831 and in 1834, was created Knight of the Legion of Honor.

All this success was due to Orfila's first book, his masterpiece, *Traité des poisons, tirés des règnes minéral végétal et animal; ou toxicologie générale, considérée sous les rapports de la physiologie, de la pathologie et de la médecine légale*, which was published in two volumes in Paris in 1814–1815. Three translations soon appeared: *A General System of Toxicology, or, a Treatise on Poisons, Drawn from the Mineral, Vegetable, and Animal Kingdoms, Considered as to their Relations with Physiology, Pathology and Medical Jurisprudence*, translated by John Augustine Waller in London in 1816–1817; Joseph Nancrede's abridged translation, *A General System of Toxicology, or, a Treatise on Poisons Found in the Mineral, Vegetable and Animal Kingdoms, Considered in their Relations with Physiology, Pathology and Medical Jurisprudence*, in Philadelphia in 1817; and Sigismund Friedrich Hermbstädt's German translation in Berlin in 1818–1819. All were received with enthusiasm in the scientific community.

One of Orfila's other major works includes *Elémens de chimie medicale*, published in two volumes in 1817 and translated as *Elements of Medical Chemistry* in 1818. Another is *Secours a donner aux personnes empoisonées ou asphyxiées, suivis des moyens propres a reconnaître les poisons et les vins frelatés, et a distinguer la mort réelle de la mort apparente*, published in 1818 and translated twice the same year, once by William Price as *A Popular Treatise on the Remedies to be Employed in Cases of Poisoning and Apparent Death, Including the Means of Detecting Poisons, of Distinguishing Real from Apparent Death, and* *of Ascertaining the Adulteration of Wines*, and once by R. Harrison Black as *Directions for the Treatment of Persons who have Taken Poison, and Those in a State of Apparent Death, Together with the Means of Detecting Poisons and Adulterations in Wine, also of Distinguishing Real from Apparent Death.* He also wrote *Leçons de médécine legale [Lessons in Legal Medicine]*, which appeared in three volumes from 1821 to 1823, and *Traité des exhumations juridiques [Treatise on Juridical Exhumations]*, published in 1831, as well as several later works specifically about arsenic, the poison most commonly preferred by murderers of that era.

Orfila was the founding editor of two important medical journals, *Journal de chimie médicale, de pharmacie et de toxicology* in 1824 and *Annales d'hygène publique et de médecine Ígale* in 1829. He also founded the Society of Medical Chemistry in 1824, the Museum of Pathological Anatomy, known as the Musée Dupuytren, in 1835, and the Museum of Comparative Anatomy, now called the Musée Orfila, in 1845.

Serving as an expert witness in several famous legal proceedings further enhanced his reputation. Using his own improvements on the arsenic detection methods of **James Marsh**, Orfila helped to uncover the truth about the murders of Nicolas Mercier in 1838 and Charles LaFarge in 1840. However, because he wished to avoid controversy, he refused to participate as an expert witness after 1843.

Like many European scientists of the early nineteenth century, Orfila fell victim to political intrigue. He was honored during both the Bourbon Restoration and the reign of Louis Philippe, but quickly fell out of favor in the 1848 revolutions. Although his medical deanship was abruptly terminated on February 28, 1848, he was still able to serve as president of the Académie de Médecine from 1850 to 1852. It is said that the stress he suffered during the Second Republic hastened his physical decline and led to his death.

SEE ALSO Physiology; Poison and antidote actions; Toxicology.

Organic compounds

Organic compounds are based on carbon and are found in living things. They are thus distinguished from **inorganic compounds**, which are those containing the other elements such as nitrogen, phosphorus, and metals (such as iron and zinc). In fact, this distinction between organic and inorganic is perhaps a little simplistic. Carbon-based compounds need not always come from living things, synthetic **fibers** like polyester and nylon are carbon-based, but are not found in plants or animals. As far as **forensic science** is concerned, both organic and inorganic compounds are found in items of **evidence**. The techniques used for determination of the chemical composition of such evidence will depend upon whether its component compounds are organic or inorganic.

An important feature of compounds based on carbon is that their chemical bonds—with other carbon atoms or with hydrogen, oxygen, or nitrogen atoms—absorb energy in the infrared, visible, and ultraviolet region of the **electromagnetic spectrum**. This is the basis of **spectroscopy**, which involves scanning samples containing organic compounds (such as textile fibers or paint fragments) with light, producing a "fingerprint" that is characteristic of the compound. The fingerprint shows the intensity of absorption in the infrared, visible, and ultraviolet region at each wavelength. This sample fingerprint can be compared to those from a reference database, which can reveal the origin of the paint or textile sample. If samples from a suspect—such as fibers found on their clothing—give the same fingerprint as the evidence, then it can be argued they came from the same source.

Another important technique for analyzing organic compounds in evidence is **thin layer chromatography**. A colored sample, such as a minute sample of ink from a questioned document, is placed on an absorbent paper that is dipped into a solvent mixture. When the mixture is drawn up the paper, it sweeps the sample with it and separates it into its components as a pattern of spots on the paper. As with spectroscopy, this pattern is characteristic of the compound and can be compared with reference or suspect samples for **identification**.

SEE ALSO Micro-spectrophotometry.

Organs and organ systems

Many forensic examinations include an **autopsy**. The surgical inspection of the exterior and interior of a body can reveal details about the death, including signs of trauma, wounds, and the presence of poisons, drugs or **toxins**.

Examination of various organs (two or more different types of tissue that work together to carry out a complex function) and organ systems (a group of organs that perform intricate functions necessary for the survival of an organism) is of paramount importance in an autopsy, since they can be the targets of the physical and chemical damage.

Sometimes an organism can survive with an impaired or nonfunctioning organ. However, when a whole system of organs shuts down, the life of the organism becomes compromised. Thus, the organ systems work together to maintain a constant internal environment, called homeostasis, within the body to ensure survival of the organism. The physical and chemical insults that are of forensic relevance (e.g., disease, use of **firearms** or poisons, drowning, asphyxiation) can disastrously disrupt the homeostatic balance.

There are 11 organ systems within the human body: integumentary, skeletal, muscular, nervous, endocrine, circulatory, lymphatic, respiratory, digestive, urinary, and reproductive.

The integumentary system acts as a protective barrier for the human body against microorganisms, dehydration, and injuries caused by the outside environment. Additionally, the integumentary system regulates body temperature. Organs of the integumentary system include hair, nails, sebaceous glands, sudoriferous glands, and the largest organ of the body, the skin.

The skeletal system is a structural framework providing support, shape, and protection to the human body. Additionally, the skeletal system provides attachment sites for organs. The skeletal system also stores minerals and lipids and forms **blood** cells. Bones, cartilage, tendons, and ligaments are all organs of the skeletal system.

The muscular system provides movement to the human body as a whole, as well as movement of materials through organs and organ systems. This system also functions to maintain posture and produce heat. The muscular system consists of skeletal muscle, smooth muscle, and cardiac muscle.

The nervous system conducts electrical impulses throughout the body to regulate and control physiological processes of the other organ systems. Organs of the nervous system include the brain, spinal cord, and nerves.

The endocrine system also functions to regulate and control physiological processes of the body. However, these functions are accomplished by sending out chemical signals called hormones into the blood. Glands, the organs of the endocrine system, secrete hormones and include: the pituitary gland, pineal gland, hypothalamus, thyroid gland, parathyroid glands, thymus, adrenal glands, pancreas, ovaries, and the testes.

The circulatory system circulates blood throughout the body and in doing so transports gases, nutrients, and wastes to and from tissues. Organs of the circulatory system include the heart, blood vessels, and blood.

The lymphatic system, also known as the **immune system**, defends the body against microorganisms and other foreign bodies. Additionally, fluids are transported from the body's tissues to the blood, thus helping to control fluid balance in the body. This system also absorbs substances from the digestive system. The organs of the lymphatic system include the lymph, lymph nodes, lymph vessels, thymus, spleen, and tonsils.

The respiratory system exchanges gases between the body's tissues and the external environment. Oxygen is inhaled from the external environment and passes from the lungs into the blood, where it is exchanged for carbon dioxide that passes from the blood to the lungs and is expelled. The respiratory system consists of the nose, pharynx, larynx, trachea, bronchi, and lungs.

The digestive system functions to digest and absorb nutrients from the food ingested into the body. Additionally, the digestive system transports foodstuff through the gastrointestinal tract. The primary organs of the digestive system include the mouth, pharynx, esophagus, stomach, small intestine, large intestine, rectum, and anal canal. Accessory organs that aid the primary organs include the teeth, salivary glands, tongue, liver, gallbladder, pancreas, and appendix.

The urinary system removes excess water and nutrients and filters wastes from the circulatory system. Additionally, the urinary system aids in red blood cell formation and metabolizes vitamin D. The urinary system's organs include the kidneys, ureters, urinary bladder, and urethra.

The reproductive system of the human body can be either male or female. The male reproductive system synthesizes gametes called spermatozoa that are responsible for fertilizing the female gametes, or oocytes, during reproduction. The female reproductive system is designed to undergo conception, gestation, and birth once a spermatozoon fertilizes an oocyte. The male reproductive system is composed of the testes, vas deferens, urethra, penis, scrotum, and prostate. The female reproductive system consists of the ovaries, uterus, fallopian tubes, vagina, vulva, and mammary glands.

SEE ALSO Autopsy; Decomposition; Poison and antidote actions; Toxicology.

Orthotolidine solution

Testing of **fluids** such as urine and **blood** is a part of routine diagnostic forensic testing. As well, such testing can yield useful forensic **evidence** of disease, presence of **toxins** and other chemicals, and even genetic material.

While fluid testing can involve sophisticated instruments, simple and reliable tests that can be done at the scene of an accident or death are still in popular use. Several urine-based tests utilize a chemical known as orthotolidine.

In the past, orthotolidine was a popular chemical used to monitor swimming pool water for the presence of excess chlorine. While that use has been supplanted by other chlorine monitoring methods, orthotolidine has remained popular in routine diagnostic testing and in forensic investigations.

The presence of glucose in the urine can be detected using a paper strip impregnated with orthotolidine and two enzymes—glucose oxidase and peroxidase. A yellow dye is also infused into the strip. When the paper strip is immersed in the glucose-containing urine, the glucose is catalytically converted by glucose oxidase in the presence of air to gluconic acid and hydrogen peroxide. Subsequently, peroxidase converts the hydrogen peroxide into a compound that reacts with orthotolidine. The result is a blue color.

The blue reacts with the yellow dye in the strip to form a potential spectrum of color ranging from light green to a dark blue color. The intensity of the color depends on the amount of glucose present in the urine.

This simple test, which can be done within a minute, allows a forensic examiner to gauge if the victim or deceased was diabetic.

Orthotolidine can be combined with another chemical, toluidine, to assess the presence of myoglobin in urine. Presence of the latter is characteristic of a malady called myoglobinuria. If myoglobin (or **hemoglobin**, as the test cannot distinguish between the two) is present in urine, the orthotolidine-toluidine chemical pair forms a blue color.

Both orthotolidine-based examinations can help identify a victim or corpse.

Albert Sherman Osborn

1858–1946
AMERICAN
QUESTIONED DOCUMENT EXAMINER

Albert Sherman Osborn was the first American to achieve prominence in the world of questioned document examination and forged document analysis. He authored *Questioned Documents* in 1910; it remains in print, and still stands as a seminal text in questioned document analysis. In 1937, near the end of his career (and not long from the end of his life), he published *The Mind of the Juror as Judge of the Facts*, or, *The Laymen's View of the Law*, another well-known forensics tome. Osborn was at the forefront of questioned document examination for more than 50 years, and was renowned for his success within the legal system as an expert witness and scholar. By the thoroughness and professionalism of his work, he was able to make significant headway with the court system's acceptance of expert testimony about forged documents as legal **evidence** in **criminal trials**. He founded the American Society of Questioned Document Examiners in 1942; this organization has continued to grow and expand in its research, knowledge base, and cadre of subject matter experts to the present day.

Albert Osborn was the first American to utilize the scientific method in the examination of **questioned documents**. His legendary texts, *Questioned Documents*, and *The Problem of Proof*, published in 1910 and 1922, respectively, were met with wide acclaim by public and private criminal justice and law enforcement agencies, the legal professions, and the public. Although the American Society of Questioned Document Examiners was chartered in 1942, Albert Osborn began holding annual informal meetings designed to share ideas and research information among experts in the fields of forged documents and questioned document analysis in 1913.

The premise inherent in questioned document analysis is to examine and compare data appearing on written or electronic evidence. It has grown from **handwriting analysis** and signature comparisons to include: handwriting; typewriting; hand printing; electronic and other printing methods; alterations; erasures; obliterations; studies of impressions on paper or other printing media; physical features of printing media (watermarks, seals, fiber contents, etc.); studies of the materials used to make the documents such as inks, ribbons, cartridges, and papers; and even shoeprint and vehicle tread impression analysis. Questioned document examiners also study and compare edges, perforations, and tears in documents, stamps, seals, and other pieces of **physical evidence**.

Albert Osborn was an acknowledged expert in the fields of **document forgery** (it was his contention that no two individuals could produce exactly the same handwriting characteristics) and questioned document analysis. His forensic methods and scientific conclusions are still studied, and his expertise is still quoted in contemporary courts of law.

SEE ALSO Document forgery; Fibers; Handwriting analysis; Impression evidence; Tire tracks.

Osteology and skeletal radiology

Within approximately two years of death, and sometimes considerably sooner, all that remains of a body is a skeleton. **Identification** of skeletal remains can sometimes be an important task in the investigation of a suspicious death. A forensic pathologist or anthropologist will use osteology, the study of bones, to find out as much as possible about the identity of a skeleton or collection of bones. Sometimes they rely on skeletal radiology, the study of bones through x rays or **fluorescence** (light-emission) to help make the identification.

When confronted by skeletal remains, the investigator works from general concepts to the more specific when trying to identify them. First, they will ensure that the items are in fact bones. It is not uncommon for the public, who often discover such remains, to mistake stones or bits of wood for bones. A physician will recognize the shape and texture of bone. It can, however, be a little more difficult to determine whether the bones are human. When it comes to intact skulls, it is relatively easy to distinguish humans from other animals. With smaller bones, especially those from children, identifying them as human is more challenging. Bear paws, for instance, can be remarkably similar to human hands and feet once stripped of their flesh. Sheep and deer ribs can be hard to distinguish from those of humans.

The investigator is fortunate if he or she gets a whole skeleton to work with. Over time, natural forces and predators tend to scatter bones, so it is more likely that a collection of bones, a single bone, or even just a fragment will be all there is to examine. If necessary, the investigator will have to extract **DNA** from the bone marrow for analysis to confirm the identification.

Bones discovered in the ground may be anything from around two to hundreds of years old. Establishing their probable age is clearly important as very old bones will not be relevant to a current forensic investigation, although they may well be of great interest in a historical or archaeological context. There are various methods for aging bones. The level of nitrogen in bones decreases over time, although this depends upon temperature and moisture. High levels of nitrogen can distinguish between bones that are a few years old and those that are decades old. Fresh bones glow when exposed to ultraviolet light. This fluorescence decreases from the outside of the bone to the inside over time. A bone that is hundreds of years old may not show any fluorescence.

Nuclear weapon use in World War II and weapons testing in the 1950s and 1960s led to the accumulation of certain radioactive materials in bones of that era. Finding substantial levels of carbon-14, strontium-90, cesium-137 or tritium, a radioactive isotope of hydrogen, suggests the bones date back from around 1950.

Having established the relevance of the bones, the investigator then sets out to discover some general characteristics which will narrow down the search for the identity of the deceased. Information on sex, age, height and race can all be deduced from careful study of skeletal remains. Of course, much depends on how many bones are available for study; far less can be deduced from single bones than from a whole skeleton.

Gender-specific changes in the skeleton do not start to appear until puberty, so distinguishing the sex of a child can be difficult. In general, males have bigger and thicker bones than females. But much depends on nutrition and level of physical activity. A woman who ate well and carried out manual labor will have bigger, stronger bones than a malnourished and inactive male. The long bones, that is, the bones of the arms and legs, are often indicative of sex. The diameter of the heads of the humerus (upper arm bone) the radius, (lower arm bone) on the thumb side, and the femur (thigh bone), are usually bigger in males. The pelvis of a male and female are quite different. A female pelvis is wider and has a wider outlet to allow

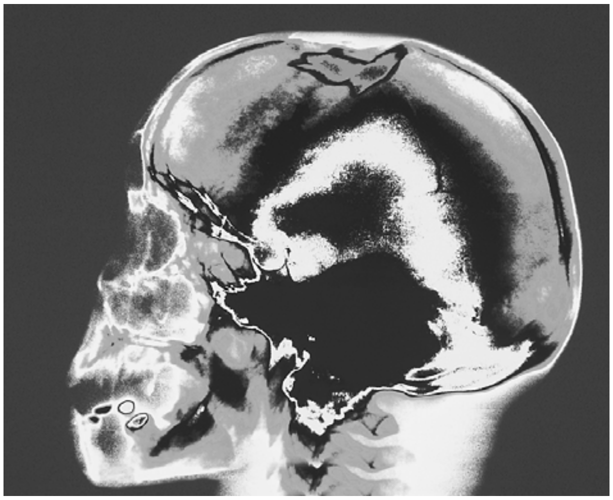
Skeletal remains of the "Millennium Ancestor," a hominid who lived six million years ago, placed in a CT scanner. © LIO/CORBIS SYGMA

for childbirth. A pathologist will look at the sciatic notch, which is the point where the sciatic and other nerves pass from the pelvic cavity to the leg. Typically, this is wider in females than in males. The back side of the pubic bone may be pitted or scarred in a woman who has borne a child. The **skull** may also be indicative of gender, for male skulls are larger and thicker, particularly in the jaw area.

Determining the age at death from skeletal remains is easier for children and adolescents than for adults. The way the skeleton grows and develops from birth to adulthood is well defined. For instance, the skull can be quite useful in determining the age of an infant. The bones of the skull knit together gradually in early childhood along lines called suture lines. The pattern of closure of these lines does, however, vary widely between individual infants so age estimation from this observation is not highly accurate. The symphysis, a thin band of cartilage attaching the pelvis to the spine, has a zigzag shape at birth, which straightens as someone ages up to the age of 50. Bone density decreases with age, as calcium is lost. Radiological examination of skeletal remains can determine bone density and this may help indicate the person's age; however, malnutrition and osteoporosis can also decrease bone density independent of age.

The long bones continue to grow till someone has reached the age of about 25. Therefore, their length may be indicative of age. The areas where the ribs join the breastbone also change with age. They start off smooth and rounded, but become more pitted and sharp over time. In general, the age at death of a skeleton can be determined to around five to ten years, inaccuracy increasing with age.

The height of a person can be estimated from a full skeleton. It will not, however, be the same as the head to heel length of the skeleton itself, because of factors like muscle relaxation and shrinkage of the



Enhanced x ray of a skull showing evidence of trauma. © FIREFLY PRODUCTIONS/CORBIS

discs between the spinal bones. If only long bones are available, the investigator can use standard tables that associate the length of these bones with height. The thickness of the bones can also indicate whether the person was of slight or muscular build. Right-handed people tend to have thicker bones on the right side of the body and vice-versa.

Using skeletal remains to determine a person's race is a difficult task, as no single trait is racially distinct. It may, however, be possible to assign a skeleton to one of three racial groups: Caucasoid, Negroid, or Mongoloid. Caucasians tend to have high, rounded, or square skulls with a straight face and a narrow nose. Negroid skulls are lower and narrower with wider, flatter noses. Monogoloids have broad, round skulls with an arched profile. Eye sockets can be distinctive as well; Caucasians' are triangular, Negroids' more squared, and those of Mongoloids tend to be rounded. If someone is of mixed racial origin, they will have a blend of these features making determination of race extremely difficult.

Once the investigator has narrowed down the search for the identity of the skeleton as above, they will look for individualizing characteristics. Should there be ante-mortem x-ray images of the deceased, they can be very useful in establishing identity. A skull x-ray can be distinctive for each person has a unique shape to the frontal sinus area which is evident on comparing the x-ray images with the skull. Ribs, the humerus, and the femur can also be usefully compared between x-rays taken in life and skeletal remains.

Clothing or jewelry found with skeletal remains can be a useful aid to identification, as can injuries found on the body. Of course, many injuries do not affect the skeleton at all. If someone is strangled, it will not be apparent by examining his or her skeleton. However, blunt and sharp force injuries do sometimes impact on bone and these marks may be informative. Similarly, bullet entry and exit wounds may sometimes be apparent. It is important for the investigator to distinguish when the wounds may have been made. During life, wounds heal and create scar tissue, which is apparent on examination of the bone. Wounds without scar tissue may have been inflicted close to the **time of death** and may, indeed, have been the cause of it. Bones may be damaged after death, but a post-mortem injury looks very different from an ante-mortem injury. Dead bones are brittle and they crumble and break cleanly. The fracture would usually occur parallel or perpendicular to the long axis of the bone. Living bone fractures in a twisted or splintering manner.

X-ray examination of skeletal remains may also indicate disease such as bone cancer or osteoporosis that may be correlated with medical records. Some people have medical appliances like hip replacements or cardiac pacemakers. It is possible that they will even bear a reference number that will reveal the identity of the deceased. DNA analysis provides the ultimate identification. It is possible to extract DNA from the bone marrow or the bone itself. There is increasing interest in looking at mitochondrial DNA, genetic material that occurs in the mitochondria of the cell rather than its nucleus. Mitochondrial DNA is passed down the maternal line and is very resistant to destruction, so is likely to be present in even very old skeletal remains. Mitochondrial DNA from the bones can be compared to that of a living family member to try to establish identity.

SEE ALSO Anthropology; Sinus print; Skeletal analysis.

Ouchterlony test

Örjan Thomas Gunnarson Ouchterlony, a Swedish bacteriologist who was born 1914 in Göteborg (Gothenburg), developed a double immunodiffusion technique in 1948 that, when used in forensics, determines whether a bloodstain is human or animal. This technique is commonly called Ouchterlony double gel diffusion test, which refers to Ouchterlony's critical analysis in 1968 in his *Handbook of Immunodiffusion and Immunoelectrophoresis*. Another synonym employed is the agar gel immunodiffusion test, AGID.

The binding of an **antibody** to an **antigen** is a fundamental reaction of immunology. Antibodies and antigens form complexes that result in the formation of a visible white aggregate, which is called precipitation, making it possible to assay antibody-antigen systems. The antigen in precipitation reactions is soluble and so small that it must combine with many antibodies to form visible clumps. Soluble antigens can be attached to particulate material serving as carriers that can be detected using the more sensitive agglutination technique. Antigen-antibody reactions are widely used in research, laboratory diagnosis of diseases, pregnancy tests, and forensic **identification** of blood.

The technique involves cutting cylindrical wells into a purified preparation of semi-solidified agar gel in a Petri dish. The wells are filled with antibody or antigen and the dish is allowed to incubate. Homologous antigen and antibody diffuse toward each other from the individual wells to a point in the agar where optimum concentration of each is reached. Subsequently, a precipitin line will form within 18–24 hours somewhere between the two wells. If challenges are mixed together in a single well and allowed to diffuse out into the agar towards the **serum** test well, multiple precipitin bands are seen routinely. Non-specific reactants diffuse past each other, forming no precipitate. The precipitation reaction is subject to inhibition if either antigen or antibody is present in excess. The qualitative Ouchterlony test can simultaneously monitor multiple antibody-antigen systems and can be used to identify particular antigens.

The Ouchterlony method is wearisome due to the time and interpretative expertise required, and the need for reagent sensitivity and selectivity validation. Today, immunoassay tests are used that rely on immunological principles similar to the Ouchterlony test. Results are accurate, more sensitive, and visible within ten minutes, however, the test apparatus is portable and simple to use, requiring no prior experience to conduct and interpret the results. They can give the crime scene examiner a rapid indication as to whether a sample should be taken for **DNA** analysis from a bloodstain. Similarly, the laboratory analyst can utilize these tests to confirm whether a bloodstain is of human origin, which may be important where DNA results have failed. If animal blood is suspected, then the Ouchterlony test is utilized.

SEE ALSO Antibody; Antigen; Blood; Bloodstain evidence; Crime scene investigation; DNA; Homogeneous enzyme immunoassay (EMIT).

P

Paint analysis

Painted surfaces are everywhere, so it is not surprising that paint is an important source of **trace evidence**. Typically, paint chips are transferred in car accidents, either from one car to another or, in the case of a hit-and-run, from the car to the victim. If there is wet paint at the scene of a crime, the perpetrator may also get it on their clothing. When tools like a crowbar are used in a breaking and entry crime, they may end up with microscopic flakes of paint on them. Analysis of paint **evidence** can therefore make an important contribution to an investigation.

Paint is a complex mixture consisting of pigments, modifiers, extenders, and binders. The pigments give the paint its color. Blue and green pigments tend to be **organic compounds**, while reds, yellows, and whites are often **inorganic compounds**. The modifiers control the properties of the paint such as gloss, flexibility, toughness, and durability. An extender adds bulk and covering capacity and is usually inorganic in nature. Some substances, such as titanium oxide, which is white, may act as both a pigment and an extender. A binder is a natural or synthetic resin that helps stabilize the mixture and form a film when it is spread. Topcoat, primer, and undercoat all have different types of chemical composition. The sample may also have been exposed to dirt, rain, and other contaminants, which can complicate the analysis.

Paint samples can be difficult to collect from the scene of a crime. They can be found on a variety of objects, including clothing, vehicles, and tools. Often the paint is mingled with other materials such as dirt or grease, and its removal may well be a specialist task. In the case of paint chips on cars, it is often the undermost layer of the surrounding paint that is most informative; great care has to be taken to preserve it. Matching chips with flakes of paint that have been knocked off a vehicle can be important individualizing evidence, so great care must be taken not to disturb any features of the surface during evidence collection to allow an accurate match.

Because paint has both organic and inorganic components, a variety of different chemical analysis techniques may be used to find out its actual composition. **Micro-spectrophotometry** in its reflectance mode will help determine the nature of the pigments, while infra red spectrometry will determine its organic components. X-ray powder diffraction is useful for determining the identity of any microcrystalline components. Because paint in the form of a chip is solid, a specialized technique called pyrolysis gas **chromatography** might be used to determine its composition. Pyrolysis involves heating the sample until it turns into a vapor. This is then injected into a gas chromatograph that separates the components. These can be identified by molecular weight using mass spectrometry, which creates a chemical fingerprint that can be compared to reference samples.

If the paint is in the form of a flake, then information on the number of layers can be obtained by various microscopic techniques. The forensic investigator compares the sample to known paints or

French researcher takes a sample of paint with a scalpel to help identify a car driven by suspects while committing a crime.
© ALAIN NOGUES/CORBIS SYGMA

control samples, by whatever techniques are most appropriate, to see if they came from the same source. The most individualizing type of paint evidence consists of flakes whose fractured edge can be matched to an area of paint loss. Thus, if a paint flake is found on the clothing of the victim of a hit and run accident, then the perpetrator's car should show a chip whose edge exactly matches that of the flake. The investigator uses a light microscope, a stereomicroscope, and perhaps even a scanning electron microscope to look for a jigsaw-like fit of the edge of the chip and the flake. Analysis of a paint can narrow down a sample to this kind to the make, model, and maybe even the year of a car, making it easier to catch the driver.

Paint analysis was used to help convict British serial rapist Malcolm Fairley, also known as "The Fox," in 1985. After one attack, investigators found minute specks of yellow paint on a tree branch around 45 inches (114.3 cm) from the ground. The paint was analyzed and identified as a type of car paint used on a single model, the Austin Allegro, between 1973 and 1975. Other evidence accumulated and the police went to an address in North London to interview a suspect. A young man was cleaning a yellow Austin Allegro outside. Examination revealed scratches on the paintwork about 45 inches from the ground that matched the paint flakes found at the scene of the crime. On this, and other evidence, Fairley was convicted on several accounts of indecent assault, rape, and burglary and given six life sentences.

SEE ALSO Gas chromatograph-mass spectrometer.

Skip Palenik

1948–
AMERICAN
RESEARCH MICROSCOPIST

For more than thirty years, Skip Palenik has worked as a research microscopist, identifying the origins of tiny pieces of materials. His work has helped provide crucial **evidence** in many criminal investigations, and Palenik has testified in and worked on many high-profile cases. As a lecturer and writer, he has also contributed to the education and literature regarding microscopy and chemistry.

Palenik was eight years old when he obtained his first microscope. This childhood hobby would later turn into a career path. From 1966 to 1969, he worked as an intelligence analyst in Germany for United States Army Intelligence. Returning to college, Palenik earned a B.S. degree in chemistry from the University of Illinois at Chicago. He also studied microscopy with two of his mentors, the Swiss microscopist **Max Frei-Sulzer** and Chicago microscopist **Walter C. McCrone**. In 1974, Palenik joined McCrone's lab, McCrone Associates, as a research microscopist. He worked for the company for eighteen years, in various positions.

As an independent researcher, Palenik developed a reputation for skill and unbiased analysis. He has worked on hundreds of criminal investigations across the United States, including such high-profile cases as the 1995 Oklahoma City bombing, the Tylenol tampering murders, the Narita Airport bombing, and the JonBenet Ramsey case. Palenik has also worked on identifying potentially fake artwork, the remains of a body thought to be that of the Sundance Kid, and the identity of Nazi war criminal Ivan the Terrible. In 1992, Palenik started his own laboratory, the Elgin, Illinois-based Microtrace. He is often consulted by the **FBI**, New Scotland Yard, and the Royal Canadian Mounted Police.

In addition to his work as a microscopist, Palenik has taught at the Illinois Institute of Technology, the University of Illinois at Chicago, and the McCrone Research Institute, as well as at individual laboratories and conferences across the United States. He has been a contributor to many books, including the *Encyclopedia of Forensic Science* and *Forensic Examination of Fibers*. He has also written articles for many trade publications, and serves on the board of directors for the McCrone Research Institute. Palenik was named the 2003 Distinguished Scientist by the Midwestern Academy of Forensic Scientists.

SEE ALSO Art identification; Careers in forensic science; Locard's exchange principle; Scanning electron microscopy.

Timothy Palmbach

8/16/1960–
AMERICAN
FORENSIC INVESTIGATOR AND EDUCATOR

From the 1980s to the present, Timothy Palmbach has been a qualified expert witness in the **processing** of crime scenes, interpretation of **blood spatter** patterns, and digital enhancement of forensic photographs, due to his expertise, experiences, and education in the investigation of hundreds of crime scenes. Some of the more famous investigations performed by Palmbach include: helping to identify in 1999 the burial site of Native American princess Pocahontas in the town of Gravesend, England; researching in 2000 into the July 1985 death of Douglas Bruce Scott, an Australian aboriginal prisoner; participating in research during 2000 with regard to the murder of Mary A. Sullivan by "The Boston Strangler," and the activities leading up to the 2001 **exhumation** of the body of Richard DeSalvo. After a distinguished career with the Connecticut State Police, Palmbach is currently the chairperson for the **forensic science** department at the University of New Haven, in West Haven, Connecticut.

In 1982, Timothy Palmbach received a bachelor's of science degree in forensic science and chemistry from the University of New Haven. Three years later, Palmbach completed a master's of science degree from the University of New Haven in forensic science with a concentration in **criminalistics**. Later, in May 1998, Palmbach received a juris doctor degree in law from the University of Connecticut School of Law in Hartford.

From 1982 to 1986, Palmbach worked as a resident trooper/trooper with the Connecticut State Police. Then, from 1986–1992, Palmbach worked as a detective in the Major Crime unit with the Connecticut State Police and, from 1992–1993, as a patrol supervisor. In these two capacities, he processed about 300 crime scene investigations, during which time he was assigned as the coordinator/liaison for the Crime Scene Processing unit with the Forensic Laboratory. In 1993, Palmbach was promoted to a supervisor in the Major Crime unit, a role he maintained until 1997. During these four years, he managed a wide variety of criminal investigations into cases including murders, kidnappings, **serial killers**, and robberies.

In January 1997, Palmbach transferred to the Connecticut Forensic Science Laboratory where, at the rank of lieutenant, he became the organization's assistant director. For the next year and one half, Palmbach managed the Support and Administrative Services area; designed and implemented a pre-accreditation program from the American Society of Crime Laboratory Directors; implemented the Laboratory Management Information Systems program; and assisted the well-known Chinese-American forensic scientist **Henry C. Lee** with case reports of crime scene reconstructions. Then, in July 1998, Palmbach transferred to the Department of Public Safety. There he was promoted to the rank of major and managed the operations of the Commissioner's Office including Legal Affairs, Legislative Liaison, and Public Information, and the operations of the Division of Scientific Services including the Forensic Laboratory, Computer Crime Unit, and Toxicology Laboratory. He also continued his assistance with Lee.

In June 2000, Palmbach became the commanding officer and director of the Division of Scientific Services, and served in this position until 2004. As division head, Palmbach had general jurisdiction over such areas as the Forensic Science Laboratory, Computer Crime and Electronic Evidence Unit, and Controlled Substance and Toxicology Laboratory. Palmbach is a certified law enforcement instructor, a classification he has held since 1992. In this capacity, Palmbach is certified to instruct such courses as Crime Scene Procedures, Principles of Investigation, Photography, Fingerprinting, and Sexual Assault/Rape crisis.

Since August 2000, Palmbach has held the positions of practitioner-in-residence and distinguished lecturer at the University of New Haven. At this institution, Palmbach teaches undergraduate and graduate courses in forensic science including Physical Analysis in Forensic Science, Pattern Analysis and Crime Scene Procedures, and Advanced Criminalistics. Some of the many workshops and seminars that he has taught include Cold Case Investigations, Effective Presentation of Expert Testimony, and Advances in DNA Profiling and Technologies for Attorneys.

Palmbach has been an adjunct lecturer at Central Connecticut State University in New Britain; where he has lectured on special topics within **criminology**. In addition, Palmbach has been a guest lecturer at such universities as the University of Connecticut School of Law, Western Connecticut University, Saint Joseph College, and Northwestern Connecticut Community College. Besides his college lectures, Palmbach also gives many professional forensic science presentations at conferences and seminars around the world, including in 2002: "Blood Stain Pattern Analysis" at the 9th Annual New Jersey State Police Advanced Homicide Investigation Conference at Princeton University, New Jersey, and "Reconstruction of Shooting Incidents" at the Southeast Law Enforcement Training Seminar in Lawrenceburg, Tennessee.

Palmbach has collaborated with other authors on such publications as: "Henry Lee's Crime Scene Handbook," (with Henry Lee and Marilyn Miller, 2001), "Digital Enhancement of Sub-Quality Bitemark Photographs," (with Henry Lee and Constantine Karazulus, 2001, *Journal of Forensic Science*), and "The Green Revolution: Botanical Contributions to Forensics and Drug Enforcement," (with H. M. Coyle, Carll Ladd, and Henry Lee, *Croatian Medical Journal* [2001]). Palmbach holds a professional affiliation with the American Academy of Forensic Scientists and is on the board of directors of the Henry C. Lee Institute of Forensic Science, which is affiliated with the University of New Haven.

SEE ALSO American Academy of Forensic Sciences; Blood spatter; Crime scene investigation; Expert witnesses.

Palynology

Palynology is the science of fossil and modern pollen, **spores**, algal cysts, and other microscopic plant bodies. It is a multi-disciplinary field with applications in **forensic science**, **geology**, geography, **botany**, **entomology**, zoology, **archaeology**, immunology, and environmental sciences. The term palynology is derived from the Greek terms *paluno*, meaning to strew, or to sprinkle, and suggestive of *palé*, meaning fine meal, or the Latin *pollen*, meaning also fine flour or dust.

The study of palynology has, by necessity, been closely associated with the development and later improvements of **microscopes**. Because pollen grains are microscopic, mankind had to wait until the invention of the compound microscope in the mid 1600s before pollen grains could be seen in any detail. During the next two centuries following the invention of the microscope, botanists studied the morphological features of pollen grains, their form and structure, and began to develop taxonomic keys for their **identification**.

Pollen carries the male gametes of flowering and cone-bearing plants, and spores are the asexual reproductive bodies of ferns, mosses, and fungi. Plants produce vast quantities of microscopic pollen and spores, which they disperse with the help of animals, wind, or water. Although individual pollen grains are invisible to the naked eye, they occur on almost every surface in nature. They are also highly resistant to decay, being found in rocks many millions of years old, and also persisting on or in soil, dirt, and other materials for many years. Pollen and spores come in an infinite variety of shapes and have complex surface ornamentation. Each plant type has distinctive pollen that can be distinguished from the pollen of other plants. For this reason pollen and spores are often called nature's fingerprints for plants.

The major commercial application of palynology is in geology, where it is used to date sediments to assist in petroleum, mining, and underground water exploration. Aeroallergy is the branch of **medicine** concerned with the seasonal occurrence, abundance, and allergenic effect of spores and pollen. The study of extant palynomorphs, which are either living, still retain their cell contents, or whose cell contents have been removed by maceration, is called actuopalynology. It includes the disciplines mellisopalynology (study of pollen in honey or other bee products), pollination ecology (distribution of pollen by wind or animals and its efficacy in fertilization and seed set), aeroallergy, and **criminology** (i.e., forensic palynology). In the discipline of archaeological palynology pollen, spores, and other palynomorphs from archeological sites are employed to reconstruct prehistoric diet, funeral practices, artifact function and source, archaeological feature use, cultivation and domestication of plants, and human impact on vegetation.

The term forensic palynology refers to the use of pollen and spore **evidence** in legal cases. It is often possible to be very specific about where a person or thing has been from the pollen types that occur together in a sample. Pollen and spore production and dispersion are important considerations. The expected production and dispersal patterns of spores and pollen (called pollen rain) for the plants in a given region will yield the type of "pollen fingerprint" to expect in samples that come from that area. Therefore, the first task of the forensic palynologist is to try to find a match between the pollen in a known geographical region with the pollen in a forensic sample. Knowledge of pollen dispersal and productivity often plays a major role in solving such problems.

Pollen can help destroy or prove alibis, link a suspect to the scene of a crime, or link something left at the crime scene to a suspect. It can also help to determine what country or state drugs, food, merchandise, and antiques among other things, have come from. In its broader application, the field of forensic palynology also includes legal information derived from the analysis of a broad range of microscopic organisms such as dinoflagellates, acritarchs, and chitinozoans that can be found in both fresh and marine environments. One of the earliest successful cases where forensic palynology was used pertained to a criminal case in Austria in 1959.

Soil, dirt, and dust are common elements at almost every crime scene. Woven cloth, woolen blankets, ropes, clothing, and fur all make excellent traps for pollen and spores. Woven materials and fur are made of tiny interwoven **fibers**. When air comes in contact with woven materials, the fibers become filters that retain solid particles, such as pollen and spores. Woolen garments, including blankets, skirts, suits, ties, and sweaters, make the best pollen and spore traps.

If working on a case, pollen is extracted from exhibits (washed or scraped from items, or taken off with tape lifts); **control samples** are collected; and if possible, the crime scene attended. The samples are then taken through various preparation procedures so that the detail of the pollen can be examined with microscopes. Some cases are quite easy and require only the comparison of assemblages in the control and forensic sample; others require much research in the laboratory with other scientists, the public, and police.

SEE ALSO Botany; Crime scene investigation; Entomology; Fingerprint; Forensic science; Geology; Identification; Microscopes; Pollen and pollen rain; Reference sample; Soils; Spores.

Parasitology

Parasitology is the study of parasites, organisms that live, grow, and feed on or in other organisms. The prevention of parasite-infested consumption of raw (or undercooked) meat, fish, seafood, vegetables, and dairy products, as well as contaminated water, is a matter of public health. The **United States Food and Drug Administration** (**FDA**), the Centers for Disease Control (**CDC**), and several other local and state sanitary agencies are responsible for regulatory food safety measures and regular inspections of food and water quality to prevent the outbreak of epidemics caused by parasites and other **pathogens**.

When an epidemic outbreak occurs in a city or when several cases of food-related poisoning suddenly happen in an area, forensic pathologists or forensic parasitologists help epidemiologists to identify the source of the problem. For example, in 1980, 32 patients, including four physicians, reported to hospitals in Los Angeles within a short period of time complaining of abdominal distention, diarrhea, intermittent abdominal cramps, and flatulence. They were diagnosed as having been infested by a flatworm, *Diphyllobothrium spp.*, a common parasite in freshwater and sea fish. All patients recalled that they had eaten sushi, a raw fish dish, ten days prior to the onset of symptoms. Alerted by hospitals, the CDC tracked the illness back to sushi made of salmon contaminated with the flatworm.

Another field where parasitology is also important is legal **medicine**, as some parasitic pathogens (disease-causing organisms) are transmitted through sexual contact and may constitute **evidence** of crime, especially in cases of child molestation.

Although some pathogenic (disease-causing) bacteria such as Chlamydia and Ricketsia can be thought of as obligate intracellular parasites (i.e., they can only be replicated inside living cells using the host cell's metabolic machinery) the strict definition of parasites refers to protozoa and helminthes or worms, also known as Metazoa. Pathogenic protozoa are unicellular (e.g., single-celled) organisms divided into four groups: Sarcodina (amoebas), Sporozoa (sporozoans), Mastigophora (flagellates), and Ciliata (ciliates). Metazoa or worms classified are divided in two groups, Platyhelminthes or flat worms, such as Trematoda (flukes) and Cestoda (tapeworms), and Nemathelminthes or roundworms. The most commonly occurring parasites in humans can be also grouped according to the areas of the body they infest, such as: 1) the intestinal tract (*Giardia* *lamblia*, *Entamoeba histolytica*, and Cryptosporidium); 2) urogenital tract (flagellate *Trichomonas vaginalis*); 3) blood and tissues (flagellates Leishmania and Trypanosoma, protozoans Toxoplasma and Plasmodium).

Giardiasis, or infestation by *Giardia lamblia*, occurs in two forms: Giardia trophozoites (active Giardia) and cysts (latent, non-mobile Giardia). Water and food contaminated with fecal residues are the main means of transmission, with the cysts developing into Giardia trophozoites in the duodenum (upper part of the stomach). Giardia attaches to the duodenal mucosa where it competes for protein and fat nutrients, causing inflammation, flatulence, foul-smelly diarrhea, intestinal cramps, nausea, anorexia, and associated protein and fatty acid deficiency. Although 50% of the hosts do not present with symptoms, giardiasis is very common among children in daycare centers, and people who camp, hike, or drink unfiltered water directly from streams, with symptoms appearing especially in those with certain immune deficiencies. Giardiasis is an endemic infestation in the United States, affecting about 5% of the population.

Entamoeba histolytica have two life-cycle phases: trophozoites or mobile amoeba and cyst (non mobile) phases. They cause intestinal cramps, dysentery, and liver lesions, being transmitted by ingestion of cysts present in water or uncooked food, as well as through fecal-oral contact in sexual intercourse. Once inside the body, the cysts mature to the trophozoites phase, the active ameba. By causing necrosis (cell and tissue death and decay) of the intestinal epithelium, amebas invade the submucosa layers of the colonic tract and reach circulation, being transported to the liver where they cause systemic hepatic disease and liver abscesses. Approximately 2% of the American population suffers from amebiasis. Other types of amebiasis are rare, such as those caused by *Acanthamoeba ssp.* and *Naegleria fowleri*, which are pathogenic free-living amebas transmitted by water inhalation (while swimming) and by air. They can multiply in the tissues of the brain and spinal fluid, causing nerve damage and death if untreated. Naegleria causes primary amoebic meningoencephalitis (PAM) and Acanthamoeba leads to granulomatous amoebic encephalitis (GAE). If untreated, PAM can kill within a week of the onset of symptoms. GAE occurs in patients with immunodeficiencies and leads to death within several weeks to a year after the onset of disease. Both diseases cause eye infections that can lead to blindness. Between 1985 and 1986, 22 cases of amoeba-related ocular lesions were reported to the Centers for Disease Control. Investigators found out that the majority of the cases were associated with poor disinfection of contact lenses and homemade saline solutions.

Cryptosporidium is another pathogen that induces diarrhea, which is more severe in small children, senior patients, and those with immunodeficiencies such as HIV. Transmission is generally under the form of oocysts present in water and may cause collective outbreaks of watery diarrhea with risk of severe dehydration, particularly to those belonging to the more vulnerable groups. Water filtration is the most effective way of preventing both giardiasis and Cryptosporidium-related diarrhea because these two parasites are resistant to water chlorination.

Almost two billion people live in parts of the world where malaria is an endemic (naturally occurring in the environment) disease. Malaria is a parasitic disease caused by four different species of the Plasmodium parasite, and is transmitted by the bite of infected mosquitoes. The worldwide use of pesticides containing DDT greatly reduced the incidence of malaria, but since DDT was found to contain possibly carcinogenic (cancer-causing) chemicals in the late 1960s, its use has declined greatly, and in turn, the incidence of malaria has increased sharply around the world. As of 2005, malaria is estimated to have killed more than 300–500 million people over the centuries and still kills an estimated 2.5 million people per year (including 1 million children) in Africa and the world's tropical areas. Many countries in these regions are returning to the use of DDT to control the mosquitoes carrying the parasite that causes malaria.

Trichomonas vaginalis is a sexually transmitted parasite that exists only as trophozoites, causing genital itching and smelly-greenish vaginal secretions as well as urethritis (a burning sensation when urinating). In men, the only symptom is urethritis, although the parasite is transmitted in the prostatic secretions (secretions of the prostate gland). The use of condoms prevents infection. When found in a child, this and other sexually transmitted diseases may suggest a case of child molestation. Some rare cases of trichomoniasis appear to be associated with contact with wet toilet seats.

Toxoplasma gondii, a blood parasite, may be transmitted through the contact with infected feces of cats and other mammals, or by consumption of raw or undercooked meat or contaminated water, causing toxoplasmosis. It can be also transmitted from mother to the fetus, in what is known as congenital toxoplasmosis. Congenital infection favors miscarriage, neonatal mental retardation, or chorioretinitis (inflammation of the choroids portion of the eye), which leads to blindness during childhood. In immunodepressed adults, toxoplasmosis may cause encephalitis, although most of the infected population remains asymptomatic, due to the action of the **immune system**. However, *T. gondii* passes from the intestinal tract to other tissues of the body, such as brain, liver, lungs, and eyes, where it remains as cysts for years. As long as the infected individual's immune system is healthy, antibodies and the immune cells will keep the infection at bay, preventing disease progression.

Diarrheal parasites and other pathogens account for 4% of deaths worldwide each year. Periodical tests for these and other parasitic infestations are a valuable preventive measure that can avert serious and unnecessary diseases and even death.

SEE ALSO Air and water purity; Antibiotics; Antibody; FDA (United States Food and Drug Administration); Hemoglobin; Immune system; Medical examiner.

Paternity evidence

The general concept of testing for paternity is centered on the establishment of information about hereditary factors that either exclude an individual from consideration of being the biological father of a child, or reveal a convincing pattern of consistency that supports a claim of biological paternity. Exclusion can be absolute—it is indeed possible to disprove a person's role as biological father. It is not possible, however, to make a positive proof of paternity. This side is always a probability calculation. Thus, the development of paternity evidence involves both physical testing, through **DNA** or other biochemical markers, and probability calculations using the laws of probability.

One important aspect of paternity testing is the development of a list of potential candidates for paternity. Since the timing of conception is fairly tightly clustered around the middle of the menstrual cycle, the mother of a baby generally knows with a fair amount of certainty who the father is, or knows the list of possible candidates with whom she has had sexual intercourse near enough to the time of conception for determining paternity to be a realistic possibility. In some cases, and for various reasons, the mother may not have a conscious awareness of all of the events surrounding the pregnancy. This may be the situation in cases of rape by an unknown assailant, intercourse which has taken place under the influence of drugs or alcohol, or when the mother is mentally retarded or has certain forms of mental illness. The first step in the process of paternity testing is to determine the candidates for whom testing makes sense. This type of testing is centered on elimination or retention of individuals who have been placed on the list of reasonable candidates.

In previous years, testing was focused on the testing of **blood** group types and the evaluation of biochemical markers for which there were significant differences among individuals in the population. This testing seems crude compared with the more precise and informationally rich DNA marker systems for testing that are currently in use. In principle, any marker that is inherited from the parents can be used as a part of the testing process, however.

In the laboratory testing phase of the analysis, the laboratory chooses a number of markers, which have different forms in the general population, for analysis. These markers are called polymorphic markers, meaning each marker has many forms. Simple markers may have just two forms, and each individual has two copies of each marker. Thus, with these simple two-marker systems, a person would fall into one of three categories: he could have two copies of the first form, one copy of each of the two forms, or two copies of the second form. There are just three possibilities for anyone in the population, and it is common to match with a genotype consistent with paternity just by chance. The greater the number of possible forms, however, the greater the number of different combinations in the population, and the lower the likelihood of matching purely by chance. For example, if there are three different forms of a marker, there are 6 combinations possible; four forms yields 10 different combinations; five forms yields 15 combinations. For many of the genetic markers available for testing, such as short tandem repeats, there may be 10 to 20 different forms and therefore many, many combinations possible.

The testing strategy would then be to select several markers for testing, and to test the mother, the child, and the suspected father for each of the markers selected. Starting with the child, for each marker studied, one would ask which of the two copies that the child has came from the mother. For highly polymorphic systems it is often true that one and only one of the child's markers could have come from the mother. The remaining marker that the child carries must have come from the father. Sometimes, the child and mother match exactly for both forms of the marker, and it is not clear which one came from the mother and which came from the father. In this case, if either form matches one of the forms of the marker that the father carries, it is consistent with paternity.

As an example, let us say that there is a marker we will call X that has twelve forms that can be found in different people. We will let X be a trinucleotide repeat that is found to have anywhere from six to seventeen copies in normal individuals in the population. Each person will have two alleles of X, one that was inherited from his mother and one that was inherited from his father at conception. Upon testing, let us say that the child has one allele that has 7 copies of the repeat, and the second allele has 11 copies of the repeat. In the mother, we find one allele that has 7 copies of the repeat, and the other has 8 copies of the repeat. We know that the mother must have passed along the allele with 7 copies of the repeat. The other allele that the child has must come from his father. We can now exclude any suspected father who does not carry at least one allele of X that has 11 copies of the repeat. But what if the father does have an allele that has 11 copies of the repeat? Does this prove paternity? No, this could be a match purely by chance. While it is consistent with paternity, it is not conclusive by itself.

In real practice, one would not use just a single marker, even if it were highly polymorphic. One would generally include several informative markers to increase the chance that the suspect will be eliminated by failing to match. By choosing markers with a lot of variability in the population, the chance of matching can be minimized. For a person to be retained as a candidate for paternity, matching has to occur for all of the markers. Even a single inconsistency can eliminate a person from consideration.

If a person matches on all of the markers included in testing, and if those markers are reasonably informative markers for testing, the individual being tested is the presumptive father. In this case, it will be necessary to compute the likelihood of a person matching purely by chance using the simple laws of probability.

The probability of an individual carrying a marker of some given size can be found by studying a large number of people and computing the number who carry the marker divided by the total number of people studied. Suppose 500 people are studied, and 50 of those people have are found to have at least one copy of marker X with 11 repeats; the chance is 50/500 or 0.10 of carrying a marker of that size.

Peruvian President Alejandro Toledo recognized 14-year-old Zarai Toledo as his daughter for the first time in 2002 after a court ordered him to take a DNA paternity test. © REUTERS/CORBIS

One rule of probability is that the probability for both of two different events happening is found by multiplying their individual probabilities together. Likewise, to compute the chance of three or more separate events each happening one would multiply each of their individual probabilities together. When the probabilities are each small, the product of the combined probabilities becomes very small. It is possible to end up with likelihood of paternity that says that the chance of matching purely by chance is one in a million or less.

A reasonable question that many people ask is what is the chance that the testing is wrong. The simple answer is that the chance of being wrong when the father has been excluded by DNA testing is very near to zero. This assumes, however, that the specimen that was studied actually came from person that you think is being testing. Great care must be given to ensuring that the blood sample or other specimen that is taken for paternity testing actually comes from the person that is suspected as being the father. It is standard practice for laboratories that perform paternity testing to document a **chain of custody** for the specimen from the time it is drawn, until the time it reaches the laboratory for testing.

What about the chance of being wrong when the testing is consistent with paternity? As the result is expressed as a probability statement, it always remains true that there is a possibility of a match by chance. When there is reason to suspect that this is the case, the study of additional markers can further reduce the likelihood of a match by chance. While it is not possible to get this probability to zero, the probability can always be further reduced by adding additional markers. This adds expense, however, and most people will quickly realize that such expense is not warranted unless there is some compelling reason to doubt the findings. It is rarely the case that a person enters paternity testing without some fairly high likelihood that he is in fact the father.

The last twenty years of the twentieth century saw dramatic developments in the understanding of genetics and the development of markers that can be used in paternity and forensic testing. Compared with the testing available in previous generations, determination of paternity is now extremely reliable and relatively inexpensive.

SEE ALSO DNA; DNA evidence, social issues; DNA typing systems; Evidence, chain of custody; Gene; Genetic code; RFLP (restriction fragment length polymorphism); Statistical interpretation of evidence; STR (short tandem repeat) analysis.

Pathogen genomic sequencing

The forensic detection of disease-causing (pathogenic) bacteria is facilitated by knowledge of target sequences of the genome of the particular organism. **Sequencing** of some **pathogens** has been undertaken by organizations such as the Institute for Genomic Research. In the national interest, the United States has embarked on a genomic sequencing program of pathogens that will have forensic applications.

The Pathogen Genomic Sequencing program initiated by the Defense Advanced Research Project Agency (DARPA) in 2002 focuses on characterizing the genetic components of pathogens in order to develop novel diagnostics, treatments, and therapies for the diseases they cause. In particular, the program will collect an inventory of genes and proteins that are specific to pathogens and then to look for patterns among these molecules.

This information will facilitate the development of tools for identifying pathogens in a variety of vectors. It will also provide a foundation for engineering antibodies to identify pathogens. Initially, one representative strain of the bacteria that cause a variety of diseases (or their close relatives) are being studied for this program: *Brucella suis* (brucellosis), *Burkholderia mallei* (melioidosis), *Clostridium perfringens* (botulism), *Coxiella burnetti* (Q fever), *Franciscella tularensis* (tulareremia), and *Rickettsia typhi* (Rocky Mountain spotted fever).

As part of the Pathogen Genomic Sequencing project, a website focusing on orthopox viruses has been created. Known as the Poxvirus Bioinformatics Resource, this website serves as a repository for genetic sequence data for orthopox viruses. It currently contains sequence data for 35 viral pathogens including the virus that causes **smallpox**. In addition, the website contains data-mining and sequence analysis software and a poxvirus literature resource. The goals of the Poxvirus Bioinformatics Resource are the development of novel therapies for human diseases caused by orthopox viruses, the ability to detect orthopox viruses in the environment and the development of quick diagnostic tools for detecting pox diseases.

SEE ALSO Biological weapons, genetic identification; DNA; *Escherichia coli*; PCR (polymerase chain reaction).

Pathogen transmission

Forensic investigation of an illness, outbreak, or a death can be concerned with disease causing (pathogenic) microorganisms and, more specifically, with their route of transmission. Unearthing how an organism infected the victim(s) can be crucial when the organism is capable of spreading through a population quickly, or is a threat to public health.

Pathogens are microorganisms such as viruses, bacteria, protozoa, and fungi that cause disease in humans and other species. Pathogen transmission involves three steps: escape from the host, travel, and infection of the new host. Pathogen transmission occurs in several ways, usually dependent on the ecology of the organism. For example, respiratory pathogens are usually airborne, while pathogens of the digestive tract tend to be food- or waterborne. Epidemiologists group pathogen transmission into two general types—direct and indirect contact—within which there are several mechanisms.

A Centers for Disease Control scientist wearing a protective suit with helmet and face mask is protected from pathogens as she conducts studies in the CDC BSL-4 laboratory. © CDC/PHIL/CORBIS

Pathogen transmission by direct contact takes place when an infected host transmits a disease directly to another host. The pathogens that travel this way are extremely sensitive to the environment and cannot be outside of the host for any length of time. For example, pathogens that cause sexually transmitted diseases (STDs) are transmitted via **blood**, **semen**, or **saliva**. Some pathogens responsible for STDs include *Tremonema palidum* (syphilis), *Neisseria gohorrhoeae* (gonorrhea) and human immunodeficiency virus (HIV) (acquired immunodeficiency syndrome or AIDS). The viruses responsible for hemorrhagic fever, such as Ebola, are also transmitted by direct contact via the blood.

Indirect transmission occurs when an agent is required to transfer the pathogen from an infected host to a susceptible host. The agent may be either animate or inanimate. Inanimate forms of transmission include air, water, and food, which are referred to as disease vehicles. Inanimate agents also include fomites, which are objects on which the pathogen has been deposited. Examples of fomites are toys, clothes, bedding, or surgical instruments. Animate, or living, agents of disease transmission are most often insects, mites, fleas, and rodents. Living agents of transmission are referred to as vectors. Diseases that are spread via indirect contact in hospitals are specifically referred to as nosocomial infections.

Many respiratory viruses and bacterial **spores** are light enough to be lifted by the wind. These agents can subsequently be inhaled, where they cause lung infections. A particularly important example of an airborne bacterial pathogen is the spore form of the anthrax-causing bacterium *Bacillus anthracis*. This bacterium forms spores that can spread through the air and causes a severe respiratory disease when inhaled.

A common route of indirect pathogen transmission is via water. The ingestion of contaminated water introduces the microbes into the digestive system, where they can attack the gastrointestinal tract. Some pathogenic organisms use the cells that line the digestive tract in order to gain entry to the bloodstream. From there, an infection can become systemic. A common waterborne pathogen is *Vibrio* *cholerae*, the bacterium that causes cholera. The contamination of drinking water by this bacterium still causes cholera epidemics in some areas of the world.

Foodborne pathogens are grouped in two categories. Those that produce **toxins** that poison the host and those that infect the host and then grow there. **Food poisoning** is most often caused by the bacterium *Staphylococcus aureus*, which produces enterotoxins that result in vomiting and diarrhea. The bacterium *Clostridium botulinum* is responsible for the disease botulism, which is an extremely severe and sometimes fatal food poisoning.

Vectors harbor the microorganisms that cause disease and transfer them to humans via a bite or by other contact. *Coxiella burnetti*, the bacterium that causes Q fever, is transmitted to humans from the handling of animals such as sheep. Insects are common vectors of disease. Mosquitoes spread the protozoan *Plasmodium vivax* that causes malaria. Deer ticks are responsible for infection by the spirochete *Borrelia burgdorferi* that causes Lyme disease. The bacterium that causes plague, *Yersina pestis*, is transmitted by the rat flea.

SEE ALSO Anthrax; Bacterial biology; Biosensor technologies; Bioterrorism; *Escherichia coli*; Spores; Toxins.

Pathogens

Forensic analysis often involves the determination of the circumstances surrounding an illness outbreak or death. Medical examiners search for pathogens in body tissues and **fluids** to determine if the cause of a death was due to an infectious process.

Pathogens are organisms, frequently microorganisms or components of these organisms, that cause disease. Microbial pathogens include various species of bacteria, viruses, and protozoa. Many diseases caused by microbial pathogens, and the frequency of these diseases, are a national security issue.

A disease is any condition caused by the presence of an invading organism, or a toxic component, that damages the host. In humans, diseases can be caused by the growth of microorganisms such as bacteria, viruses, and protozoa. Bacterial growth, however, is not mandatory to cause disease. For example, some bacterial pathogens cause disease by virtue of a toxic component of the bacterial cell such as lipopolysaccharide. Finally, the damaging symptoms of a disease can be the result of the attempts by the host's **immune system** to rid the body of the invader. One example is the immune-related damage caused to the lungs of those afflicted with cystic fibrosis, as the body unsuccessfully attempts to eradicate the chronic infections caused by *Pseudomonas aeruginosa* (a cause of pneumonia).

Not all pathogens cause diseases that have the same severity of symptoms. For example, an infection with the influenza virus can cause the short term aches and fever that are hallmarks of the flu, or can cause more dire symptoms, depending on the type of virus that causes the infection. Bacteria also vary in the damage caused. For example, the ingestion of food contaminated with *Salmonella enteritica* causes intestinal upset. But, consumption of ***Escherichia coli*** O157:H7 causes a severe disease, which can permanently damage the kidneys and which can even be fatal.

There are three categories of bacterial pathogens. Obligate pathogens are those bacteria that must cause disease in order to be transmitted from one host to another. These bacteria must also infect a host in order to survive, in contrast to other bacteria that are capable of survival outside of a host. Examples of obligate bacterial pathogens include *Mycobacterium tuberculosis* (tuberculosis) and *Treponema pallidum* (syphilis).

Opportunistic pathogens can be transmitted from one host to another without having to cause disease. However, in a host whose immune system is not functioning properly, the bacteria can cause an infection that leads to a disease. In those cases, the disease can help the bacteria spread to another host. Examples of opportunistic bacterial pathogens include *Vibrio cholerae* (cholera) and *Pseudomonas aeruginosa* (bacterial pneumonia).

Finally, some bacterial pathogens cause disease only accidentally. Indeed, the disease actually limits the spread of the bacteria to another host. Examples of these "accidental" pathogens include *Neisseria meningitides* (bacterial meningitis) and *Bacteroides fragilis* (normal intestinal flora that can cause serious infection if it gets into the bloodstream, usually through intestinal ulceration or trauma).

Pathogens can be spread from person to person in a number of ways. Not all pathogens use all the available routes. For example, the influenza virus is transmitted from person to person through the air, typically via sneezing or coughing. But the virus is not transmitted via water. In contrast, *Escherichia coli* is readily transmitted via water, food, and blood, but is not readily transmitted via air or the bite of an insect.

While routes of transmission vary for different pathogens, a given pathogen will use a given route of transmission. This has been used in the weaponization of pathogens. The best-known example is **anthrax**. The bacterium that causes anthrax—*Bacillus anthracis*—can form an environmentally hardy form called a spore. The spore is very small and light. It can float on currents of air and can be breathed into the lungs, where the bacteria resume growth and swiftly cause a serious and often fatal form of anthrax. As demonstrated in the United States in the last few months of 2001, anthrax **spores** are easily sent through the mail to targets. As well, the powdery spores can be released from an aircraft. Over a major urban center, modeling studies have indicated that the resulting casualties could number in the hundreds of thousands.

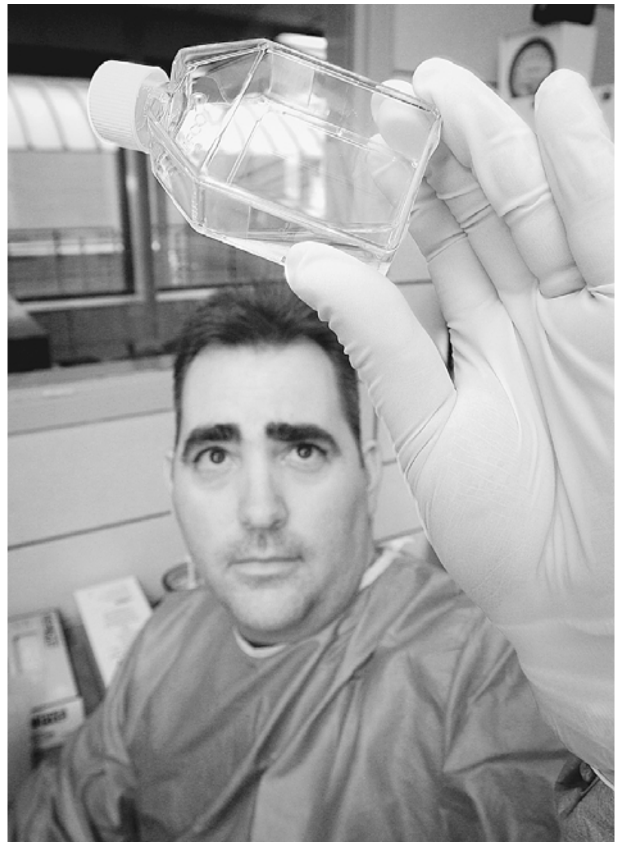
Contamination of water by pathogens is another insidious route of disease spread. Water remains crystal clear until there are millions of bacteria present in each milliliter. Viruses, which are much smaller, can be present in even higher numbers without affecting the appearance of the liquid. Thus, water can be easily laced with enough pathogens to cause illness.

Food-borne pathogens cause millions of cases of disease and hundreds of deaths each year in the United States alone. Frequently the responsible microbes are bacteria, viruses, or protozoa that usually reside in the intestinal tract of humans or other creatures. Examples of microorganisms include *Escherichia coli* O157:H7, *Campylobacter jejuni*, and rotavirus.

Pathogens can be transmitted to humans through contact with animals, birds, and other living creatures that naturally harbor the microorganism. The agent of anthrax—*Bacillus anthracis*—naturally dwells in sheep. Other examples include *Brucella abortic* (Brucellosis), *Coxiella burnetti* (Q fever), and viruses that cause hemorrhagic fevers such as Ebola and Marburg.

Microorganisms have various strategies to establish an infection in a host. Some microorganisms recognize molecules on the surface of the host cell, and use these as receptors. The binding of bacteria or viruses to receptors brings the microorganism in close contact with the host surface.

The nature of the interaction between the host receptor molecule and the attachment molecule on the surface of the bacteria, virus, or protozoan has in some cases been defined, even to the genetic level. The use of recombinant **DNA** technology—where a target section of genetic material is removed from one organism and inserted into a certain region of the genetic material of another organism, in a way that does not affect the expression of the gene—allows the genetic manipulation of a microorganism so as to enhance its ability to cause an infection. Alternatively, the addition of a **gene** that codes for a toxin into a bacterium that is a normal inhabitant of an environment like the intestinal tract could produce a formidable pathogen. This altered bacteria would readily associate with host cells, but would also carry the toxin.



A scientist at the Centers for Disease Control (CDC) examines a T-25 flask used in the SARS virus isolation, as part of a global collaboration to address the emergence of the SARS virus.

Viruses almost always damage the host cells. Because viruses cannot reproduce on their own, they rely on the replication mechanism of the host cell to make more copies of themselves (i.e., they are obligate pathogens). Then, the new viral particles will exit the cell and search for another cell in which to infect. This exit is often very physically damaging to the host cell. Thus, viral infections can be detrimental because of the loss of function of host cells.

Some viral pathogens are capable of causing a disease long after they have infected a host. This delayed response occurs because the viral genetic material becomes incorporated into the genetic material of the host. Thereafter, the viral genetic material is replicated along with that of the host, using the replication enzymes and other machinery of the host. But, in response to a number of signals, the viral material can be excised from the host material and form the template for the manufacture and assembly of new virus particles. A prominent example of such a virus is the human immunodeficiency virus (HIV), which is acknowledged to be the cause of acquired immunodeficiency syndrome, or AIDS.

SEE ALSO Bacterial biology; Biosensor technologies; Bioterrorism; Prions; Toxins.

Pathology

Pathology is the scientific study of disease processes that affect normal anatomy and **physiology**. Anatomical and physiological changes are pathological changes when they result from an underlying disease process or abnormality. **Forensic science** is geared towards deducing the nature of the physical and chemical insults that have been inflicted on one or more persons. Sometimes these insults can cause changes in the body. When that occurs, the forensic examination overlaps with pathology. Forensic pathology is the study of the anatomical or physiological changes that are suspicious in their origin.

Pathologists play an increasingly important role in diagnosis, research, and in the development of clinical treatments for disease. A specialized branch

South Korean pathologists inspect a 600-year-old mummy through an endoscope at a laboratory in Seoul, July 2004.

of pathology, forensic pathology, offers a vast array of molecular diagnostic techniques (including **DNA fingerprint** analysis) toward **identification** of remains, gathering of **evidence**, and identification of suspects.

Modern pathology labs rely heavily on molecular biology techniques and advances in biotechnology. During the last two decades, there have been tremendous advances in linking changes in cellular or tissue morphology (i.e., gross appearance) with genetic and/or intracellular changes. In many cases, specific molecular tests can definitively identify disease processes and help make a correct diagnosis at an earlier stage in the disease process.

Pathologists attempt to relate observable changes to disease process. Whether the changes are evident morphologically (structurally) or are distinguishable only via sophisticated molecular tests, the goal is to determine the existence and/or etiology of disease (the cause of disease). Once the etiologic agents are identified, the general goal of research is to document and gather evidence of the pathogenesis of disease (i.e., the mechanisms by which etiologic agents cause disease).

On a daily basis, pathologists perform a broad spectrum of tests on clinical samples to determine anatomical and physiological changes associated with a number of disease processes, including the detection of cancerous cells and tumors.

Major branches of pathology include the study of anatomic, cellular, and molecular pathology. Specific clinical studies often focus on transplantation pathology, neuropathology, immunopathology, virology, **parasitology**, and a number of clinical subspecialties (e.g., pediatric pathology).

Forensic pathology has several specific aims in addition to the aforementioned. The pathological examinations seek to establish what weapon was used, if that is relevant. Also, whether a death was self-inflicted or was a **murder** is another goal. Finally, the contribution to the death of a pre-existing disease or condition is a goal. For example, a person who is infected with the Human Immunodeficiency Virus often has a compromised **immune system** that lays them open to the development of other maladies that might otherwise not be fatal (i.e., fungal infections).

SEE ALSO Amphetamines; Barbiturates; Botulinum toxin; Death, mechanism of; Electrical injury and death; Food poisoning; Hemorrhagic fevers and diseases; Pathogens; Toxicological analysis.

Pathology careers

Pathology is the investigation of death and disease. It emerged as a discipline from the mid-nineteenth century with the development of the microscope. Physicians began to see that the microscopic examination of tissue was relevant to the study of disease and had practical application in diagnosis and research. Two branches of pathology emerged; anatomic pathology involved the study of cells, tissues, and organs, while clinical pathology covered the study of body **fluids** such as **blood** and urine. The discipline of forensic pathology developed during the twentieth century, and is the application of pathology to the investigation of crime, particularly when injury or death have occurred.

The **medical examiner** (ME) is a key person in a forensic investigation. He or she is charged with looking into any suspicious death reported to them, be it a homicide, suicide, accident, or in any other way suspicious. To this end, their work involves specific tasks, chief of which is the determination of the cause and manner of the death through performing an **autopsy**. The ME also takes control of the analysis of **evidence**, works with the police investigating the scene of the crime, and presents evidence in court. Ideally and increasingly, the ME is a forensic pathologist. In practice, they must merely be medically qualified and may not even be a pathologist. In such cases, they may well contract out some of their duties, such as carrying out the autopsy, to a forensic pathologist elsewhere.

Becoming qualified as a forensic pathologist involves a lengthy course of study. After completing an undergraduate degree, the individual completes four years of medical school (in the United States; course lengths elsewhere may differ). Then, postgraduate **training** in pathology, which is done in a teaching hospital, takes at least four years more. After that, a further year's training is needed to become a forensic pathologist, and this is usually done in an ME's office, to get the necessary experience. The forensic pathologist can then take an exam to become board certified, which means he or she is finally qualified to assume the job of a medical examiner. Given the strong legal content of the ME's work, some forensic pathologists may also have some training in the law, or even a law degree.

The work of the forensic pathologist is quite varied. They will, like any other physician, often be involved in reviewing a patient's medical history. Many of the apparently suspicious deaths reported to the ME are actually from natural causes and the pathologist must be as aware of common diseases as of the methods used for homicide and suicide. If it appears as if a crime has been committed, then witness statements will be reviewed and, ideally, the scene of crime visited. Evidence of many types must be considered, from bloodstains and **DNA**, to **toxicological analysis** of blood and urine. All of this will help the medical examiner to determine the cause and manner of death.

Perhaps the most important part of the forensic pathologist's job is to carry out the autopsy, if one is required. This is done according to a standard procedure with notes and photographs taken at every stage. The forensic pathologist is also responsible for writing up a report on the investigation, which includes autopsy results and other findings, and presenting this to the court.

The forensic pathologist does not operate alone; he or she is part of an investigating team. In a large jurisdiction, the ME may have one or more assistants who may also be medically qualified. There are also posts for those who have degrees in science rather than **medicine**. A degree in biology, chemistry, or physics may secure a job as a technician, scientist, or laboratory manager in a facility where forensic pathology is done, particularly for candidates who have the appropriate post-graduate training in a branch of **forensic science** or experience in an appropriate laboratory.

Forensic pathology itself includes a number of specialties, including **toxicology**, **serology**, **odontology**, **anthropology**, and **taphonomy**. Laboratories, both governmental and private, devoted to each discipline will have openings for those qualified in medicine or science. A forensic pathologist needs to undertake further training to specialize in any of these disciplines. Toxicology involves the analysis of body fluids and tissues for poisons or drugs of abuse. There are two kinds of tests, a screen, which determines whether the drug is present, and a confirmatory test, which determines the amount of drug present. The two main applications of toxicology testing are in autopsy and in workplace drug testing, including **sports testing**. Work in the toxicology laboratory involves chemical analyses using techniques such as **thin layer chromatography**, gas **chromatography**, and ultraviolet **spectroscopy**. Technicians may be qualified in chemistry and chemical analysis. The pathology side involves determining the contribution that an individual drug may have made to a death. Drug overdose is involved in many deaths, but it can be challenging to work out whether such a death has been a suicide or an accident. Homicide by poisoning is rare nowadays, thanks, at least in part, to developments in toxicological analysis that make it easy to detect the most common poisons in human tissues.

Forensic serology is the study of blood and other body fluids. The work requires clinical pathology technicians to type blood that can incriminate or eliminate a suspect. Analysis of other body fluids, like **semen**, can help in the investigation of serious crimes such as rape. Body fluids, including **saliva**, can also be used to extract DNA, the ultimate form of individualizing evidence. The analysis of DNA and the interpretation of results is a specialized task, even though much of the instrumentation is automated these days. DNA technicians are expected to have training in molecular biology techniques.

DNA analysis is rapidly becoming the "gold standard" for identifying an individual. Dental records can be very useful in the **identification** of skeletal remains, one of the main uses of forensic odontology, or the application of dentistry to the investigation of crime. The other major application of forensic odontology is the analysis of bite marks left behind at the scene of a crime. Dental technicians may create casts of impressions of bite evidence; the interpretation of dental evidence is a specialist task involving comparison between dental records or impressions and the evidence. Even if only a few teeth are available with a set of human remains or if a bite mark is incomplete, the forensic odontologist can still offer an opinion as to the age and habits of that person, which can be set into context with other identifying information.

Like teeth, bones are enduring and their forensic analysis can often be used to make an identification. Forensic anthropology is the study of human skeletal remains to estimate, first of all, the age, sex, and race of the deceased. The anthropologist may also use toxicological and DNA analysis if these can be obtained from the remains. If a **skull** is available, identification can sometimes be made by comparing it with x rays obtained antemortem (before death). The forensic anthropologist needs a depth of knowledge to be able to estimate the age of bones (they may be so old as to be of little forensic significance), and whether they are indeed human.

The forensic pathologist deals with a "fresh" body, the anthropologist with bones. The study of the in-between stage, the decomposing body, is the realm of the forensic taphonomist. A human body undergoes specific changes after death. The rate of these changes, however, depends very much on the individual and the environment. Evaluation of these changes may help establish the all-important **time of death**.

A pathologist prepares a microscope slide from a tumor that was removed in a brain biopsy. © ROGER RESSMEYER/CORBIS

Any pathologist working in the above disciplines may be called in as an expert witness to help resolve cases where the facts are unclear or in need of some explanation. A pathologist can help with the difficult question of **cause of death** when a body is recovered from water or how long it may have been in a shallow grave.

Being an expert witness is not a profession in its own right and a pathologist who carries out this work does not need to have special legal qualification. The expert witness is created and recognized as such by the judge and the court; he or she will usually have undergone training in court procedures so they can present their evidence to the best of their ability to help the judge and jury come to their decision.

Either the prosecution or the defense may call in a forensic pathologist as an expert witness. He or she is expected to look at the evidence relevant to their discipline, whether it is skeletal remains or analyses of body fluids, and put it in the context of the whole case. They will produce a report that can be taken up to the witness stand. First of all, the party who engaged the expert witness will ask questions that prove their identity, qualifications, experience, and background to the court. Then they will ask questions that generally take the court through the expert witness's report.

The expert witness can expect to be cross-examined by the opposing counsel who will ask questions as to the reliability of the evidence and the expert's conclusions. Many pathologists are experts in their subject, but it takes special skill and training to defend one's findings in public while still remaining objective and impartial.

The expert witness is the only one in court who is allowed to give opinion as well as facts. This is because the court has confidence in the facts and knowledge on which the opinion is based. Thus, the forensic anthropologist is allowed to say, for example, "I believe these bones are only about two years old and the cause of death was probably a blow to the head."

SEE ALSO Expert witnesses; Forensic science.

Pattern evidence

Pattern **evidence** is defined as any forensic evidence that can be read and analyzed from a specific type of pattern left by the physical contact between different people (such as victim and assailant), persons and objects (such as victim and automobile), and different objects (such as automobile and tree). These types of pattern evidence can result in various designs such as depositions, imprints, recesses, residues, and striped markings. When injuries result on the victim's body, so-called patterned injuries can oftentimes identify the features of the assailant or object and describe the specific characteristics of injuries. For example, burns result when an assailant shoves a victim into a container of hot water. Burns that are characterized as symmetrical (balanced) and bilateral (appearing on both sides) provide a reasonable initial indication that they were intentional.

Specific examples of sources that often result in pattern evidence include **blood** splatters (such as from a bullet's exit wound), fire burns (such as from **accelerant** residue), footwear, furniture positions (such as what results after a fight between victim and assailant), projectile trajectories (such as a bullet's path from an assailant's gun, through a victim, and into an object), shattered **glass** fractures (such as from vehicle windshields), and tire and skid marks.

Forensic experts examine all forms of pattern evidence in order to eliminate any possible accidental and natural causes for the pattern. For example, fires from flammable liquids often leave behind certain residue patterns. Such fires will normally burn downward unless specifically forced to burn upward. Specifically, accelerants poured from a container will often flow to the lowest spot and accumulate in a pool. After being ignited, the liquid will generally scorch the floor in a puddle configuration. Well-defined boundary lines between the burned and unburned areas will often be obvious to the investigator. In addition, flammable liquids will frequently penetrate cracks and other similar holes, and flow beneath surfaces. The ignited liquid may burn beneath the surface where it was first poured. Areas around such holes will often burn more rapidly when liquid concentrates in those places. All such actions must be considered by the forensic expert.

Pattern evidence, which is for the most part permanent in nature, is often compared to transient evidence, which is evidence that is temporary in nature. Examples of transient evidence that can easily change or disappear include odors, temperatures, and vapors. Forensic scientists, when specializing in pattern evidence, use many different types of instruments and methods to determine the chemical and physical characteristics of pattern evidence. Such professionals also perform investigations of crime scenes to collect and preserve pattern evidence in order to reconstruct relevant events through the analysis of such patterns.

SEE ALSO Ballistics; Blood spatter; Flame analysis; Gunshot residue; Shoeprints; Tire tracks.

PCR (polymerase chain reaction)

PCR, or polymerase chain reaction, is a biochemical technique that can generate millions of copies of a template strand of **DNA**. The technique relies on the same enzymes that cells use to replicate DNA, however it is performed in a simple test tube using controlled cycles of heating and cooling. PCR has revolutionized the field of biotechnology, making it quick and inexpensive to replicate, or amplify, specific segments of DNA.

PCR was conceptualized by molecular biologist **Kary Mullis** in 1983. While driving the highway between San Francisco and Mendocino, California, Mullis realized that very simple molecules could be used to replicate DNA in vitro, given the proper conditions. Prior to PCR, molecular biologists relied on bacteria to make copies of DNA. This process was both slow and subject to inaccuracies. After developing a conceptual model for PCR, Mullis refined the technique over the next seven years while working for Cetus Corporation in Emoryville, California. In 1993, Mullis was awarded half of the Nobel Prize in Chemistry for his work.

The DNA molecule is a double helix, which means that it consists of two long strands of smaller molecules. These long strands twist around each other. Each strand is made up of a sequence of four different smaller molecules called nucleotides. The four nucleotides are adenine (A), guanine (G), cytosine (C), and thymine (T). Each nucleotide always associates itself with a complementary nucleotide so that if adenine is on one of the strands, thymine is found across from it on the other strand. Similarly, if cytosine is on one strand, guanine is found across from it on the other strand.

Each strand of DNA has an orientation. One end of the molecule is known as the 5′ (or 5 prime) end and the other is called the 3′ (or 3 prime) end. This is because each nucleotide contains a 5′-phosphate on one side and 3′hydroxyl on the other side. The nucleotides are linked together by a reaction between the phosphate and the hydroxyl. The nucleotide on one end of the strand has an unconnected phosphate, the 5′ end, and the nucleotide on the other end has an unconnected hydroxyl, the 3′ end. The two strands of DNA are oriented in opposite directions so that the 5′ end of one strand matches the 3′ end of the other.

In order to make copies of DNA, the two strands are first separated from each other. Then a short molecule called a primer attaches itself to a location toward the 5′ end of the part of the DNA to be replicated on one of the strands. A primer is usually about 20 nucleotides long. Next, a special enzyme called DNA polymerase attaches itself to primer. This enzyme has the unique ability to add nucleotides to a growing DNA molecule. DNA polymerase uses the original strand of DNA as a template as it, in effect, slides along the original strand of DNA and pieces together a strand of complementary nucleotides. If, for example, the original strand contains the sequence CGGTA, then the DNA polymerase builds a strand with a sequence GCCAT. Because of the complementary nature of the nucleotides that make up DNA, after the original strands are separated and copied by DNA polymerase, the result is two copies identical to the double-stranded original. DNA polymerase moves along the DNA in the 5′ to the 3′ direction only.

The primer is extremely important to DNA replication because DNA polymerase can only add nucleotides to a growing chain, it cannot begin a new molecule. In cells, the primer is often a piece of RNA that binds to the DNA on the 5′ end of a **gene**. In biotechnological applications, primers are synthesized so that specific portions of DNA are reproduced. In order to copy both strands of DNA for a specific gene, two primers are needed, one for each strand. These two primers are not simple complements of each other because, due to the orientation of the two strands, the two primers will attach to DNA on opposite sides of the gene.

The biochemicals required for PCR are: at least one strand of the target DNA; two primers, one for each strand of the DNA; the enzyme DNA polymerase; and the four nucleotides found in DNA, adenine, guanine, cytosine, and thymine. These molecules are all combined in an instrument that carefully controls the heat of the mixture.

The steps required for PCR are fundamentally simple. First the strands of DNA are separated from each other by heating them to about 90°C (194°F) for roughly 30 seconds. At this high temperature, DNA is denatured and does not form a double strand. As a result, the primers are unable to bind to the target DNA. In the second step, the mixture is cooled to about 55°C (131°F), a temperature at which the DNA molecule takes on its double-stranded conformation. During this step, the primers bind to each of the target DNA strands on the 5′ side of the region to be copied. An excess of primer is added to the mixture to ensure that the primers anneal to the target DNA strands rather than the target DNA strands reattaching to each other. This second step takes about 20 seconds. Finally, the temperature is raised to about 75°C (167°F), which is the temperature that the DNA polymerase most commonly used in PCR is most effective. The DNA polymerase then extends the complementary strand of DNA, which takes about a minute. The result, after the first cycle, is two complete copies of the target DNA.

The cycle is then repeated multiple times. The second time it is repeated, both the original target DNA and the newly synthesized strands are copied; the result is four complete copies of the target DNA. The third time the cycle is repeated, eight copies result and so on. Usually between 20 and 30 cycles are completed, taking just a few hours, and the result is between one million and one billion copies of the original target piece of DNA.

The DNA polymerase usually used in PCR is known as *Taq* polymerase, because it is derived from the bacterium *Thermus aquaticus*. This bacterium is thermophyllic, meaning that it lives in locations with very high ambient temperatures, such as hot springs. In particular, the DNA polymerase of *T. aquaticus* is thermally stable at temperatures as high as 95°C (203°F), and so the high heating required to separate the double strands of DNA has no effect on the molecule. In addition, at higher temperatures, the chance of a primer binding to non-target DNA decreases. Because the *Taq* polymerase operates optimally at 72°C (161°F), the specificity of the PCR reaction is high and the DNA copied by the process is homogeneous.

Because PCR can be used to generate a large number of copies of very small amounts of DNA in very little time, it has quickly become an extremely useful and popular technology. Only ten years after it was developed, PCR had been referenced in more than 7,000 scientific publications. The applications of PCR are so great that it has become a standard research tool.

In forensics, the field of DNA fingerprinting relies on PCR. A very small sample of **blood**, **semen**, hair root, or tissue can be used to identify a person using PCR on the DNA from the nucleus of cells. The Federal Bureau of Investigation houses a genetic database called **CODIS** (Combined DNA Index System) that holds genetic information on convicted criminals and missing persons. A sensitive technique that can be used to establish maternal relationships between people is called **mitochondrial DNA analysis**, which relies on PCR. Biological material that is degraded or very old or tissues that do not contain nuclei, such as hair shafts and bones, are often more likely to yield information using this technique instead of DNA fingerprinting.

PCR is also important in answering basic scientific questions. In the field of evolutionary biology, PCR has been used to establish relationships among species. In anthropology, it has used to understand ancient **human migration patterns**. In **archaeology**, it has been used to help identify ancient human remains. Paleontologists have used PCR to amplify DNA from extinct insects preserved in amber for 20 million years. The Human Genome Project, which had a goal of determining the sequence of the 3 billion base pairs in the human genome, relied heavily on PCR. The genes responsible for a variety of human diseases have been identified using PCR. For example, a PCR technique called multiplex PCR identifies a mutation in a gene in boys suffering from Duchenne muscular dystrophy. PCR can also be used to search for DNA from foreign organisms such as viruses or bacteria. For instance, the presence of the HIV virus that causes AIDS can be determined using PCR on blood cells.

SEE ALSO DNA banks for endangered animals; DNA databanks; DNA fingerprint; DNA sequences, unique; Electrophoresis; Hair analysis; Mitochondrial DNA typing; RFLP (restriction fragment length polymorphism); STR (short tandem repeat) analysis; Y chromosome analysis.

Pentagon, 2001 attack upon SEE September 11, 2001, terrorist attacks (forensic investigations of)

Performance-enhancing drugs

The use of performance-enhancing drugs in athletics began to accelerate in the 1960s. Then, athletes from East Germany received drugs as part of a state-sanctioned program designed to ensure Olympic dominance. In 1988, such drug use became infamous when Canadian sprinter Ben Johnson was stripped of his Olympic 100-meter gold medal (and then world record time) following the detection of a metabolic remnant of an anabolic steroid in his urine.

Aside from any moral or ethical considerations of this behavior, the use of performance-enhancing drugs can pose health dangers. Recognizing these dangers, many professional and amateur sporting organizations are increasingly imposing their own standards for performance enhancement and monitoring participants to try to ensure athletic performance is determined by natural talent and training excellence.

In the realm of Olympic sports, the World Anti-Doping Agency, which is headquartered in Montreal, Canada, is responsible for actively discouraging the use of illegal performance-enhancing drugs. A list of prohibited drugs is maintained and updated annually.

Part of the agency's efforts also involves the accreditation of analysis laboratories for the examination of samples. The obtaining and analysis of urine and other samples is essentially a forensic process. The investigators delve back in time to determine what chemical methods might have been used to enhance performance.

Performance-enhancing drugs may exert their effects in different ways. Some, like anabolic steroids, increase the mass and the strength of muscles. Bones can also be strengthened. Other drugs cause more oxygen to be delivered to muscles, which allows the muscles to perform at an intensity that could not otherwise be possible. Still other drugs can blunt pain, stimulate the production of chemicals that spur the body to greater levels of athletic activity, or reduce weight. Some drugs are even taken just to mask the presence of a performance-enhancing drug.

A number of drugs can be used to enhance the amount and strength of muscles. This list includes anabolic steroids, beta-2-agonists, human chorionic gonadotrophin, luteinizing hormone, human growth hormone, insulin-like growth factor, and insulin.

A steroid is derived from cholesterol. Anabolic steroids, which build muscle and bone by stimulating protein production from muscle and bone cells, derive their name from the constructive process of anabolism (the opposite breakdown process is called catabolism).

Anabolic steroids include testosterone, a hormone that predominates in men, and other steroids structurally similar to testosterone. As a result, these steroids, in addition to increasing the intensity and length of athletic training that muscles and bones can tolerate, enhance male reproductive and secondary sexual characteristics including development of testicles, body hair growth, and thickening of the vocal cords (females taking anabolic steroids can thus experience a deepening of their voices).

Besides testosterone, other examples of anabolic steroids include dihydrotestosterone, androstenedione (commonly known as Andro, which reputedly was taken by baseball star Mark McGuire), dehydroepiandrosterone, clostebol, and nandrolone.

The gains in athletic performance bestowed by anabolic steroids come with a price. Mood swings and feelings of depression and aggression (commonly known as "roid rage") can occur, as can liver damage and jaundice. Males can become infertile and experience breast growth, while females can develop facial and body hair and an altered or completely suppressed menstrual cycle.

Beta-2 adrenergic agonists can be life saving to an asthmatic. When inhaled, they mimic the action of epinephrine and norepinephrine, which are secreted by sympathetic nerves, and cause airway muscles to relax, making breathing easier. However, when injected into the bloodstream, the agonists can help build muscle mass and stimulate the utilization of fat. The result is a leaner and stronger athlete, but an athlete who can be prone to nausea, muscle cramps, and even an irregular heartbeat. Examples of beta-2 adrenergic agonists include clenbuterol, tertbutaline, salbutamol, fenoterol, and bambuterol.

Human chorionic gonadotrophin (HCG) is produced naturally by a developing fetus. Indeed, its detection is the basis of home pregnancy tests. HCG functions to stimulate the development of male and female sex steroids. This is exploited as a muscle-boosting performance enhancer in male athletes via the increased production of testosterone.

Luteinizing hormone (LH) is produced by the pituitary gland, which is located at the base of the brain. Normally, the peptide hormone regulates the level of testosterone in males and the ovulation-signaling estrogen in females. In men, excess LH or synthetic forms of LH, such as tamoxifen, boosts levels of testosterone and so produces the increased muscle mass.

Human growth hormone (HGH) is another natural hormone that is produced by the pituitary gland. Normally, the hormone functions to promote growth in childhood and adolescence. But, when exploited as an athletic performance enhancer, the hormone builds muscle, strengthens bone, and stimulates the destruction of fat. Side effects of deliberate misuse include: abnormal enlargement of the hands, feet, and face (acromegaly); enlarged heart, kidneys, tongue, and liver; and heart malfunction.

Both LH and HGH function to promote increased muscle mass. The enhanced athletic performance that can result comes at a potentially lethal price of low blood sugar (hypoglycemia).

Muscles need a supply of oxygen to function. Supplying more oxygen increases the capacity of the muscles to perform. Protein hormones, artificial oxygen carriers, and blood doping (the addition of whole blood into an athlete) are all illicit means of increasing the oxygen content in tissues.

A protein hormone called erythropoietin (EPO) is naturally produced and secreted by the kidneys when oxygen levels are low. The hormone stimulates bone marrow cells to manufacture red blood cells, which function to bind oxygen and ferry the molecule to tissues throughout the body.

By boosting the oxygen levels in the body's tissues, EPO can be a performance enhancer for athletes engaged in sports that require endurance, as opposed to the raw power of an activity like power lifting. Thus, marathon runners, cyclists, and cross-country skiers have all been accused of injecting EPO. Indeed, American cyclist Lance Armstrong, who has won the Tour de France six times in succession through 2004, has long been under a cloud of suspicion regarding EPO use, despite his repeated and vehement denials and lack of evidence of impropriety.

While EPO does boost oxygen levels by up to 10%, the increased number of red blood cells can thicken the blood. The blood, honey-like in consistency, does not flow as well through blood vessels, which causes the heart to work harder. The risk of a stroke or heart attack is increased.

Artificial oxygen carriers are synthetic compounds that mimic the oxygen-binding behavior of **hemoglobin** (the active component of the oxygen-binding red blood cell). They were initially conceived and made to help assist in conditions of clinical distress, such as breathing difficulties experienced by premature infants or those whose lungs have been damaged. However, the compounds have been exploited in the quest for greater athletic excellence.

The athletic benefits of artificial oxygen carriers are not clear. Moreover, this dubious benefit increases the risk of kidney damage, cardiovascular difficulties, and problems with the **immune system**.

Blood doping, by transfusing whole blood to an athlete, increases the amount of blood in the body (or more precisely the number of oxygen-binding red blood cells) and the overall oxygen carrying capacity is increased. This process occurs naturally when athletes train at higher altitudes, where the oxygen content in the air is less than at sea-level.

While altitude training is an ethically acceptable training practice, deliberate infusion of blood is not. Furthermore, injection of blood can cause infections and the increased amount of blood can cause similar problems as EPO. As well, if the infused blood is from someone else, there is a risk of acquiring a blood related infection such as acquired immunodeficiency syndrome or hepatitis.

Injury is a natural part of training and competition. A natural part of injury is pain; the signal to cease whatever is causing the damage. Many injuries heal with time and therapy. But, pressure to continue the athletic activity can drive an athlete to dull the pain rather than to stop training.

Narcotics including morphine, methadone, and heroin are effective at masking pain. They are, however, very addictive and can disrupt the mental focus that can be vital to peak athletic performance.

Adrenocorticotrophic hormone (ACTH) is produced by the pituitary gland. Normally, ACTH stimulates the production of other hormones by an organ called the adrenal cortex. The hormones reduce inflammation and so can be used illicitly to ease the trauma of injured muscles. However, immediate side effects include stomach irritation and ulcers. In the longer term, bones and muscles can become weaker.

Stimulants such as caffeine (the wake-up ingredient of coffee), cocaine, and **amphetamines** increase the beating of the heart, lung activity, and even brain activity. For an athlete, these physiological responses are manifest as increased alertness, decreased fatigue, and promotion of an aggressive, competitive attitude. Side effects include an irregular heartbeat and high blood pressure.

Relaxants such as alcohol and marijuana decrease brain and nervous system activity. They can ease competition jitters. However, impaired focus and coordination can undermine athletic performance.

Beta-blockers are another illicitly used relaxant. They slow down the heartbeat, which can help lessen the movement of the hands and arms that occurs in concert with pumping of blood by the heart. Thus, they can be used by athletes competing in archery or shooting competitions, where steady hands can be a key to the first-place podium.

Paradoxically, athletes may need to take drugs to hide the use of other **illicit drugs**. One example is epitestosterone. The compound is a natural form of testosterone. Testing for elevated levels of testosterone rely on the comparison of the levels of testosterone and epitestosterone. By artificially increasing the levels of the latter, the presence of increased testosterone can be masked.

The tendency of blood to thicken because of the administration of agent like EPO can be masked by diluting the blood with additional fluid. This process is called plasma expansion.

Organizations such as the World Anti-Doping Agency are actively engaged in testing samples obtained from athletes during training and following competition.

Urine is most often tested. Illicit chemicals can be detected using the technique of gas chromatograph/mass spectrometry, where individual components can be separated from one another based on their different rates of movement through a medium.

Compounds including HCG, LH, and ACTH stimulate the production of antibodies by the body's immune system. These antibodies are used to detect the presence of the compounds in urine samples.

Testing procedures are constantly being refined. Some drugs such as EPO remain difficult to detect. A San Francisco a company called BALCO was exposed in 2004 as the source of a variety of performance-enhancing drugs for athletes, including New York Yankees star Jason Giambi, who has admitted his steroid use. A forensic investigation of BALCO uncovered evidence that existing drugs were being chemically modified to be undetectable.

SEE ALSO Illicit drugs; Saliva; Souvenirs from athletic events; Sports testing.

PERK (physical evidence recovery kit)

The physical evidence recovery kit (PERK) is an assembled set of necessary materials, instructions, and forms for the purpose of collecting and protecting the physical **evidence** of a sexual assault investigation whenever the victim decides to initiate criminal charges against the alleged assailant. Under most circumstances, the only requirements with regard to using the PERK is that the assault must have taken place within 72 hours of the medical examination and the assailant's **semen** must be collected from the victim within 24 hours of the sexual assault.

The PERK, also called a sexual assault determination kit, assists the attending doctor and nurse in collecting specimens for evidential analysis by forensic experts. In many cases, a Sexual Assault Nurse Examiner (SANE nurse) or Forensic Nurse Examiner (FNE nurse) will perform the collection of evidence through the use of the PERK, along with documenting any physical damage on the victim. The kit may be used at the hospital or at the crime scene by a qualified criminal investigation team.

In addition to the medical examination, the victim will be asked about details of the assault to be included within the PERK. To document all aspects of the sexual attack, a variety of information will be recorded, such as the type of assault, type of sexual penetration, location of the attack, and past medical history of the victim, along with her past and present health conditions, date of last menstrual period, history of contraceptive use, date of most recent consensual sexual activity, and other such personal information.

In order to obtain all relevant materials and information in the most accurate, consistent, and methodical way possible, the PERK is a very convenient way to collect and document the forensic evidence. Usually within a container made of cardboard or other similar material, the PERK generally contains (but is not limited to) the following items: instructions for the medical examination; one procedural checklist; one report form; one patient consent form; one patient information form; tape for sealing evidence; one label for the outside container; one roll of wrapping material such as cellophane tape; numerous paper envelopes for hair samples (from the pubic area, head, chest, face, and other body areas), **saliva**, **blood**, foreign materials, and other necessary specimens; one orange stick for fingernail undersurface scrapings; one blood vacuum tube; two standard-sized combs; one pre-sharpened pencil; three sets of prepackaged swabs and smear (usually for collecting vaginal, rectal, and oral smear samples); three frosted-end microscope slides; and three rectangular cardboard tubes.

SEE ALSO Privacy, legal and ethical issues; Rape kit; Semen and sperm.

Perspective analysis

As used in crime scene analysis, **photography**, and **photogrammetry**, perspective analysis involves the use of measurement techniques to determine the relative (and exact) sizes of objects within a photograph, digital image, or video image. Essentially, the process involves measurement of the distance between the camera and target item in the image of a known size, and utilizing those two measurements to calculate the size of other objects in the image.

At a crime scene, there are several important perspective aspects or views for photographic documentation. First, the entire scene is captured from a distance (a known or marked distance) in order to gain an overview of the entire scene before it is disrupted. Next, images are taken from midrange in order to estimate the size, or to document the relationships, of items. Finally, close range photographs are taken of individual items of **evidence**. For evidence items, one-to-one photography is used when possible. This technique involves taking actual size photographs of specific evidentiary items, and using them to make direct comparisons with the suspect. This technique is most often employed with fingerprints, bare footprints, and shoe prints.

In its most rudimentary form, perspective analysis can be used when examining a photograph containing an object of known size by measuring the image of the known object and developing a ratio of the image size to the sizes of other objects in the photograph. This is a cruder and less accurate form of perspective analysis than that involving the direct use of a scale, or the use of camera distance measurement techniques.

Several pieces of equipment are essential for accurate perspective analysis and object measurement: a ruler or scale, a tripod, and a level, in addition to a multilensed camera (35 mm, digital, instant, video, and other **cameras** are often utilized at crime scenes). When a ruler or scale is used for actual item measurement, the object should first be photographed alone, and then photographed again with the ruler lying in exactly the same plane as the object, and the camera situated in a plane parallel to both. It is also essential to measure the distance from the focal area of the camera to the object being photographed, in order to calculate the size of the objects being photographed.

The ruler or scale used for perspective measurement must be at least as precise as the camera doing the scene recording. The same scale used at the scene should be used to measure with when printing the photographs to a particular magnification. All rulers and scales should be individually marked so as to be readily identified both in the photographs and later during legal proceedings (court testimony or evidentiary presentation).

SEE ALSO Architecture and structural analysis; Automobile accidents; Bullet track; Computer modeling; Crime scene reconstruction; Photogrammetry.

Peruvian Ice Maiden

The Peruvian Ice Maiden is a 500-year-old mummy that was discovered in the Peruvian Andes in 1995. She is the first mummy found frozen, rather than dried, and as a result her **DNA** is very well preserved. **Mitochondrial DNA analysis** demonstrated that the mummy shares ancestry with Native Americans and with the Ngobe people of Panama.

In 1990, Nevado Sabancaya, a volcano in the Peruvian Andes, began erupting. The heat of its

The frozen mummy known as the "Ice Princess," the first frozen Incan mummy ever found, is displayed in Arequipa, Peru, in this Oct. 26, 1997, photo. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

eruption, as well as the hot ash that spewed from it cleared a layer of snow pack from the mountains in the area, including Mount Ampato. Five years later, in September 1995, anthropologist Johan Reinhard and his climbing partner Miguel Zarate climbed Mount Ampato to get a look at the active volcano nearby.

As they neared the summit, they spotted some bright feathers in the snow. Reinhard recognized the feathers as part of an Inca headdress of a ceremonial statue. It was made from a spondylous shell, the shell of an oyster that was sacred to the Incas, and it was preserved perfectly, with its textile clothing in excellent condition. The find had likely been uncovered by the melting of snow during the volcanic eruptions. Nearby, the two explorers noticed stones that appeared to be from an Inca ceremonial platform. As they looked down a ravine near the platform, they spotted a cloth bundle, which was frozen in place.

When Zarate hiked down the ravine to recover the bundle, he found a frozen mummy. The mummy was in the fetal position wrapped in colorful textiles made of alpaca (llama) wool. Pottery shards, bones from llamas and corn kernels surrounded her. The mummy was from a teenage girl, probably between 12 and 14 years old. Reinhard believed that Inca priests had sacrificed her, probably as part of a ritual to the gods they believed were part of the mountain. Reinhard recognized that mummy was a major archaeological find because she was the first frozen female mummy discovered in the Andes. She was later determined to be about 500 years old.

Reinhard and Zarate documented the site with photographs and collected the artifacts associated with the mummy. They knew that either exposure to sun and ash would damage the mummy or looters would destroy her remains and therefore they decided to take her from the mountain so she could be preserved. They carried the body down from the mountain and brought her to Universidad Catolica de Santa Maria in Arequipa, where refrigeration was arranged.

In 1996, the mummy was brought to the United States and several types of forensic techniques were performed to learn more about the girl's life, her last hours and about the people who may have descended from the Incas. Because a traditional **autopsy** would destroy the mummy, less invasive techniques were used. At Johns Hopkins Hospital in Baltimore, Maryland, computerized tomography (CT)—which is similar to a 3-dimensional x ray—was performed in order to determine the girl's bone structure and condition. Researchers at Johns Hopkins also removed small samples from the girl's heart and stomach using thin needles.

Radiologists determined that the mummy's bones were in good condition. She also had plenty of muscle mass and healthy teeth. She showed no evidence of disease or nutritional deficiency. This indicates that the girl was in excellent health at the time of her death. The girl's **skull** shows evidence of a violent blow. There was a fracture above the right eye and damage to the eye socket. The girl's brain was displaced to one side. These findings suggest that the girl was killed by being hit on the side of the head with a club, fracturing her skull. Subsequent bleeding filled the skull and pushed the brain to one side.

A sample of the contents of the girl's stomach contained only vegetable material. No meat was present. Because it probably took the girl several weeks to freeze, the fact that any material was found in her stomach suggests she had a full stomach when she died.

The tissue samples were sent to the Institute for Genomic Research in Rockville, Maryland. The mitochondrial DNA in the sample was copied using **PCR (polymerase chain reaction)**. In old tissues or tissues that might be degraded, mitochondrial DNA is often easier to study than nuclear DNA because cells contain many more copies of mitochondrial DNA than nuclear DNA. The mitochondrial DNA extracted from the Ice Maiden was of excellent quality, probably because she had been frozen rather than "dried" as is common in most **mummies**.

Mitochondrial DNA can be divided into two major regions. The first is a region that codes for the genes that make the molecular products used by mitochondria, which are sub-cellular organelles. The other region is a non-coding region and it does not contain any genes. Within the non-coding region, two regions on mitochondrial DNA have very high rates of mutation and are therefore optimal for studying differences among people. The two regions are called HV1 and HV2 (hypervariable region 1 and hypervariable region 2).

Comparisons of the sequence of the Ice Maiden's mitochondrial DNA from HV1 showed four differences from a reference sequence. Searching through databases of sequences of HV1, researchers found that these four differences exactly matched those differences found in a group of Native Americans. These people belong to a group called Haplotype A and they are one of the four founding lineages of Native Americans.

The HV2 sequence of mitochondrial DNA from the Ice Maiden varied in eight nucleotides from a reference sequence. These variations did not match any sequences found in databases of HV2 sequences. The closest match agreed in six of the eight nucleotide positions and was from a group of people called the Ngobe who live in Panama. Because of its unusual sequence, the Ice Maiden's mitochondrial DNA from the HV2 region is of great value for learning more about ancient people.

SEE ALSO Mitochondrial DNA typing.

Petechial hemorrhage

A petechial hemorrhage is a tiny pinpoint red mark that is an important sign of asphyxia caused by some external means of obstructing the airways. They are sometimes also called petechiae. Their presence often indicates a death by manual strangulation, hanging, or smothering. The hemorrhages occur when blood leaks from the tiny capillaries in the eyes, which can rupture due to increased pressure on the veins in the head when the airways are obstructed. If petechial hemorrhages and facial congestion are present, it is a strong indication of asphyxia by strangulation as the **cause of death**.

The forensic pathologist usually needs a very good light source and maybe even a magnifying glass to detect petechial hemorrhages. They range in size from the size of a speck of dust to around two millimeters and may occur in distinct groups. Often they are seen in the conjunctiva of the eyes and also on the eyelids, especially after hanging. They may also be found elsewhere on the skin of the head and face, such as in the mucous membrane inside the lips and around or behind the ears. When found in a case of suspect hanging, the presence of petechial hemorrhages strongly suggests the victim was hung when still alive. This helps distinguish hangings staged to make a **murder** look like a suicidal act.

Petechial hemorrhages on the face are also found in other conditions such as cardiac arrest. Internal examination may reveal petechiae on the surfaces of the lungs and heart in cases of death by heat stroke and sudden infant death syndrome (SIDS, or crib death). In the latter circumstances, they are not considered a cause of the child having been smothered or otherwise asphyxiated. The forensic pathologist will also look out for petechiae in cases of sexual assault. Petechial hemorrhage may also occur postmortem as the capillaries start to break down, but these lesions tend to be rather bigger than pinpoint size and may blur into one another rather than occurring as distinct groups. As ever, the pathologist must be aware of all the circumstances surrounding the death when interpreting these findings.

SEE ALSO Asphyxiation (signs of); Hanging (signs of).

Photo alteration

A common sight at the scene of a forensic investigation is one or more photographers. Recording the details of the scene prior to the removal of **evidence** is an essential step to the subsequent reconstruction of the course of events. Whether using traditional photographic film or the recently developed digital photographic capability, photographs can be manipulated or altered to enhance the information.

However, as a caveat, the ability to add or remove details digitally from photographs requires the authentication of the photographic file to ensure that the photographs produced of a crime or accident scene, in fact, represent reality.

The camera was invented in 1839. By the next decade, photographers had already begun to manipulate photographic images. Initially, the manipulation was part of the exploration of the artistic potential of the new medium. Soon, the informational power of the photograph became recognized.

The ability to produce photographs that reveal more detail than do traditional photographs, especially at longer distances or using small **cameras**, has increased the information that can be gathered.

With new technology, the ability to alter a photographic image is easier than ever before. For example, in a traditional photograph, the difference in skin tone between a face and the neck or shadows that point in different directions can be clues that an image has been manipulated. However, these visual discrepancies can be eliminated in the digital image. Thus, the ability to generate false or misleading information has become routine.

In the days before digital technology, photo alteration was accomplished in the darkroom during the development and printing of the photograph. In a technique called dodging, the light shining through the photographic negative onto light-sensitive paper was obscured. Because less light strikes the paper, that region appears lighter in the developed image. In contrast, the technique of burning allows an increased amount of light to strike the photographic paper. The result of burning is to make the region appear darker in the print.

The traditional techniques of dodging and burning are used to enhance or disguise aspects of the photo. As well, details can be excluded from an image by the use of cropping, where only the selected portion of the image is printed. Photographs can also be enlarged to selectively print portions of the image. Enlarging cannot be done indefinitely, however, since the eventual inability to separate the informational components of the image from one another produces a blurry picture.

The coming of digital **photography** revolutionized the ability to alter photographs. The laborious darkroom manipulations of preceding times could be accomplished by a few commands in specialized photographic software.

In traditional photography, the reflected light from the subject enters the camera through the lens and is focused onto the surface of a light-sensitive emulsion. The emulsion records the image, which can be beamed onto light-sensitive photographic paper. The paper is subsequently treated with chemicals to make the image appear. It is during this latter printing process that the alteration of the photograph can be accomplished.

In digital photography, the reflected light that enters the camera is focused onto a chip that is known as a charged coupling device (CCD). The surface of the CCD contains an array of light-sensitive photo diodes. Each diode represents a pixel (the basic unit of programmable color in a computer image). Each photo diode is hooked up to a transistor, which sends an electrical signal (whose voltage corresponds to the light intensity that registered on the photo diode) to another chip. The second chip converts the electrical signal to digital information—1s and 0s—that can be interpreted by computerized photo manipulation software programs.

Colors are assigned a code sequence between 0 and 255, 0 is black and 255 reveals the most intense shade of red possible by the software. These coded assignments are in turn converted to sequences of 0s and 1s. Black, for example, is 00000000, while the most intense red is 11111111. Shades in between are mixtures of the eight-digit sequence of 0s and 1s.

Digital photo manipulation involves the alteration or elimination of the digital 1s and 0s. Changing an eight-digit sequence is trivial. When the digital information is reconstructed into an electronic image, the result can be an altered color.

In addition to color change, a myriad of effects are possible, including color enhancement, elimination of regions of the image, increased contrast, correction of a blurred image, and the merging of other images with the original image (a photographic version of the "cut and paste" operations in word processing). Images of **missing children** or crime victims also can be digitally manipulated to create an aged appearance, and have proved useful in identifying victims years later.

As digital photo manipulation software has increased in technical sophistication, and people have become more adept at using the software, the task of detecting manipulated images has become very challenging. Digital photographic manipulation is now so sophisticated that it can sometimes be impossible to discern whether people or objects in a photographic were actually there when the photo was taken. This has spurred efforts, especially in the military and intelligence communities, to establish a system of image verification. In this regard, the United States Air Force Research laboratory in Rome, New York, has developed a technique called digital watermarking. Akin to the watermarking of paper currency to establish authenticity, digital watermarking embeds an encrypted image over the actual photo image. The encrypted image is invisible to the naked eye, but can be detected by specially designed image scanners. The lack of the digital watermark is evidence of a altered image.

SEE ALSO Crime scene investigation; Digital imaging.

Photogrammetry

The American Society for Photogrammetry and Remote Sensing (ASPRS) defines photogrammetry as "the art, science, and technology of obtaining reliable information about physical objects and the environment through the processes of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena." In this context, "art" refers to an advanced level of skill that can only be achieved through significant practical experience.

Photogrammetrists are skilled at using photographs to obtain reliable measurements. As used in **forensic science**, photogrammetry involves applying scientific and mathematical techniques to two-dimensional images in order to accurately measure two- or three-dimensional objects or to create three-dimensional models or reconstructions from the two-dimensional images. Photogrammetry is sometimes referred to as remote sensing, because it is used to measure objects without coming into physical contact with them.

Although photogrammetry can encompass far range and aerial image creation, it is most often used in crime scene documentation at close range for either object **identification** or measurement. At crime scenes, it can be used to derive the locations of the perpetrator and victim during the event. It can be scientifically applied, long after the crime, to photographs and other images taken on-scene by forensic investigators in order to extract additional detail such as **blood spatter**, wound patterns, bite marks, and other minute **evidence** from photographs and other images. The extracted information can be used to develop evidence measurements or to create detailed crime scene maps.

During fire and **explosion investigations**, there may be minimal **physical evidence** and poor visibility, but much photographic (or other image) evidence gathered. Photogrammetric digital image processing techniques can produce enhanced images that may be readily viewed and interpreted, often providing important forensic information.

Photogrammetric techniques can be used to make corrections in oddly angled images in order to place objects in the correct planes and at the proper angles for **crime scene reconstruction**, as well as to make virtually unlimited three-dimensional measurements from available crime-scene photographs. This can be done at any time, which is useful for providing answers to new questions, or for allowing more detailed analysis of existing data.

Forensic photogrammetrists utilize specialized **cameras** and/or other **imaging** equipment, targets, measurement devices, and **computer modeling** software for the purposes of crime scene measurement and reconstruction. By so doing, they make it possible to create scaled images, diagrams or three-dimensional models in which there is accurate placement of evidence without necessitating physical contact with any aspect of the original scene.

SEE ALSO Architecture and structural analysis; Biosensor technologies; Bomb (explosion) investigations; Crime scene reconstruction; Fire investigation; Imaging; Photography.

Photographic resolution

Photographic recording of an accident or crime scene, or other venues where a forensic investigation is held, is vitally important. After the scene has been cleaned, photographs preserve the scene in time and allow visual analyses to be done long after the fact. The quality of the photographs is therefore extremely important. This is the reason why forensic **photography** is the domain of a professional photographer, rather than, for example, the investigating officers.

A critical aspect of photographic quality is resolution. The term resolution in the context of photography refers to the degree to which adjacent objects can be distinguished from one another in a photographic image. Obviously, the higher the degree of resolution—which is a function of the acuity of the photographic equipment used, as well as the abilities of the operator—the better the quality of the photograph.

The lower the figure given for the resolution, in metric or English units, the higher the degree of resolution. For example, the first four satellites of the CORONA project, which remained aloft throughout most of the period from June 1959 to December 1963, had a relatively high resolution of 25 feet (7.6 m), meaning that objects smaller than that size were likely to be indistinguishable from one another. Higher still was the resolution of the fifth satellite in the series, KH-4B (September 1967 to May 1972), at 6 feet (1.8 m). Photographs taken by KH-5, a satellite deployed for mapping purposes between February 1961 and August 1964, had a much lower degree of photographic resolution: 460 feet (140 m).

Modern satellite **cameras** such as Landsat, SPOT, and Quickbird **digital imaging** systems send photographic images that show resolutions of 2 feet (0.62 m) for panchromatic images and 7.9 feet (2.4 m) for color images. Quickbird images were used to help identify debris from the space shuttle *Columbia*, when it exploded over Texas in 2003.

SEE ALSO Crime scene investigation; Digital imaging; Geospatial Imagery; GIS; Photo alteration; Photography; Satellites, non-governmental high resolution.

Photography

Photography has many applications in **forensic science**. It is used in the first instance to photograph the crime scene. Then, photographs are taken of individual items of **evidence**, from fingerprints and bloodstains, to wounds on a victim's body both at the scene and during an **autopsy**. Specialized techniques such as microphotography and infrared photography can be extremely useful in particular settings. Forensic photography is a skilled job, for all photographs must be of high enough quality to be admissible as evidence in court.

A crime scene is always photographed as soon as possible, so there is a permanent record of the location in its original condition. This will probably occur after the preliminary survey of the scene when, ideally, nothing will have been touched or moved. Sometimes, however, the priority is to get emergency help for a victim and this may lead to some movement of objects. The photographer will take shots of these items in the place they have been moved to. Returning them to their original position would amount to disturbing the scene, which is bad practice. It is not possible to specify how many photographs will be taken for so much depends on the type and nature of scene. As a general guide, the forensic photographer will err on the side of caution and take too many pictures instead of too few.

Three types of photographs are taken, overall, mid-range, and close-up photographs. Overall photographs will be taken of the exterior and interior of the crime scene. Exterior photographs will show buildings and other major structures, roads, or paths to and from the scene, streets signs, and address numbers. If possible, aerial photographs will be taken because these give the broadest possible view of a crime scene in relation to its surroundings. Interior photographs are taken using the corners of the room as a guide. Overlapping views are taken, to ensure everything is covered. It is also important to take photographs of the common approach path, that is, the agreed route through which investigators enter and leave the scene of the crime. This comprises an access point and a focal point and is chosen so that there will be minimal disturbance of evidence. For instance, investigators would not choose a common approach path involving the perpetrator's possible entry point for fear of contaminating evidence at this location. A body, if there is one, is often the focal point of a common approach path. The photographer will also take shots of any possible routes taken by perpetrators or victims including entry or exit points.

Mid-range photographs will show items of evidence and any bodies in their immediate surroundings. Close-ups will focus on evidence like weapons, victims, footprints, and other evidence. A scale, such as a ruler, will give a guide to the size of the item of evidence. This is important because the photographs will later be enlarged to the appropriate size for comparison work, with **shoeprints**, for instance. Photos with and without this scale are generally taken. An L-shaped ruler that shows the length and breadth of the item is particularly useful. All photos taken must be recorded in a special photo log with the date, time, photographer, film, camera settings, and a brief description of what the photo shows. The settings of the camera must be such as to allow good illumination, filling in shadows with flash where needed. Flash can also be used to enhance detail or patterns. No extraneous objects such as investigators or their equipment should be seen in any of the photographs. The forensic photographer's scene of crime kit typically will include a 35-millimeter camera, normal, wide-angle, and close up lenses, an electronic flash with a cord, color and black-and-white film, scales or rulers, and a tripod. Photography is often supplemented by taking a video of the scene. But the still photographs are essential, because they are of higher resolution than a video film. The aim is to take examination quality photographs which can be studied back in the forensic laboratory in comparison with samples taken from suspects or from reference databases.

When it comes to photographing evidence that could easily be damaged or lost, such as fingerprints, shoeprints, **tire tracks**, and toolmarks, it is important to take the photographs as soon as possible. Fingerprints may need to be made visible, by exposing to **laser** or ultraviolet light, or by applying special powders before they can be photographed at the scene. Similarly, shoeprints may need treatment before they can be visualized, although those in mud or **blood** can usually be captured on film without special preparation. It is important to take photographs of shoeprints at a 90-degree angle to its surface and centered in the camera lens. This avoids distortion in the image and makes comparison with control shoeprints more reliable. Tire track photographs need to be taken both as part of a general scene photograph, so that their location can be precisely determined, and also close up, to determine the pattern detail on the tire so it can be identified. Photographs of toolmarks should at least show the location of this important source of evidence. However, even macrophotography may not reveal enough detail to allow the photographs to be used for laboratory comparison with suspect tools. Each item of evidence is photographed individually before being touched if at all possible, and several shots of each item are taken.

Bloodstains are found in many different locations and patterns at crime scenes. The overall photographs will show their location and distribution, which may be significant in revealing the relative positions of the victim and perpetrator. Then the photographer takes more shots close up of the individual stains that reveal the detail needed to back up pathological analysis of the injuries inflicted. Bloodstains and **blood spatter** patterns on the victim's body are also photographed.

It is also important to photograph any injuries on living or dead victim. A corpse is always photographed before being moved from the scene of a crime. Full body and close-ups are taken. The place where the victim lay will also be photographed again once the body has been moved and then searched for evidence. If the victim is living, the photographer will take pictures of only the minor injuries at the scene. Serious **knife wounds** or gunshot injuries will generally be photographed at the hospital in the interests of getting the victim medical help as soon as possible. Photography plays an important role in an autopsy, too. The body is photographed both clothed and unclothed. Frontal and profile photographs of the face and body are important, especially if there is a question of **identification**. Each birthmark, tattoo, scar, and any other body mark is also photographed. Photographs are taken at each stage during the autopsy process.

Photography may be an important aid to identification of a body. Photos of the face of a corpse may be simply compared with images or descriptions of missing persons. A forensic anthropologist, who is an expert in human remains, may be able to determine whether two pictures are of the same person by analyzing their bone structure. Even though two pictures may be very different in quality and in their age, similarities or differences in certain elements of bone structure may be apparent. The investigator will superimpose the two pictures, at the same image size, and compare the eyebrow area, nasal openings, and the contours of the chin.

Special illumination techniques are often used to take photographs in particular situations. Photographs taken in infrared light can sometimes help distinguish two types of ink, which look very similar in ordinary light. This may help determine whether writing has been added to an original document. Ultraviolet illumination enhances images of injuries while laser light illumination is valuable in recording fingerprints. There is also a trend towards using digital rather than conventional photography in forensics as well as in other applications. Digital images can be readily enhanced. For instance, if a **fingerprint** appears on an interfering background, such as a bank note, then the background can readily be removed to make the actual evidence clearer. However, it is this very ability to manipulate which makes some courts wary of digital photographic evidence.

Good quality photographs have many uses in the investigation of a crime. They can help investigators carry out a **crime scene reconstruction**, where the sequence of events leading up to and occurring after the actual crime is deduced. Sometimes photographs are used to help witnesses recall more about what they saw. Photographs can be faxed and widely distributed in the media or throughout a neighborhood in the search for missing persons or suspects. Judge and jury may be presented with photographs during a trial to help them understand the nature of a crime. Sometimes a photograph of an item of evidence will even be allowed to stand in for the real thing if the actual item could not be removed from the scene of crime for some reason. Photographic techniques are advancing all the time and it is the task of the forensic photographer to make best use of these to create strong, detailed images of all the evidence pertaining to a particular crime.

SEE ALSO Imaging; Photo alteration; Ultraviolet light analysis.

Physical evidence

A successful crime investigation depends upon the collection and analysis of various kinds of **evidence**. Forensic scientists classify evidence in different ways and have specific ways of dealing with it. One major distinction is between physical and biological evidence. Physical evidence refers to any item that comes from a nonliving origin, while biological evidence always originates from a living being. The most important kinds of physical evidence are fingerprints, tire marks, footprints, **fibers**, paint, and **building materials**. Biological evidence includes bloodstains and **DNA**.

Locard's Exchange Principle dictates that evidence, both physical and biological, is to be found at the scene of a crime because the perpetrator always leaves something behind by having contact with victims and objects there. Similarly, he or she will often take something away with them, which can be found on a search of their person, their garment, a vehicle, or their premises. Such evidence is often found in minute quantities and known as **trace evidence**. One important source of physical trace evidence is textile fibers, which usually comes from clothing or furniture involved in the crime. It may either be left behind by the perpetrator or picked up from the victim. Typically, trace evidence is invisible to the naked eye and is collected by brushing or vacuuming a suspect surface. Once collected and back in the laboratory, microscopic techniques will often be used in its examination and analysis as, for example, in the case of paint fragments or textile fibers.

Impression marks are another important kind of physical evidence. When an item like a shoe or a tire comes into contact with a soft surface, it leaves behind a pattern showing some or all of its surface characteristics, known as an impression. The collection and analysis of **impression evidence** found at the scene of a crime can often be very important to an investigation.

The collection of objects, marks and impressions that make up the physical evidence of a crime is a specialized task. The general principles of preserving physical evidence and assuring a secure **chain of custody** apply whatever the crime. However, the time and effort put into collecting evidence will be more if a serious crime, like **murder** or rape, is involved compared to a so-called volume crime such as burglary or car theft. In the latter case, the investigators will concentrate on the entry and exit points taken by the perpetrator where they will hope to find, above all, fingerprints and possibly tool marks.

Fingerprints are perhaps the most significant type of physical evidence in most crimes. The technology of collecting and analyzing fingerprints has been well known for over a century and has been refined over the years. A **fingerprint** is important as individualizing evidence. It can tie a specific person to a crime, because no two individuals have ever been found to have the same fingerprint. If a fingerprint from the scene of a crime can be linked to one in a database or from a suspect, then an **identification** can be made. The courts will readily accept fingerprint evidence, so long as it is properly collected and analyzed. DNA evidence, however, is rapidly becoming the gold standard of identification evidence, and when it is made less costly, will likely take over from fingerprints as the foremost manner of identification. At present, the technology is too expensive for routine use. DNA is, of course, biological rather than physical evidence.

Other kinds of physical evidence such as **tire tracks** and **shoeprints** are class evidence, rather than individualizing, evidence. This means that on its own such evidence may not be enough to convict. A shoe print taken from a relatively new shoe merely suggests the make, style, and maybe the size of a shoe. However, no shoe wears down in the same way. People walk with their own individual gait. They also take a unique path when they walk; no two people walk the same streets over time, and encounter different types of damage to the soles as they encounter the ground. Thus, over time, shoe prints may change from being class evidence to being individualizing evidence.

Class evidence such as prints from relatively new shoes or textile fibers can be valuable in identifying a suspect if taken together. A victim may have been wearing a sweater or jacket from a chain store and fibers could be found on the clothing of a suspect. If this is taken with shoe prints found at the scene from a type of trainer owned and worn by the suspect, then both items of physical evidence are strengthened and link that suspect to the crime scene.

Physical evidence can, therefore, be a highly significant part of a crime investigation. However, to play its role, the evidence must be collected and analyzed properly. In the case of a serious crime, every possible item of physical evidence must be collected. As some evidence is trace evidence, this means an extremely thorough search, or "fingertip" search, of the scene is conducted. The way this search is accomplished depends largely on the nature of the scene, but will often focus on a point such as a body, and then work outwards or inwards in a spiral. Sometimes, investigators will work in a grid formation to ensure nothing is missed. The body itself is an important source of physical evidence and a search for fibers or fingerprints will always be made before it is moved to the mortuary.

Some items of physical evidence, such as weapons, can be easy to locate and collect. However, the investigator must take care not to contaminate these items by, for instance, leaving their own fingerprints. Investigators generally cover themselves with protective clothing in order to avoid contaminating evidence at the scene. When it comes to trace evidence, other methods must be used to collect it. Hairs and fibers may stick onto a piece of sticky tape laid down on a surface. Dusting with special chemicals may reveal fingerprints or shoe prints that are otherwise invisible. Sometimes a cast is made of impression evidence like shoe prints. All the physical evidence will be photographed before anyone touches it because it is so important to keep a record of the crime scene.

It is crucial that physical evidence, whatever its nature, is not contaminated by handling. Packaging methods vary according to the nature of the evidence. Tape lifts of hair and fibers may be adhered to a piece of film and then sealed into a clean polythene bag. Fibers lifted with tweezers will be placed inside clean slips of paper called druggists' folds or **bindle paper**, and then sometimes sealed in plastic bags. Collection of an impression is a specialized forensic task for, unlike a hair or bullet, an impression cannot just be packaged and taken back to the lab. Impression evidence is often fragile; a tire track may deteriorate or even be destroyed by rainfall, for example.

If physical evidence is to be admissible in court, then the chain of custody must be proved. That is, each person who handled the evidence from its collection to its appearance in court must have signed for it. Therefore, the court knows who had custody of it at each stage of this journey. Precautions will have been taken to prevent any **cross contamination**. If someone attended the crime scene and then examined a suspect, it is possible they could transfer evidence such as textile fibers from the scene to the suspect. Ideally, the same officer would not transfer between the scene and a suspect's residence. If they do, owing to limitations on the number of personnel investigating a crime, they must undergo decontamination between locations and be able to prove to the court they have done so.

In the case of a murder, a further search for physical evidence will be made at the mortuary. Once the body is removed, the search for evidence at the scene will continue, particularly around the site where the body was found. While items of evidence are being collected, thought must also be given to collecting **control samples** from the scene. Thus, if chemicals have been spilled on a carpet in an incident, then it is important to have comparison samples from an unaffected piece of carpet.

Once physical evidence has arrived at the forensic laboratory, it must be stored under secure conditions. Care must be taken that items not deteriorate under their storage conditions in case there is a long interval before any criminal trial begins. There are a number of different techniques in the laboratory that can help to analyze and identify the source of physical evidence. For instance, **visible microspectrophotometry** is useful in identifying the chemical nature of fragments of paint or textiles. Typically, these will be compared to reference samples or to those taken from a suspect. It may be that not all the items of physical evidence will turn out to be relevant to solving a crime, but it is better the investigators collect too much physical evidence than too little. As long as they know how to keep it safe and the best way to interpret it in the context of other evidence, physical evidence can be a powerful guide as to the circumstances and perpetrator of a crime.

SEE ALSO Crime scene investigation; Evidence; Paint analysis; Trace evidence.

Physiology

Physiology is the study of how various biological components work independently and together to enable organisms, from animals to microbes, to function. This scientific discipline covers a wide variety of functions from the cellular and sub-cellular level to the interaction of organ systems that keep the complex biological machines of humans running.

Because a forensic examination involving an injury or death is often concerned with establishing cause, a forensic investigator will of necessity be concerned with physiology. By understanding the proper functioning of **organs and organ systems**, a forensic investigator is able to recognize abnormalities. Moreover, the nature of an abnormality can provide clues as to the nature of its cause.

For example, if a person experienced a rapid onset of paralysis prior to their death, the investigator might suspect the involvement of the toxin produced by the bacterium *Clostridium botulinum*. Appropriately, nervous tissue and **blood** would be examined for the presence of the toxin.

More generally, physiological studies are aimed at answering many other questions in addition to forensic questions. Physiologists investigate topics ranging from precise molecular studies of how food is digested to more general studies of how thought processes relate to electrical and biochemical patterns found in the brain (a branch of this discipline known as neurophysiology). It is often physiology-related investigations that uncover the origins of diseases.

While physiological studies are one of the cutting-edge tools in a forensic examination, the roots of the discipline date back to at least 420 B.C. and the time of Hippocrates. More refined physiological approaches first appeared in the seventeenth century when scientific methods of observation and experimentation were used to study blood movement, or circulation, in the body. In 1929, American physiologist W. B. Cannon coined the term homeostasis to describe how the varied components of living things adjust to maintain a constant internal environment conducive to optimal functioning. Proper physiology relies on homeostasis.

Homoestasis is an important aspect of **forensic science**. A specific disturbance to the body caused by, for example, a poison such as a toxin can have other effects (e.g., loss of muscle control, difficulty breathing, mental confusion) as the body is more generally affected.

Physiological studies have evolved from the first visual-based methods to now encompass a variety of analytical procedures. The use of analytical instruments such as the gas chromatograph, electrophoretic techniques that can detect and identify components such as **toxins**, the elemental analytical power of mass **spectroscopy**, and various other techniques have made forensic physiological determinations highly sensitive and specific.

SEE ALSO Analytical instrumentation; Blood; Death, mechanism of; Epilepsy; Hemorrhagic fevers and diseases; Immune system; Nervous system overview; Organs and organ systems.

Plague, bubonic SEE Bubonic plague

Plant identification SEE Botany

Point-by-point analysis

Point-by-point analysis (also referred to as side-by-side comparison) is a subset of the **forensic science** of image analysis, although it is also widely utilized in many other disciplines. Essentially, it involves the photographic, or other image, comparison between two objects for the purposes of **identification**, or to draw conclusions about the contents of the image. **Photogrammetry** is sometimes used as a means of conducting a point-by-point analysis involving measurement, or measurement comparisons, of the object depicted in the image.

Side-by-side assessment with photographic, digital, or video images is used to make comparisons between aspects in images and known objects in order to proffer an expert opinion on either elimination or identification. Some common subjects of point-by-point analysis are facial comparisons made between identified suspects and images captured on surveillance video film (used at banks, retail and convenience stores, ATMs, etc.). Questioned images are often compared with those of a known camera in order to ascertain if the image was created by that specific camera. Cars, boats, planes, or other motor vehicles captured on surveillance or chase video are often compared with those impounded or recovered during the course of an investigation.

In the process of making the analysis, the image is examined in order to extract as much information from it as will be necessary in order to accurately compare the two objects (image and actual object). It is sometimes necessary to create an enhanced or otherwise improved version of the features within the image in order to optimally assess each point of comparison. An important aspect of point-by-point analysis involves the examination of content of the image. The process of content analysis involves arriving at conclusions based on the comparisons made, such as the exact contents of the image, the means or the process with which the image was created, the physical environment captured in the image (the lighting, composition, etc.), and the attributed origin (also called the provenance) of the image. Some examples of content analysis include patterned injury analysis, correlation of apparent injuries depicted in am image with **autopsy** or emergency medical records, adjudication of the type of camera used to create a particular image, and verification of a specific feature in an image, such as the registration or license plate number on a motor vehicle.

SEE ALSO Art identification; Ear print analysis; Fingerprint; Identification; Photogrammetry.

Poison and antidote actions

A variety of chemical and biological compounds can damage tissues, organs, and organs systems of the body. **Amphetamines**, **barbiturates**, and **botulinum toxin** debilitate the nervous system, for example. Other **toxins** produced by bacteria such as ***Escherichia coli*** and *Vibrio cholerae* can damage the cells lining the intestinal tract. A particularly vicious strain of *E. coli* designated O157:H7 produces a toxin that can permanently disable the kidneys.

These and other poisons can become an important focus of a forensic examination that seeks to determine the cause of an illness or death.

A poison is a compound that produces a deleterious change on or in the body. Toxicity is a general term used to indicate adverse effects produced by poisons. As touched on above, these adverse effects can range from slight symptoms such as headaches or nausea to severe symptoms such as coma, convulsions, and death.

The hallmark of a poison is the change elicited in a body function. This change can involve the speed of a function. Examples of this can include increased heart rate, excessive sweating, and decreased (or completely stopped) breath.

The target of poisons vary widely. With some poisons only a particular region or organ may be damaged, while other poisons, such as a bacterial toxin that can circulate in the bloodstream, may have more general effects. Another example of the latter is an insecticide called Parathion. It inactivates a particular enzyme that functions in communication between nerves. The enzyme is very widespread in the body, and thus many varied effects are seen.

These differing manifestations of poisoning mean that a forensic investigator must be familiar with the spectrum of possible poison hazards and their toxic effects.

Toxicity is based on the number of exposures to a poison and the time it takes for toxic symptoms to develop. Acute toxicity is due to short-term exposure and happens within a relatively short period of time. Chronic toxicity is due to long-term exposure and happens over a longer period.

Some poisons produce a mild reaction. Poison ivy, poison oak, and poison sumac all contain a sticky sap comprising a compound called toxicodendrol. For individuals who are allergic to the compound—more than half the population—a red, blistering rash called rhus dermatitis results upon contact with the plant. There are no antidotes per se, as the rash cannot be reversed. Antihistamines or drying agents such as calamine provide comfort and lessen the rash.

The toxins produced by bacteria are can be far more potent poisons than toxicodendrol. The effects of bacterial toxins are varied, ranging from the vomiting and diarrhea associated with toxins of *E. coli* and Shigella, to the paralysis and death caused by the toxin produced by *Clostidium botulinum*. If detected early enough, relief is brought by the injection of an antitoxin, which neutralizes the toxin that has not yet bound to its target. This antidote is ineffective on toxin that has already bound to host tissue.

Plants are another source of poisons. Very many plants, if ingested, can cause vomiting, depression, tremors or convulsions, stomach pain, kidney or liver failure, coma, or death. The antidote depends on the type of plant. Treatment with ipecac to induce vomiting is a common antidote, but in some cases, an antidote does not exist.

Compounds that are effective in one setting, or drugs that are therapeutic at certain concentrations, can be poisonous if used in an inappropriate way or at too high a concentration. As examples, bleach and other household detergents and cleaning agents are poisonous if ingested. Barbiturates taken in a prescribed quantity can help calm a person, but an accidental or deliberate overdose of the drugs can kill. And, while two aspirin are effective for treatment of a headache, 30 aspirin at one time are poisonous.

SEE ALSO Amphetamines; Barbiturates; Bioterrorism; Botulinum toxin; Chemical and biological detection technologies; Food poisoning; Nervous system overview; Toxins.

Polarized light microscopy

One of the microscopy techniques that can be beneficial in a forensic examination involves the use of polarized light (light in which the electromagnetic waves all vibrate in the same plane). The use of polarized light microscopy can not only detect the presence of small pieces of **evidence** including **fibers**, crystals, and soil, but can help identify this **trace evidence** based on the distinctive appearances of different materials under the polarized illumination.

The basis of polarized light microscopy is the wave nature of light. From its source, a beam of light moves outward. Similar to the waves in a pond that move outward from the point of entry of a rock, light waves consist of a series of alternating crests and troughs. These crests and troughs can be oriented vertically, horizontally, or in any other plane in between. In general, this form of light, which is known as unpolarized light, can be thought of as vibrations in the horizontal and vertical planes.

Unpolarized light can be transformed into polarized light. The most common means, which is used in microscopy and even in polarizing sunglasses, is to pass the unpolarized light through a special filter. This Polaroid filter, or polarizer, blocks the vibrations in either the horizontal or vertical plane while permitting the passage of the remaining plane of light. The light emerging from the filter represents the polarized light.

The construction of the filter allows for this selectivity. Within the filter, molecules comprising long carbon chains are arranged in the same direction. The effect is visually akin to the pattern of a picket fence. If the alignment is horizontal, then the "polarization axis" will be vertical. The filter will block all light waves that are vibrating in the horizontal plane, while permitting waves vibrating in the vertical plane to pass through. Alignment of the filter molecules in the vertical direction produces a horizontal polarization axis, so that only waves vibrating in the horizontal plane will pass through the filter.

Some polarization light **microscopes** are equipped with two filters that can be rotated to permit the sensitive tailoring of the light wavelengths that emerge (since, in reality, waves vibrate in other than the horizontal and vertical planes). If these filters are in exact opposition (i.e., vertical polarization axis superimposed on horizontal polarization axis) then the passage of all the light is blocked and no image is seen. At other filter configurations, different vibrational forms of the light will pass through.

Polarized light has a number of uses other than for microscopy. One of the most appreciated is three-dimensional (3-D) movies. The use of two slightly offset projectors casts two movie images on the screen. One is aligned horizontally and the other is aligned vertically. By wearing the distinctive 3-D glasses, which contain polarization filters, the viewer experiences a sense of depth in the viewed image.

Polarized light microscopy can be used with different types of materials. Materials such as cubic crystals and **glass** that is not under stress are symmetrical in their optical properties. Light impinging from any direction on these so-called isotrophic materials will behave the same. In contrast, anisotrophic materials have optical properties that vary depending on the orientation of the object in the light beam and on the vibrational property of the light (unpolarized, polarized, horizontally- or vertically-polarized). In the latter, which includes almost all solid materials, the appearance of the object can vary depending on the above parameters.

These different appearances can be exploited to determine the compositional nature of the object being examined. For example, as an object is reoriented, areas of brightness can appear or the color can change. These changes can be directly related to the height differences of the surface and on the presence of differently composed regions. An experienced forensic microscopist can learn a great deal about a sample from these patterns.

As one example, chrysotile, crocidolite, and amosite forms of asbestos can be differentiated from one another based on their microscopic appearance under polarized light. This can be important in a forensic examination, since the chrysotile form of asbestos does not pose the health threat that the latter two forms do. Without the rapid discrimination power of polarized light microscopy, such an assessment could not be made.

Polarized light microscopy can also be done using light that passes through thin and transparent objects (transmitted light) and light that has reflected back off from the surface of an opaque object (reflected light). Thus, the technique can be used to examine the surface of objects like rocks, computer chips, and fibers.

Other potential forensic uses of polarized light microscopy include the determination of the mineral content of a rock chip, the **identification** of natural and synthetic polymers, and the identification of nylon fibers.

SEE ALSO Alternate light source analysis; Fluorescence; Monochromatic light; Scanning electron microscopy; Trace evidence.

Pollen and pollen rain

Pollen is an important form of **trace evidence**, which can help link a suspect to a crime scene. This branch of **forensic science** has developed alongside advances in microscopy. Experts in forensic pollen analysis are called palynologists. They can determine whether the pollen species and patterns found on a suspect are characteristic of a particular area. It is not just the identity of the pollen that is important, but also the way in which it is dispersed, known as pollen rain. Each area has its own type of pollen rain that depends upon its native flora.

Pollen is the male sex cells of flowering or cone-bearing plants. It is microscopic and found on nearly every surface and object, so suspects will be carrying it, unknowingly, on their clothes, hair, and body. Pollen is also found on victims and on significant items such as ransom letters and money involved in crimes like bank robberies or drug dealing. The investigator has to know where to look to collect pollen samples; good places include any samples of soil, dust, mud or dirt, on clothing or perhaps in the suspect's vehicle.

Each plant spreads its pollen in a different way and a different plant ecology is found in each region. Wind-pollinated plants produce a lot of pollen, while self-pollinated and insect-pollinated plants produce much less. These properties lead to the characteristic pollen rain patterns of different regions.

Pollen rains down continually and can contaminate the sample containing the pollen of interest. It has been found useful to brush the desired sample with a clean, dry, cosmetic brush to get rid of this contaminating pollen that has nothing to do with the crime event. Then a sample of the pollen-containing material is scraped or brushed into a clean container. If the sample is dust, then a lift onto adhesive tape might be made. Hair is a very good source of pollen. Every time wind blows through someone's hair, pollen clings to it. The pollen sample can be washed off a hair sample with detergent. Pollen can also be found on many other surfaces which may be relevant, such as blankets, carpets, and packaging, including envelopes, and can be brushed or scraped off. The usual precautions in handling trace **evidence** apply—the **chain of custody** of the evidence—must remain intact if the evidence is to be admissible in court. Great care must be taken to prevent contamination; this is particularly important with pollen because the investigators will also have pollen on their own clothes and hair.

Examination of pollen from a victim sometimes provides evidence not otherwise readily available. Since pollen settles on food, analysis of pollen found in stomach content can give a clue as to where the individual was just prior to their death. Since pollen takes a long time to decay, samples taken from decomposed and even skeletal remains can still be informative.

It is important that the investigator collects plenty of control pollen samples from the scene. This will provide a baseline of the pollen type and pollen rain expected for that area. The forensic samples are compared to these and so help determine their relevance. If a body has been moved, for instance, the pollen will differ from that which is characteristic of the place where it is found.

Once back in the lab, the pollen has to be extracted from the evidence for microscopic examination. There are standard ways for doing this, but they are usually destructive of the evidence. If that particular piece of evidence, such as hair, has to be subjected to other analysis, then the pollen analysis must be done last. Microscopic evidence can identify a pollen grain by comparison with standard samples held in a database. The pollen rain pattern can also be identified by looking at the different pollens present and their density. Low density of grains suggests self-pollinating species; high density suggests wind-pollinated species.

In one early case, which was solved with the help of forensic **palynology**, a man had disappeared near the Danube River in Vienna in 1959. There was a suspect with a motive, but no body had been found and the suspect denied any crime. However, the investigators found mud on the suspect's shoes, revealing spruce, willow, and alder pollen, as well as a fossil hickory pollen grain that had survived for millions of years. Only one small area in the Danube valley had this particular pollen mix. When confronted with this fact, the suspect broke down, confessed, and led police to the body that was, indeed, buried in this area.

SEE ALSO Botany.

Polygraph, case histories

Since antiquity, civilizations have assumed that there were means to make individuals tell the truth against their own will and interests. Torture was (and still is) one of the most common tools used by interrogators around the world. Along with its inhumane aspects, torture is highly imprecise in revealing the truth, as under torture, a person may confess to exactly what the torturers want to hear in order to end his or her discomfort.

Among ancient Romans, alcoholic intoxication was another way of obtaining information from politicians or foreign diplomats who could not be simply arrested and tortured. This gave rise to the expression, *"In vino veritas,"* meaning the truth is in the wine. The Italian physician Cesare Lombroso was a pioneer in the late 1880s in the search for devices that could measure physiological changes associated with lies during **interrogation** of criminal suspects, such as the pletymosograph. The device was a modest ancestor of modern **polygraphs** that recorded blood circulation variations during interrogation. Lombroso asserted that through the observation of how physiological signs changed during interrogation, a reliable and humane means of detecting when individuals were telling the truth or lying could be developed. In 1915, William M. Marston at Harvard University developed an instrument to measure blood pressure that he named the "lie detector." In the early 1920s, American criminologist and psychiatrist John Larson started to develop the first modern polygraph machine that recorded blood pressure levels, pulse rates, breathing rates, and perspiration.

By the 1980s, polygraphing had a one-billion-dollar industry in the United States, with different models and testing methods of application not only for criminal investigation, but also as a tool for testing employees in the workplace. However, its efficacy and accuracy became increasingly disputed by scientists who labeled the polygraph a tool of "junk science" because of the many variables involved physiological changes, the subjective nature of data interpretation by polygraph examiners, the misuse and abuse found in many cases, and the many documented cases of false positive and false negative results. Increased privacy law protection and a string of notable failures in polygraph examinations by those who successfully defeated counterintelligence polygraph examinations brought polygraph practice into increasing disrepute. The failures were well publicized, especially in the wake of the 1985 arrest of Navy spies in the Walker family spy ring and the 1994 arrest of CIA officer Aldrich Ames for selling secret information to the Soviets for years despite being "cleared" by repeated polygraph examinations.

In contrast, many individuals who were convicted for crimes based on polygraph tests in the first half of the twentieth century were later found to be innocent (false positive results), which led courts in general to deny the acceptability of polygraph tests as valid **evidence**. For that matter, even **J. Edgar Hoover**, during his many years as director of the Federal Bureau of Investigation (**FBI**), banned polygraph testing of FBI employees, deeming it a waste of time and money. Nevertheless, polygraphs were again introduced in the FBI and gained increasing prestige in other agencies as well as a tool of interrogation rather than as an accurate scientific test. Today they are largely used in both criminal and security investigations by the police, governmental agencies, and private enterprises.

More controversy on the validity of polygraph tests was sparked in 1999, when Chinese American nuclear physicist Wen Ho Lee was accused of mishandling highly classified data on nuclear weapons. Lee was tested by two different polygraph examiners from the U.S. Department of Energy (DOE). Lee passed one polygraph test, failed a second one, and then passed a third test. Department of Energy (DOE) polygraph examiners still disagree about the tests' contradictory results. Former Energy Secretary Bill Richardson, elected in the wake of the Lee controversy, recommended a wide polygraph-screening program for DOE employees instead of using guards and x-ray scanning at the entrances of DOE laboratories, which had been cancelled by his predecessor.

When Congress approved Richardson's petition, another great controversy ensued as scientists and engineers working in some facilities unanimously refused to be tested. The scientists claimed that polygraphs did not increase security, but rather undermined it, since spies are trained to pass the tests; polygraphs create a false sense of security; polygraphs drain valuable resources from other effective and sound security measures; and polygraph tests demoralize the staff, possibly jeopardizing the safety of information in such vital issues as nuclear technology.

A leading voice in this issue was Alan P. Zelicoff, the senior scientist at the Center for National Security and Arms Control at Sandia National Laboratories. Zelicoff decided to take the case against polygraphs to the public after both the DOE and the Congress had ignored scientists' concerns. Among his arguments, Zelicoff (who is a physicist and physician) alerted the public that polygraphs are deceptive devices subject to the manipulation and incompetence of polygraph examiners. Such examiners, he noted, routinely induce nervousness and anxiety in the subjects being tested by telling them that the machine is indicating "deception" (which it is actually not) and by continuously pressing the individual to "clarify" his or her answers by providing more personal, intimate information.

Zelicoff also reinforced his case by citing how innocent people had their lives and careers ruined by erroneous interrogation of polygraph tests. Such was the case of David King, a Navy veteran held in prison for 500 days under the suspicion of selling classified information. King was arrested after failing a polygraph test and was subjected to repeated polygraph scrutiny, with some of these sessions lasting up to 19 hours, all with contradictory results. After a military court dismissed all charges against King, he was released, but his further military career prospects were tainted. As a physician, Zelicoff argued that the four parameters measured by polygraphs—blood pressure, pulse, perspiration, and breathing rates—can be affected by a myriad of emotions. He asserted that there is no medical literature that associates variations in these parameters with the intention of hiding the truth by individuals.

Charles R. Honts, a psychologist at Boise State University in Idaho, is considered one of the most qualified U.S. experts on the use and misuse of polygraphs, and is frequently requested to serve as an expert witness in court. Honts has spoken against the use of polygraphs in the workplace by government and private companies. Since the appearance of polygraphs, the main advocates of polygraphs have been psychologists and law enforcement agents. However, a growing number of studies by psychologists are concluding that polygraphs constitute incomplete science and are more likely a tool for suspect intimidation, where suspects are led by examiners to believe that polygraphs are high-precision devices that detect lies without human inference. The ethical aspects of how tests are conducted by inexperienced or poorly prepared examiners, plus the alleged use of unethical intimidation techniques by some examiners, have been the object of questioning in scientific literature, as well.

FBI forensic scientists, in turn, are testing methods of improving polygraph accuracy by using the test in association with a variety of known psychological methods utilized for detecting deception. One such psychological method is known as the guilty knowledge test/technique (GKT). GKT was adopted in 1959 as a valid psychological test for interrogating suspects in association with polygraphs. GKT is based on the premise that guilty subjects will show higher levels of physiological reactions when exposed to details of a crime that were not publicized when such facts are presented among incorrect information. It also assumes that innocent people will not show the same levels of physiological reactions. GKT is a popular test in association with polygraph tests among the Israeli law enforcement and security agencies. A paper published in *Forensic Science Communications* in 2003 showed the results of a study with 758 examinations made by polygraph examiners of 25 FBI field offices from November 1, 1993, to August 31, 1994, indicating that GKT should be used as a supplement in order to improve prevention of false positive results in polygraph tests.

Despite the controversies, the use of the polygraph is still advocated by some. Besides the strong power for lobbying that a billion-dollar industry has, polygraphs remain die-hard devices because they were also ingrained in the popular imagination as an infallible tool, partially due to the way they are portrayed in movies, **television shows**, and in thriller novels. Electroencephalograms (EEGs), however, are much more useful in detecting facts, because the brain stores true experiences and the fabricated facts in different areas. When individuals wired to an EEG machine are shown a sequence of images, including a crime scene and pictures of other persons, the brain areas responsible for true memories are activated by the recognition of images associated with the individual's real experiences.

In 2005, experiments on lie-detector technologies were being assessed by forensic experts at the Human Brain Research Laboratory in Fairfield, Iowa. Scientific methodologies and specific criteria for tests must first be adequately developed and validated, in order to prevent the birth of another popular myth.

SEE ALSO Brain wave scanners; Circumstantial evidence; Ethical issues; Evidence; Expert witnesses; FBI (United States Federal Bureau of Investigation); Federal Rules of Evidence; Interrogation; Malicious data; Psychology; Statistical interpretation of evidence.

Polygraphs

A forensic investigation may implicate an individual or group of people as suspects in a crime. Once identified as a suspect, an individual can typically expect to be questioned about the incident and their potential role. Questioning can involve the use of a polygraph test. As well, an individual may choose to participate in a polygraph test to exonerate themselves.

A polygraph test is administered to determine whether or not statements made by the subject taking the test are deceptive. During the test, the subject is monitored by a polygraph machine and interrogated by an administrator trained in forensic psychophysiology. The machine measures changes in the subject's blood pressure, heart rate, respiration rate, and sweat production. The theory underlying the polygraph test is that a person who is lying exhibits involuntary physiological responses that can be detected by the polygraph instrument. These changes include rapid breathing and heartbeat and increased blood pressure and perspiration.

The polygraph test usually measures four to six physiological reactions made by three different medical instruments that are combined in one machine. Older polygraph machines were equipped with long strips of paper that moved slowly beneath pens that recorded the various physiological responses. Newer equipment uses transducers to convert the information to digital signals that can be stored on computers and analyzed using sophisticated mathematical algorithms.

The three components of the polygraph instrument include the cardio-sphygmograph, the pneumograph, and the galvanograph. Blood pressure and heart rate are measured by the cardio-sphygmograph component of the polygraph, which consists of a blood pressure cuff that is wrapped around the subject's arm. During the questioning the cuff remains inflated. The movement of blood through the subject's veins generates a sound that is transmitted through the air in the cuff to a bellows that amplifies the sound. The magnitude of the sound relates to the blood pressure and the frequency of the changes in the sound relates to the heart rate. The pneumograph component of the polygraph records the subject's respiratory rate. One tube is placed around the subject's chest and a second is placed around his or her abdomen. These tubes are filled with air. When the subject breaths, changes in the air pressure in the tubes are recorded on the polygraph. The galvanograph section records the amount of perspiration produced. It consists of electrical sensors called galvanometers that are attached to the subject's fingertips. The skin of the fingertips contains a high density of sweat glands, making them a good location to measure perspiration. As the amount of sweat touching the galvanometers increases, the resistance of the electrical current measured decreases and these changes are recorded by the polygraph. Most forensic psychophysiologists consider the cardio-sphygomgraph and the pneumograph components more informative than the galvanograph.

During the polygraph test, the examiner and the subject are alone in the questioning room. Before the test begins, the examiner spends about an hour talking with the subject. This permits the examiner to obtain a baseline reading on the subject's emotional state. Before the test begins, the examiner goes over each question with the subject so that he or she knows exactly what to expect. When they are ready start, the person administering the polygraph attaches the various components of the polygraph instrument to the examinee.

The polygraph test itself usually consists of about 10–12 questions that require yes or no responses. Several methods of composing questions for polygraph tests exist, but all include asking the subject both relevant questions and control questions. Relevant questions relate directly to the focus of the polygraph test. Examples of relevant questions are "Did you commit crime X?" or "Did you ever use drug Y?" Control questions vary depending on the type of test administered. The most common type of polygraph test is the Control Question Test (CQT), in which control questions are composed so that the subject can answer them honestly, however, the examiner may make them slightly provocative to evoke an emotional response. Examples of control questions are "Did you ever think of doing crime Y?" or "Were you ever drunk in the last year?" This allows the examiner to understand the subject's physiological responses to challenging questions. In the CQT, greater physiological responses to the relevant questions than to the control questions indicate deceptive behavior.

There are variations to the CQT. In Directed Lie Tests (DLT), the examiner substitutes very broad questions for the control questions and the subject is directed to answer them with lies. An example is "Have you ever told a lie?" to which the subject is directed to respond "No." This response gives an examiner an understanding of the subject's physiological response associated with lying. In Positive Control Tests (PCT), a relevant question itself is used as a control. The subject is instructed to answer truthfully the first time the question is asked and falsely the second time it is asked. The only factor that influences the response is whether or not the subject is lying. In the Truth Control Test (TCT), the control questions are composed to make the subject think that he or she is being accused of a fictitious crime. This gives the examiner information on how the subject responds to a truthful denial.

During the post-test, the forensic pschophysiologist analyzes the subject's responses to the questions and scores them. Each channel of the polygraph is scored individually. For any channel, if the control response is larger than the relevant response, the score is from +1 to +3, dependent on the magnitude of the difference. If the relevant response is larger the score is from −1 to −3. The scores are summed over all channels and all repetitions of the questions to get to the total score. If the final score is sufficiently large and positive, then the subject is considered to have made truthful statements. If the final score is sufficiently large and negative, then the statements are considered deceptive. If the result is close to zero, then the test is inconclusive.

There is much debate as to the accuracy of polygraph tests. Forensic psychophysiologists generally concur that the rate of detecting deceptive behavior is greater than the rate of detecting truthful behavior. The American Polygraph Association claims that the accuracy rate for polygraph tests is between 85 and 95%. However, reports of false positives have reached as high as 75% in research done by the Congressional Office of Technology Assessment.

In the 1980s, the scientific validity of polygraphs was brought into question by psychologists. In 1988, the federal Polygraph Protection Act was passed, prohibiting employers from using polygraphs for employment screening. As a result of this legislation, businesses can ask an employee to take a polygraph, but the employee's refusal will not result in any disciplinary treatment. This law does not protect government employees including people who work in schools, prisons, public agencies, and businesses under contract with the federal government.

The use of polygraphs in court was brought to trial in 1989. In the case of *United States v. Piccinonna*, a polygraph was deemed admissible as **evidence**, only if both sides agree to its use or the judge allows it based on criteria set forth in the case. A Supreme Court ruling in 1998 expanded the judge's authority in the use of polygraphs in federal cases. Some states accept this ruling, but not all. On the state level, polygraph use is dependent upon the judge and the case.

SEE ALSO Interrogation; Polygraph, case histories; Truth serum.

Polymerase chain reaction analysis SEE PCR (polymerase chain reaction) analysis

Georg Popp

GERMAN
FORENSIC GEOLOGIST

Georg Popp is credited as the first forensic scientist to utilize geological **evidence** to solve a crime. In October 1904, while working as a forensic scientist in Frankfurt, Germany, Georg Popp was asked to assist in solving the **murder** of a young woman named Eva Disch, who had been strangled in a field. The murder weapon was Ms. Disch's scarf, and the perpetrator had apparently left his own well-used handkerchief near the body. Upon microscopic examination of the contents of the handkerchief, Georg Popp noted that the enclosed mucous contained particles of snuff and bits of coal. The most forensically interesting aspect of the mucosal contents were a variety of **minerals**, particularly that of hornblende.

The principal suspect in the case was a man named Karl Laubach, who was known to use snuff, who worked part-time in a gasworks fired by burning coal, and who was also employed part-time at a local gravel pit. Popp examined the body of the murder victim and extracted bits of coal and grains of several minerals, including hornblende, from under her fingernails. Georg Popp was able to obtain the clothing worn by the suspect on the day of the murder; he made a close examination of the legs of Mr. Laubach's trousers and removed a variety of soil samples from them. When he performed a microscopic examination of the soil samples, he discovered a lower layer consistent in makeup to a soil sample previously obtained from the murder scene. When he examined an upper layer of soil from the trousers, he found a mineral blend consistent with soil samples removed from the path between the murder site and the suspect's home.

Popp's forensic scientific conclusion was that the suspect's clothing picked up the lower layer of soil at the scene of the murder; this layer was then covered by mineral-laden mud splashed upon the trousers during the suspect's return home. When interrogated and presented with the analysis of evidence found in his handkerchief and clothing, Karl Laubach confessed to the murder. The publicity surrounding the solution of this case established Georg Popp as a forensic geological expert.

The use of geologic information in forensic settings was established internationally in 1908, when Georg Popp was again called upon to assist in the solution of a murder. In this case, he focused his examination on the shoes of the principal suspect; he examined the layers of dirt encrusted between the sole and the front of the heel. The shoes were known to have been cleaned by the suspect's wife on the night before the murder occurred, so it was Popp's hypothesis that the soil had been sequentially accumulated on the day of the murder with the layer closest to the shoe leather deposited first, and so on. By carefully removing each individual layer of soil and examining it microscopically, Popp was able to retrace the steps, literally, taken by the suspect on the day of the murder. He was able to match the soil from the shoes to the soil surrounding the suspect's home, to the scene of the crime, and to the location where the shoes had been hidden by the suspect. His solution of this case firmly established Georg Popp at the forefront of forensic **geology**. Georg Popp's microscopic examination of minerals and soil samples set a precedent for the continuing use of soil samples as an integral part of forensic investigation.

SEE ALSO Crime scene investigation; Geology; Inorganic compounds; Microscopes; Minerals.

Post death injuries SEE Antemortem injuries

Posterior SEE Anatomical nomenclature

Presumptive test, blood SEE Blood, presumptive test

Prions

Forensic investigations can often be focused on an illness outbreak or death that is suspected of being of infectious origin. Then, a critical task of forensic scientists is to identify the source of the illness and, if it is determined to be contagious, to track the pattern of the infection in order to help quell the present and future outbreaks.

Bacteria, viruses, fungi, and protozoa are the usual causes of infections. However, within the past several decades, a protein found in the brain has been determined to be the cause of one or more similar diseases of humans and animals (variant Creutzfeld-Jacob disease in humans; Bovine Spongiform Encephalopathy [BSE] or "mad cow" in cattle) that produce a progressive destruction of brain tissue.

The determination of the involvement of the protein, dubbed prion, is an example of **forensic science**. Post-mortem examinations of tissue samples are geared toward unearthing the indications of prion activity and in detecting the presence of the abnormal form of the protein. As in other infectious disease investigations, establishing the origin of the infection becomes a priority.

Prions are proteins that are infectious. Indeed, the name prion is derived from "proteinaceous infectious particles." The forensically relevant investigations that have implicated prions in degenerative brain diseases have been revolutionary. The discovery of prions and confirmation of their infectious nature overturned a central dogma that infections were caused by intact organisms, particularly microorganisms such as bacteria, fungi, parasites, or viruses. Since prions lack genetic material, the prevailing attitude was that a protein could not cause disease.

Prions were discovered and their role in brain degeneration was proposed by Stanley Pruisner. This work earned him the Nobel Prize in medicine or physiology in 1997.

In contrast to infectious agents that are not normal residents of a host, prion proteins are a normal constituent of brain tissue in humans and in all mammals studied thus far. The prion normally is a constituent of the membrane that surrounds the cells. The protein is also designated PrP (for the aforementioned proteinaceous infectious particle). PrP is a small protein, being only some 250 amino acids in length. The protein is arranged with regions that have a helical conformation and other regions that adopt a flatter, zigzag arrangement of the amino acids. The normal function of the prion is still not clear. Studies from mutant mice that are deficient in prion manufacture indicate that the protein may help protect the brain tissue from destruction that occurs with increasing frequency as someone ages. The normal prions may aid in the survival of brain cells known as Purkinje cells, which predominate in the cerebellum, a region of the brain responsible for movement and coordination.

The so-called prion theory states that PrP is the only cause of the prion-related diseases, and that disease results when a normally stable PrP is "flipped" into a different shape that causes disease. Regions that are helical and zigzag are still present, but their locations in the protein are altered. This confers a different three-dimensional shape to the protein.

As of 2005, the mechanism by which a normally functioning protein is first triggered to become infectious is not known. One hypothesis, known as the virino hypothesis, proposes that the infectious form of a prion is formed when the PrP associates with nucleic acid from some infectious organism. Efforts to find prions associated with nucleic acid have, as of 2005, been unsuccessful.

If the origin of the infectious prion is unclear, the nature of the infectious process following the creation of an infectious form of PrP is becoming clearer. The altered protein is able to stimulate a similar structural change in surrounding prions. The change in shape may result from the direct contact and binding of the altered and infectious prion with the unaltered and still-normally functioning prions. The altered proteins also become infective and encourage other proteins to undergo the conformational change. The cascade produces proteins that adversely effect neural cells, and the cells lose their ability to function and ultimately die.

The death of regions of the brain cells produces holes in the tissue. This appearance led to the designation of the disease as spongiform encephalopathy. This appearance is a hallmark of forensic examinations.

The weight of evidence now supports the contention that prion diseases of animals, such as scrapie in sheep and BSE in cattle, can cross the species barrier to humans. In humans, the progressive loss of brain function is clinically apparent as Creutzfeld-Jacob disease, kuru, and Gerstmann-Ströussler-Scheinker disease. Other human diseases that are candidates (but as yet not definitively proven) for a prion origin are Alzheimers disease and Parkinsons disease.

In the past several years, a phenomenon that bears much similarity to prion infection has been discovered in yeast. The prion-like protein is not involved in a neurological degeneration. Rather, the microorganism is able to transfer genetic information to the daughter cell by means of a shape-changing protein, rather than by the classical means of genetic transfer. The protein is able to stimulate the change of shape of other proteins in the interior of the daughter cell, which produces proteins having a new function.

The recent finding of a prion-related mechanism in yeast indicates that prions may be ubiquitous features of many organisms and that the protein may have other functions than promoting disease.

SEE ALSO Animal evidence; Mad cow disease investigation.

Privacy, legal and ethical issues

Evidence collection, searching of private premises, obtaining samples for genetic and various biochemical examinations, and questioning suspects are all parts of a forensic investigation. Although the need to acquire evidence is pressing, the need to preserve and protect the privacy and liberty of individuals is also paramount.

Among the foundational principles of the Western liberal tradition that binds the American political system is the belief that the rights of the individual, wherever possible, must be preserved against the authority of the state. Emanating from that principle is the implication that individuals have a right to privacy, a right implied—as noted by several distinguished Supreme Court justices over time—in the United States Constitution. Balancing, and sometimes contradicting, this right to privacy is the need for security on a national and local level, which can include the collection of forensic evidence and the use of forensic testing.

An array of U.S. tort and constitutional laws support the individual's right to privacy. In tort law, persons have a right to seek legal redress for invasions of privacy undertaken for the purposes of material gain, mere curiosity, or intention to defame. These protections extend to all persons under U.S. law, though public figures—a term strictly defined in legal statutes—have somewhat less broad rights of privacy.

Some national constitutions spell out the rights of the individual, with the assumption that all other privileges belong to the government. The U.S. Constitution, by contrast, outlines government authority, with the provision that all other rights belong to the states and individuals. To James Madison and other founders of the republic, these guarantees did not go far enough, and therefore, Congress passed the Bill of Rights, or the first ten amendments to the Constitution. Among these are several that would later figure heavily in debates over privacy: the First Amendment, with its protection of free speech; the Fourth Amendment, which stands against unlawful search and seizure; and the Fifth Amendment, which provides for due process under law. The Fourteenth Amendment, passed after the Civil War to protect the rights of freed slaves, extended Fifth Amendment provisions to states as well, because citizenship of both the nation and the resident state was extended to persons born or naturalized in the United States (i.e., rights of citizenship could not be denied at the state level because of race).

Contrary to popular belief, neither the Constitution nor its amendments contains any reference to privacy as a right *per se*. The concept of "The Right to Privacy" comes from an influential 1890 *Harvard Law Review* article by that title, under which Supreme Court Justice Louis Brandeis, writing with Samuel Warren, put forward the proposition that privacy rights extend beyond mere protection against clear-cut intrusions on privacy. Thereafter, a number of landmark decisions in the Supreme Court broadened the concept of privacy as defined in constitutional law. Among these was *Griswold v. Connecticut* (1965), involving a state law that prohibited the use of contraceptives. Writing for the Court, which struck down the law, Justice William O. Douglas held that the "penumbra" of the First, Fourth, and Fifth collectively provides a "zone of privacy."

The 1970s saw a revolution in privacy rights, not only through the Court—whose *Griswold* decision set the stage for the protection of abortion rights in *Roe v. Wade* (1973)—but also in the legislative branch of government. In 1974, Congress passed the Privacy Act, which restricts the authority of government agencies to collect information on individuals or to disclose that information to persons other than the individual. The Privacy Act also requires agencies to furnish the individual with any information on him or her that the agency had in its files.

In 1967, Congress had passed the Freedom of Information Act (FOIA), which limits the ability of U.S. federal government agencies to withhold information from the public by classifying that information as secret, but it greatly expanded FOIA provisions in 1975. Together with the Privacy Act—the two are often referred to collectively as the Freedom of Information-Privacy Acts (FOIPA)—these served to further extend the rights of individuals against government intrusion. Like FOIA, the Federal Wiretapping Act of 1968 had been passed earlier, but it, too, was extended in the 1970s. Today, all U.S. states have laws against wiretapping and telephone recording.

Many of these changes occurred as a response, either directly or indirectly, to the Watergate scandal and the subsequent revelations of illegal wiretapping, recording, and surveillance activity conducted by the Nixon White House and other compartments of the federal government. In 1976, Congress passed the Foreign Intelligence Surveillance Act (FISA). FISA, which became law in 1978, placed checks and balances on the authority of government agencies to conduct surveillance on persons accused of conducting espionage—authority that had been misused by Federal Bureau of Investigation director **J. Edgar Hoover** in some domestic intelligence campaigns during the 1950s and 1960s.

In September, 1997, Congress passed the Fair Credit Reporting Act (FCRA), which requires potential employers to obtain written authorization from a job candidate or employee before accessing records from a consumer reporting agency. The employer is also required to notify the employee or applicant if any adverse action is taken pursuant to a negative report. Thus federal law extended privacy rights to protect the individual from intrusion by businesses as well as the government.

Many privacy issues at the dawn of the twenty-first century involved new technologies and new developments in science. In the area of technology, the broadening of access to the Internet brought with it a number of concerns regarding government monitoring of e-mail and other electronic communications traffic.

With specific regard to forensic evidence, debate still exists about the extent of privacy protections. In particular, the collection and matching of **DNA** sequence information in **DNA databanks**, especially if the information is used for other than **identification** of remains.

SEE ALSO Criminal responsibility, historical concepts.

Processing

It is of critical importance to properly identify, collect, preserve, and transport forensic scientific **evidence** for processing. During the investigation of a crime, the initial objectives regarding evidence are to thoroughly document and photograph the scene and to annotate the description and location of evidence to be gathered. A systematic process is then used to collect and package evidence for transport to the laboratory. Photographing may continue throughout the sample collection process, particularly if there are multiple layers of evidence that can only be seen as those above them are removed.

Paper packets, envelopes, and bags are most commonly used for specimen collection, because they do not gather evidence-destroying moisture or condensation. Nonporous, leakproof, and unbreakable containers are used for collecting and moving liquids, and clean, airtight metal canisters are used to transport **arson** evidence. Plastic bags are sometimes used to collect dry or powdered evidence. **Blood** and other moist evidence can be moved from the crime scene to the lab in plastic containers only if the transport time is less than two hours, in order to avoid the introduction and proliferation of contamination-causing bacteria. Upon receipt at the processing area, all items of evidence must be cataloged, then removed and allowed to completely air dry. After drying, evidence can be repackaged in paper or other suitable containers as necessary.

When packaging evidence, it is imperative to avoid cross-contamination by separately and securely packaging and sealing different items. At the start of the custody chain, the evidence container must be clearly marked with the initials of the collector, the date and time of acquisition, a detailed description of both the evidence specimen and the location from which it was collected, and the investigating agency's name and case file number.

The **chain of custody** typically refers to the paper trail, evidence log, or other forms of documentation pertaining to the collection (whether by sampling or legal seizure), custody, control, transfer, analysis, presentation, and final disposition of material and/or electronic evidence.

In order for evidence to be admissible and credible in court, it is essential that the chain of custody remain intact. Every contact with, or movement of, a piece of evidence must be documented in detail in order to verify that it was never unaccounted for or potentially tampered with. A specific, and appropriately credentialed, individual must be assigned physical custody of individual items of evidence. In law enforcement proceedings, this generally means that a detective will have overall responsibility for the integrity of the evidence; he or she will document its receipt and sign it over to an evidence clerk who is responsible for storing the evidence in a locked and secured area. Every single transaction involving any piece of evidence must be chronologically documented in minute detail from the moment of collection through presentation in court, in order to establish authenticity, and to defend against allegations of tampering. The documentation must include a detailed description of the location and conditions under which the evidence was collected, the identity (and possibly the credentials) of every handler of the evidence, the duration of each movement of the evidence, the level of security for each movement, as well as the overall storage of the item, and a specific description of the manner and conditions under which each transfer of the evidence occurred. If the chain of custody is broken at any time, the evidence is likely to be inadmissible or of minimal, if any, legal value.

SEE ALSO Bloodstain evidence; Cameras; Crime scene investigation; Disturbed evidence; Physical evidence; Quality control of forensic evidence.

Product tampering

Product tampering is the deliberate contamination of goods after they have been manufactured. It is often done to alarm consumers or to blackmail a company. The individual involved may have mental health problems or be politically motivated. Investigation of product tampering often involves forensic **toxicology** to discover the nature and timing of the contamination. Psychological **profiling** of the perpetrator may also prove useful. Both tampering itself and threatening to tamper are criminal offences, as is claiming tampering has occurred when it has not. Although there have been few deaths from tampering, compared to the number of complaints about it, the potential for spreading fear and doing actual physical harm to large numbers of people is great.

As consumers, trust is put in companies to provide safe foods, beverages, and medicines. Occasionally errors are made during manufacture and a harmful substance is added to a product, such as Sudan 1, the illegal dye that turned up in over 160 food products in the United Kingdom in 2005. When this happens, retailers generally remove the product from their shelves and issue prompt warnings to customers. Even so, consumer confidence is impacted and the manufacturer and retailer may suffer financially. With product tampering, contamination is done deliberately and generally to goods that are already in circulation. It is then up to a forensic investigation team to trace the source and nature of the contamination before people are harmed.

A wide variety of contaminants have been found in products that have been tampered with. Mice, syringes, cyanide, needles, liquid mercury, and **glass** have all turned up in a wide range of goods. The forensic laboratory must take a look at the physical and chemical nature of the contaminant using a range of techniques. If the contaminant is an organic compound, then infrared **spectroscopy** and either gas or liquid **chromatography** in conjunction with mass spectrometry can rapidly provide an identity. Chromatography experiments against an uncontaminated sample, in the case of a soft drink, for example, will reveal the proper composition of the product. Extra components could be contaminants and these will be analyzed more closely. Inorganic contaminants, such as acids or sodium hydroxide (lye), can be examined with techniques such as atomic absorption, which can show the elements involved.

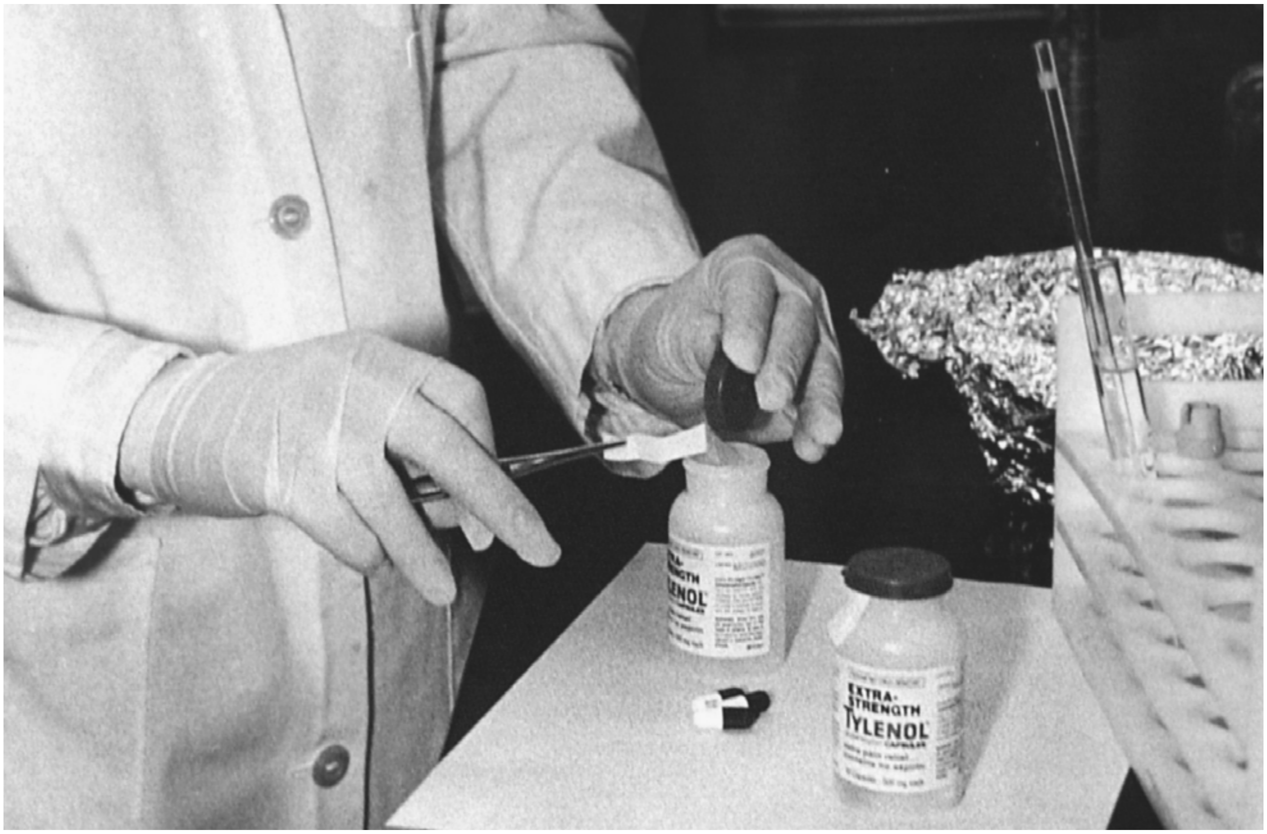
The lab will then carry out more tests to find out when the tampering occurred, as this will help the search for the perpetrator. A contaminant may change chemically once inside the product, and analysis may show how long it has been there. Rarely, a disenchanted employee will contaminate a product during manufacture. More often, however, the perpetrator interferes with the product when it is on the shelf of the retailer's, or once it is in circulation. Most big supermarkets have video **cameras**, so if the store where the tampering took place can be found out through investigation of the packaging and its contents, it may be possible to identify a perpetrator in the act on camera.

Probably the most famous case of product tampering occurred in 1982 when seven people died in Chicago after ingesting capsules of the pain reliever Tylenol® laced with cyanide. Autopsies showed cyanide poisoning but, at first, no one could see the connection between the victims. Then it turned out they had all purchased a pack of Extra-Strength Tylenol®. These had been contaminated with cyanide. Psychological profilers were fascinated by the case, because this was a new kind of crime, with no apparent motive. As the victims were random and probably unknown to the attacker, it was a crime involving great psychological distance probably motivated by rage at society and seeking power through the fear generated by the tamperings. Naturally, the crimes aroused great public anxiety, for anyone could become a victim at any time. Yet the incidents stopped as suddenly as they began and no one was ever arrested or convicted. However, one man was imprisoned after trying to blackmail the manufacturers of Tylenol®.

There must, however, be a large psychological element to product tampering, because the publicity surrounding the 1982 Tylenol poisonings triggered a wave of other attacks. Many of these turned out to be fake or staged tamperings, often carried out by attention-seeking individuals. Sometimes criminals have sought to defraud companies by blackmail with threats of tampering. There have been 20 arrests in connection with such threats in the U.S., but no one was injured as no tampering took place. Some suicides have tried to cover up the true nature of their death by staging a tampering.

Publicity about tampering in the media also leads to an increase in reports of suspect tampering. That is, a consumer reports packaging that appears to have been interfered with, or links a symptom they experience with possible contamination of a product. Most of these complaints prove unfounded although they must, of course, be investigated.

In 1984, the Food and Drug Administration (**FDA**) began to compile figures on tampering. Unlike other crimes, where rates either increase, decrease, or stay steady, the rate of tampering is linked to the publicity about a specific case. In early 1984, pins and needles were found in cookies meant for a group of young girl scouts and reports of tampering went up from 20 to 200 in the following month. Once press coverage died down, the rate fell to 10 incidents reported a month. There was another fatal Tylenol poisoning in Westchester in February 1986 and, again, the reports of other tamperings went up to 326 a month. Later that month, there was huge publicity when glass was found in baby food. The next



Bottles of Extra-Strength Tylenol® are tested after tampered, cyanide-laced Tylenol killed seven people in 1982. The incident lead to tamper-resistant packaging on most foods and drugs sold today. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

month, reports of tampering reached an all time high of 456. It was in 1987 and 1988 when there were no publicized incidents that reports fell to an all time low. Some experts suggest that publicity should be minimized in cases of tampering but, of course, the public has to be warned and, indeed, may have valuable information that could lead to the perpetrator.

In another famous case, **murder** was staged to look like tampering. Sue Snow collapsed suddenly and died in 1986 at her home in Seattle. It looked like a drug overdose, but the only medication she had been taking was Excedrin, a normally safe painkiller. During **autopsy**, however, the pathologist noted the telltale odor of almonds around the corpse, suggesting cyanide poisoning. Toxicology tests revealed its presence. As with the 1982 Tylenol case, all packs of Excedrin had to be removed from the shelves of drugstores across the country. The police found two other contaminated bottles, one in Auburn, WA and one in nearby Kent, WA.

This proved to be no random case of product tampering, however. A few days later, Stella Nickell told police her husband had also died suddenly after taking Excedrin. His death certificate gave **cause of death** as emphysema. The police would have exhumed Bruce Nickell's body, save that a **blood** sample had been retained because he was a registered organ donor. Toxicological investigation showed that he had died of cyanide poisoning. Nearly 250,000 Excedrin capsules were examined by the Food and Drug Administration in an attempt to find a link between the two victims. Five contained cyanide and two of them were in the possession of Stella Nickell. The finding of another chemical contaminant in the capsules, an algicide used to clean fish tanks, suggested her guilt when a fish tank was discovered on her premises. Other **evidence** helped to convict Nickell, who is now serving a 99 year prison term for murder.

Product tampering could, of course, be a potent tool for terrorists. There have been various incidents and hoaxes involving a number of groups such as animal rights activists, extreme religious groups, and others. In 1978, for instance, a Palestinian group told the Dutch government it was responsible for injecting mercury into citrus fruits from Israel. These turned up in The Netherlands, the United Kingdom, Belgium, Germany, and Sweden. Investigation suggested the poisoning had occurred at point of retail because the pattern of discoloration in the fruit was not consistent with it having occurred in Israel. No one died, but a dozen were affected by mercury poisoning and Israeli orange exports fell 40% as fruit sales plummeted all throughout Europe.

Following the Tylenol incidents, over-the-counter drugs have been sold in tamper-proof packaging. This may deter the impulsive criminal, but those bent on spreading harm and anxiety could find a way around the packaging. The Food and Drug Administration (FDA) recently expressed some concern that Al Qaeda might tamper with the domestic food and drug supply and may find a way of specifically targeting illegally imported prescription drugs. The FDA has a special unit dedicated to the forensic investigation of product tampering. Recent incidents included the contamination of baby food with ground castor beans, which contain the deadly poison **ricin**. In what may have been a hoax, a shipment of lemons from Argentina was said to be impregnated with an unspecified biological toxin. Nothing harmful, however, was found in the fruit on examination at border control.

SEE ALSO Food supply; Toxins.

Professional publications

Forensic science is a fast moving field, with new techniques, theories, and information being introduced all the time. The forensic professional, whether he or she is a **medical examiner**, a specialist, or a laboratory technician, needs to keep up-to-date. There are several professional publications that the scientist can consult to learn about the latest research. If they so wish, they can use the journals to correspond and debate with colleagues all over the world on the latest forensic science issues. They can also build their scientific reputation, and that of their laboratory, by publishing original research. The Internet has made using professional publications much easier. Often, a paper will be published online before it appears in the print edition so that everyone can have access to it earlier. A searchable online index for a journal means that a subject can be researched easily by those who do not have ready access to an academic library. Subscriptions to journals are expensive, but most now provide a "pay for view" facility so that one can purchase a copy of an article of interest without having to visit a library or take our a subscription to a journal.

Like other academic journals, forensic science publications are usually overseen by a panel of experts whose opinions ensure that all the work published there is accurate, timely, and relevant. It is usual for all research papers to be peer-reviewed, that is, scrutinized by professionals to check the originality and quality of the research. The peer review system can lead to delays in publication, although these are now reduced as communications are handled electronically. Although peer review is open to abuse, and accusations of bias or favoritism are not unknown, it is the best guarantee that research published in a professional journal is of a high standard.

There will always be a role for the academic library for those consulting professional publications. Universities and hospitals providing postgraduate **training** in forensic science are likely to subscribe to at least the main journals. These will usually be shelved in the **pathology** section in a medical library. Forensic science publications may often be found near the chemistry section of a science library. The range of journals available is wide. There are academic journals containing important and groundbreaking research papers on the one hand and, on the other, newsletters containing items about the business of a society or association and articles of more general interest.

One of the most comprehensive and popular academic publications for the forensic scientist is the *Journal of Forensic Sciences*. This is the official publication of the **American Academy of Forensic Sciences**. The editors accept original investigations, observations, scholarly inquiries, and reviews. The following areas are covered by the Journal: **anthropology**, **criminalistics**, engineering, law, **odontology**, pathology, **psychiatry**, **questioned documents**, and **toxicology**. The *Journal of Forensic Science* began publication in 1956 and appears once every two months.

Forensic Science International is a more commercial journal and has been published since 1978. It is produced by Elsevier, an academic publisher, every two weeks. The journal's scope is broad, covering forensic pathology and histochemistry, chemistry, biochemistry and toxicology, biology (including hair and fiber analysis), **serology**, odontology, psychiatry, anthropology, physical sciences, **firearms**, and document examination. The editors accept research papers, review articles, preliminary communications, letters, book reviews, and case reports. There are also articles on specialist topics such as accident investigation and mass disaster, **fingerprint evidence**, **toolmarks**, and bite mark evidence.

The *American Journal of Forensic Medicine and Pathology* is essential reading for forensic pathologists and medical examiners, because it is published by the National Association of Medical Examiners. First published in 1980, it appears four times a year and features articles on new examination and documentation procedures. This journal is a useful discussion forum for the expansion of the role of the forensic pathologist in new areas including human rights protection, suicide and drug abuse prevention, and occupational and environmental health. It also includes case reports, technical notes, and reports of medico-legal practice worldwide.

Legal Medicine is a relatively new journal, first appearing in 1999 and comprising five issues a year. It is the official journal of the Japanese Society of Legal Medicine and it is intended for forensic scientists, forensic pathologists, anthropologists, serologists, odontologists, toxicologists, and lawyers specializing in the medico-legal area. *Legal Medicine* is an international forum for the publication of a wide range of original articles, reviews, and correspondence. Besides covering all the main areas of forensic science, it also accepts submissions on malpractice, insurance, child abuse, and medical ethics.

The Australian Academy of Forensic Sciences launched its official publication, the *Australian Journal of Forensic Sciences*, in 1968. It covers a wide range of topics: **arson**, aircraft accidents, money laundering, sex offenders, voiceprints, and even the philosophy of evil. There are also topics that are of special interest to Australian forensic scientists, such as the treatment of aboriginal people within the justice system.

Science and Justice is the official journal of the Forensic Science Society, founded in 1959 and one of the world's oldest and largest associations for forensic scientists. The journal has a comprehensive range of articles and appears four times a year.

The American College of Forensic Psychiatry publishes the *American Journal of Forensic Psychiatry*, which first appeared in 1979. It publishes papers written by psychiatrists who act as **expert witnesses** and by attorneys who deal with civil and criminal mental health cases. The Journal appears quarterly and has published over 800 papers at the interface between psychiatry and the law. It covers historical and cultural aspects of mental health. Topics that have been written about include anti-social behavior, suicide, air rage, stalkers, malingering, and violent behavior.

Laboratory-based forensic scientists have their own specialist professional publications. For instance, The American Society of Crime Laboratory Directors publishes an online newsletter. This is intended as a forum for the discussion of issues concerning the management of the crime laboratory as well as a channel for informing members about the business and activities of the Society.

There are several journals which deal in detail with specialized branches of forensic science. One example is *Environmental Forensics*, the journal of the International Society of Environmental Forensics. The publication deals with legal and technical aspects of environmental pollution, a subject that is of importance for those working to protect the air, water, soil, and biological ecosystems. In a completely different area, the American Society of Questioned Document Examiners publishes an academic journal for its members, and other interested parties, twice a year.

Busy forensic scientists often do not have the time to read all the journals they would like to. That is why abstracting journals, such as *Forensic Science Abstracts*, are so useful. They provide what is known as a current awareness service, scanning all the relevant journals. A short summary, known as an abstract, of the articles in each journal is produced and all the scientist needs to do is to browse through the abstracts on a regular basis and then track down the articles of major significance to his or her work. *Forensic Science Abstracts* is part of a larger publication called *Excerpta Medica*, which surveys over 4,000 biomedical journals.

Another important type of publication for the busy professional is the communications journal. This contains short papers or letters which are meant to give the reader a rapid update on developments in their field. One good example is *Forensic Science Communications*, which is published by Federal Bureau of Investigation scientists and appears four times a year.

A recent development is the appearance of the electronic journal with no paper equivalent. Anyone can set up an electronic journal; it may be free to access to all, or it may be restricted by password. Papers may or may not be peer-reviewed. One example is *Scientific Testimony*, which is produced by the faculty and students at the Department of Criminology, Law and Society at the University of California, Irvine. Its declared aim is to improve the quality of scientific testimony in the courts. The editors invite research papers, tutorials, where a specific scientific or technical topic is reviewed, and have set up a debating forum where people can advance their views. Areas that will be covered regularly include the work of the expert witness, forensic science in general, and science and the jury.

However, probably the first online forensic journal of this kind was Anil Aggrawal's *Internet Journal of Forensic Medicine and Toxicology*, which was set up in 2000 and goes on-line twice a year. Anil Aggrawal is a professor of medicine in New Delhi, India, and chose a forum where those working in forensic medicine and toxicology could share their experiences. Often, a professional will make an observation or try something out which they may not have time to write up for an academic journal. It is easier, however, to email the idea to an Internet journal where the work is more likely to appear and interesting feedback from others can be generated. Professor Aggrawal's journal has now developed so it can accept full-length research papers with color photographs. No doubt, there will be other online developments of this kind. If professionals can communicate with one another easily in a journal format and have the chance for exposure to new ideas, it can only help develop their knowledge and accelerate the progression of their science.

SEE ALSO Careers in forensic science; Training.

Profiling

Profiling is the process of developing descriptions of the traits and characteristics of unknown offenders in specific criminal cases. It is often used in situations for which authorities have no likely suspect. There are two basic varieties of profiling: inductive, which involves the development of a profile based on known psychological typology; and deductive, which reasons exclusively from the details of the victim and crime scene to develop a unique profile. Profiling as a law enforcement tool emerged in the late 1960s, and today, the leading entity engaged in profiling is the National Center for the Analysis of Violent Crime (NCAVC) of the Federal Bureau of Investigation (**FBI**).

Profiling should not be confused with racial profiling. Racial profiling, a topic surrounded with considerable controversy, came to the forefront in the late 1980s and 1990s, when a number of activists and social scientists maintained that law enforcement officials tended to single out African Americans, particularly young males, for arrest and abuse. After the September 2001, terrorist attacks, random searches and other forms of attention directed against Middle Eastern males were also dubbed in some quarters as racial profiling.

Criminal profiling is still controversial among law enforcement authorities and forensic scientists, not all of whom agree on its merits or on the proper approach to obtaining a profile. However, profiling is acceptable by the general public. In fact, television programs concerning crime, as well as dramatic portrayals in popular films have raised considerable public interest in profiling. Thanks to this interest, leading profilers are well-known outside the law-enforcement community.

Indicative of this popularity was the attention given to profiling opportunities on a frequently asked questions (FAQ) page in the employment section of the FBI's Web site in 2003. Alone among FBI specialties, profiling was featured with the question "I just want to be a FBI 'profiler.' Where do I begin the application process?" As the bureau noted in its response, "You first need to realize the FBI does not have a job called 'Profiler.'" The answer went on to discuss the NCAVC, located at FBI headquarters in Quantico, Virginia. The FBI also noted on the site that "These FBI Special Agents [involved in profiling] don't get vibes or experience psychic flashes while walking around fresh crime scenes. [Instead, profiling] is an exciting world of investigation and research. . . ."

Criminal profiling originated from the work of FBI special agents Howard Teten and Pat Mullany in the late 1960s. It is especially used in cases involving **serial killers**, who usually are not personally acquainted with their victims. Most murders involve people who know one another, and in most **murder** investigations, likely suspects can be readily identified. For example, if a married woman is murdered, her husband often quickly becomes the focus of police investigation. If, however, there is nothing to suggest that a victim has been murdered by someone he or she knows, or if the victim's identity is unknown, profiling may be necessary in order to develop a set of leads for investigators.

Criminal profilers make use of two types of reasoning, which, in the view of some profiling experts, constitute two schools of thought. Inductive criminal profiling, like the larger concept of induction in the philosophical discipline of epistemology (which is concerned with the nature of knowledge) develops its portrait of a suspect based on the results gathered from other crime scenes. Inductive criminal profiles draw on formal and informal studies of known criminals, on the experience of the profiler, and on publicly available data sources, to provide guidance.

By contrast, deductive criminal profiling relies purely on information relating to the crime scene, the victim, and the **evidence**. Instead of drawing on the facts of other crimes, the deductive profile draws only on the information relating to the crime in question. For instance, if a search of the crime scene reveals that the killer had smoked an expensive variety of cigar, this would lead the deductive profiler to presume that the killer was wealthy and probably well educated. The profiler working through pure deduction would not, however, seek to compare this fact with information on other killers in the past who had smoked expensive cigars.

FBI profilers are supervisory special agents with NCAVC. In order to be considered for the program, an individual must have served as an FBI special agent for three years. However, due to high competition for placement in the program, individuals selected usually have eight to ten years of experience with the bureau. Newly assigned personnel typically undergo a structured **training** program of more than five hundred hours. Alongside these special agents work other, civilian, personnel in positions that include intelligence research specialists, violent crime resource specialists, and crime analysts. It is their job to research violent crime from a law enforcement perspective, and to provide support to NCAVC special agents.

In addition to developing criminal profiles, NCAVC provides major case management advice and threat assessment services to law-enforcement officials around the nation and the world. Special agents may also provide law enforcement officials with strategies for investigation, interviewing, and prosecution. Among the services provided by NCAVC to the law enforcement community at large is VICAP, the Violent Criminal Apprehension Program. VICAP is a nationwide data information center tasked with collecting, collating, and analyzing information on violent crimes, particularly murder. Cases eligible for VICAP include solved or unsolved homicides or attempts, especially ones involving an abduction; apparently random, motiveless, or sexually oriented homicides; murders that are known or suspected to be part of a series (i.e., serial murder); unresolved missing persons cases, particularly those in which foul play is suspected; and unidentified dead bodies for whom the manner of death is known or suspected to be homicide.

Local law enforcement agencies participating in VICAP are able to draw on its information database in solving crimes. For example, if a murder was committed with a rare variety of handmade pistol, VICAP could be consulted for information on other cases involving such a weapon. Once a case has been entered into the VICAP database, it is compared continually against all other entries on the basis of certain aspects of the crime. VICAP has been used to solve a number of homicides nationwide.

SEE ALSO FBI (United States Federal Bureau of Investigation); Interrogation; Psychological profile; Psychopathic personality.

Profiling, criminal SEE Criminal profiling

Profiling, ethical issues

Profiling is known by a variety of terms, including criminal investigation analysis, crime scene analysis, behavioral **evidence** analysis, psychological profiling, biopsychosocial profiling, psychosocial profiling, investigative process management, **criminal profiling**, psychological criminal profiling, criminal behavioral profiling, offender profiling, and criminal personality profiling. As part of the criminal investigative process, profiling can add depth to crime scene investigations; the behavior of an offender is reflective of his or her underlying psychological process. The appearance of a crime scene can also reveal important information regarding the perpetrator's underlying psychopathy, sociopathy, psychopathology, or enduring character traits. Profiling is also useful when attempting to find subtle commonalities in serial crimes.

Profiling has not been developed as a means of identifying a specific offender in a particular case; rather, it has evolved as a means of adding depth to an investigation. Profiling aids in conducting psychological examination in cases of equivocal death, where a profile can assist investigators in establishing the likelihood that the death was a result of natural, accidental, suicidal, or homicidal origin. Profiling can suggest new avenues of investigation, support the working hypotheses of investigating officers, create a framework for **interrogation** after suspect apprehension, and assist the defense or prosecution in formulating a strategy for case presentation in the courtroom, or paving the way for plea construction.

There are many typologies and definitions of profiling, most likely at least as many as there are names for the cluster of activities that fall under the profiling heading. In the Unites States, the widespread use of profiling largely resulted from the Federal Bureau of Investigation's (**FBI**) work with serial murders and the perpetrators thereof. Its formal use was popularized by the FBI's Behavioral Science Unit (BSU), starting in the 1970s, as part of an effort to incorporate the principles of behavioral science into the law enforcement community. Profiling has received a great deal of attention in the media. It has been the subject of novels and nonfiction crime books (including a large number written by former FBI BSU staff members), featured in movies, and the central topic in numerous **television shows** and series. Because there are so many labels and definitions, the field of profiling has suffered a lack of credibility in the legal, and often the public, arenas. Additionally, the lack of uniformity has led to a significant number of **ethical issues** with the entire concept of profiling.

There are two predominant methodologies currently utilized for profiling: inductive, which is typically used by the FBI and moves from specific case findings to general theories, and deductive, which builds from general theories to specific case findings.

Profiling is currently practiced by a large number of professionals (and paraprofessionals), in a variety of occupations and, as such, currently lacks standardization or uniformity of practice. The concept of profiling is, by its very nature, one that involves interplay among numerous disciplines. In order to achieve some degree of homogeneity, the practice of profiling must attain several developmental milestones; it must have an infrastructure, or set of rules, procedures, guidelines, standards of practice, and requires a universally, or at least consensually, agreed upon vocabulary and set of ethical guidelines. There has been considerable resistance in the field to the concepts of standardization and "professionalization" of profiling, to which a number of reasons have been attributed. Profilers in different disciplines have displayed an inability to find common ground in which to discuss the principles of practice (a police detective has different mandates than a forensic psychiatrist or an FBI Special Agent, forensic nurse, forensic anthropologist, and so on). Profilers often decline (or are prohibited from so doing) to publicly discuss the details of cases due to issues of confidentiality (this can be circumvented by de-identifying case materials). There is also a vocal group of diverse profilers who oppose standardization because it may limit their creativity. In many ways, the art of profiling may be likened to a niche market, in which individuals have honed their expertise (often local) to the point that they have achieved some degree of indispensability in their law enforcement arena. To standardize the profession would be to suggest that any trained profiler (by whatever means trained were to become defined) could be contracted by any jurisdiction to be brought in, create the necessary profiling process, and then leave. This possibility could conceivably threaten to create a loss of livelihood for private, small, and local agencies.

There are a significant number of ethical issues raised by the lack of professionalization of profiling. There are no specific educational or **training** requirements in order to label oneself a profiler. The lack of educational or training requirements also means that there are no minimum standards for the measurement of competency; the lack of competency standards leads to an inability to either discipline or sanction practitioners who are irresponsible or incompetent. There is no juried or peer-reviewed system of practice measurement, there is no agreement as to what the process of creating a profile entails, nor what one should contain, and there is no agreed upon methodology for the conduction of the profiling process. That means, there is no scientific basis upon which profiling rests, as it cannot be subject to analysis and its process cannot, therefore, be replicable. In terms of the actual outcome of the practice of profiling, there are ethical difficulties associated with the use of personality and psychological theories as a means of directing the outcome of a criminal investigation. Profiling has been portrayed by the media as a romantic or heroic profession, possibly resulting in an inaccurate perception of the life and role of a profiler. As a result, the field may attract individuals who are poorly suited to competent practice. When not credibly accomplished, profiling can cause serious harm or impose delays in the actual solution of a case by suggesting inappropriate directions of investigation. The pursuit of suspects who fit a typology suggested by the profiler that is very different than that of the actual perpetrator could also result in the implication or arrest of innocent parties. Finally, there are no official ethical standards for the practice of profiling.

The Academy of Behavioral Profiling (ABP), an internationally recognized, not-for-profit corporation, was initiated in 1999 and incorporated in 2004. The ABP was created, in part, to address some of the ethical concerns raised by the lack of standardization in the field of profiling. Its mission statement describes a commitment to raising the professional bar for profilers by promoting the concepts of peer review, multidisciplinary education and training, and common professional standards for practitioners of evidence based criminal profiling. Among its initial goals were: the creation of written multidisciplinary practice and ethical code of conduct guidelines; development of readily accessible, uniform educational and continuing professional education opportunities; creation and promulgation of a profiling general knowledge exam in order to create some common competency standards; promotion of research opportunities for the advancement of the field of knowledge in evidence-based profiling as well as replicability of results; creation of an informational profiling database; to evolve the peer review process in the professionalization of the practice of profiling; and to increase positive public awareness of behavioral profiling.

The ethical guidelines and code of professional conduct created by the ABP suggest the need for increased professionalism on the part of profilers. They call for a universal attitude embodying integrity and support the need for an unbiased approach to the profiling and reporting process by mandating impartiality, independence, and objectivity. As such, they set standards for maintenance of confidentiality of case information to ensure the dignity of crime victims and their families. They also require that the interpretations and conclusions developed as a result of the profiling process be strictly limited to the information and evidentiary materials reviewed and discovered to avoid the introduction of bias. The ABP ethical code of conduct requires limiting expert witness testimony to the facts of the case, and mandates against the use of conjecture and the offering of opinions regarding guilt or innocence of a suspect in a particular crime. Finally, the ethical guidelines set the standards for reporting unethical conduct, or ethical code violations, to the appropriate authorities associated with the governing bodies of the profession in which the violator was credentialed.

Within the ABP, there are three levels of possible sanction for members who violate the ethical guidelines for professional conduct: (1) advisement—an individual who is responsible for the violation receives a written notice that they are to cease and desist the unethical activity. A member who receives two such advisements is automatically issued a warning; (2) warning—the individual who is responsible for the ethical violation is given a written warning that failure to immediately end the unethical conduct may result in expulsion form the ABP. Notification of a warning is made publicly available to all ABP members, and receipt of two warnings will result in automatic expulsion form the ABP; (3) expulsion—an individual responsible for the ethical transgression will be given written notice of expulsion from the ABP. Such notices of expulsion are made available to the general public. The underlying premise of the sanction process is to educate membership about the importance of maintaining the highest standards of ethical professional behavior.

The ABP has achieved all of its initial goals and continues to grow internationally, suggesting that it may be possible to unite the professionals involved in the practice of profiling, and to someday achieve standardization and adherence to the highest standards of ethical conduct, while maintaining the art of the multidisciplinary process.

SEE ALSO Careers in forensic science; Crime scene investigation; Criminal profiling; Criminalistics; Forensic Science Service (U.K.).

Profiling, screening

Screening of all kinds plays an increasing role in everyday life. Luggage is screened by x rays at the airport to ensure it does not contain any dangerous items. People are screened for cancer to enable cases to be caught and treated early. Employees may be screened at random for the presence of alcohol or drugs. Psychological screening is carried out to ensure someone's suitability for a particular job. Screening is a useful way of a forensic psychologist gaining some basic knowledge of a suspect's mental and psychological characteristics before proceeding to more specialized testing and a full **psychological profile**. The tests used in screening are quick and simple. Sometimes they can even be done and assessed by computer. These tools differ from the psychology quizzes sometimes found in magazines in that they usually have been validated by years of research and experience so the results are meaningful. There are two basic types of psychological screening used in forensic investigation, personality and cognitive screening. Each type gives the psychologist a mini-profile of the suspect which can form a useful basis for more detailed and individual examination.

Personality screening often involves standardized tests such as the Minnesota Multiphasic Personality Inventory or the California Psychological Inventory. These are designed to measure key personality characteristics such as introversion or extroversion, intuition, honesty, neuroticism, optimism, and so on. The results may give the psychologist a feel for whether the person was likely to have committed the crime in question. In the forensic context, more specific screening tools, such as the Psychopathy Check List may also be used. Psychopathy, or anti-social personality disorder, is very common among criminals and a high score may be a useful pointer although not, in itself, proof of guilt. Another specialized screening tool is the Structured Interview of Reported Symptoms, which detects malingering (pretending to be still ill or injured).

Most people are used to taking personality tests in everyday life—after all, they are often used in recruitment so they have become a standard part of a job interview. In many kinds of work, such as teaching and law enforcement, there will be an emphasis on trying to discover the person's integrity and this is often a focus in a criminal investigation. People may think they can cheat a personality test but, in reality, the list of questions is designed to minimize this possibility because certain items are designed to spot untruthfulness and the test as a whole looks for consistency in the replies. Outright lying on the part of the suspect is also common during an investigation. That is why the forensic psychologist will always take the mini-profile alongside other **evidence** to form his or her conclusions. Thus, if the person does not want to seem like a loner in the belief that makes them look guilty of the crime, they may try to skew the answers on the personality test to make themselves look sociable. However, in an interview their true tendencies will emerge.

The other kind of basic screen which is done by the forensic psychologist is the cognitive test which profiles a person's mental ability. He or she may use a standard instrument such as the Wechsler Adult Intelligence Scale, which measures the intelligence quotient or IQ. On its own this is limited, as people have different kinds of intelligence. Someone who is good with numbers, for example, may have little verbal ability. Nevertheless, it is useful, because a person of very low intelligence is unlikely to have committed a sophisticated computer crime, for instance. They may, however, have carried out a violent attack. Other tests of cognitive ability such as memory, verbal reasoning, and comprehension can also help reveal whether the suspect was capable of the crime. Sometimes the crime scene will yield evidence of detailed planning. This may or may not match the mini mental profile the psychologist builds of the suspect. Again, most people encounter such tests on an everyday basis. In most jobs, the employer wants to know if the person has at least minimal mathematical ability and the ability to follow instructions.

The advantage of psychological screening tools is that they are standardized, validated, and therefore, accepted by the courts as part of the evidence. However, on their own they are limited. Just as recruitment for a top job cannot be done on testing alone, it must be followed up with one or more interviews, a criminal cannot be convicted by the use of a screening tool. Nevertheless, preliminary psychological screens play a very useful role in the assessment of suspects.

SEE ALSO Psychological profile; Psychology.

Proximal SEE Anatomical nomenclature

Pseudoscience and forensics

For over a century, science has held out the hope that the administration of criminal justice can be placed on a firmer and more rational footing, one that does not have to rely on ambiguous **circumstantial evidence** or potentially unreliable eyewitness testimony to put criminals behind bars. Defendants may lie, and witnesses are often mistaken about what they know or have seen, but science relies on observable and testable facts. A criminal usually leaves behind **physical evidence** that can be found, examined, and identified through scientific techniques, and linked to the criminal in a way that gives new meaning to the phrase "beyond a reasonable doubt."

In the twentieth century, science began to take on an almost mystical aura of infallibility as some of the tools of the forensic trade began to emerge. The first case that relied on **fingerprint** analysis, for example, was heard in 1911 in Illinois (*People v. Jennings*), and soon the claim that no two persons have identical fingerprints became axiomatic (taken for granted). In 1936, Bruno Richard Hauptmann was convicted for kidnapping and murdering the infant son of Charles Lindbergh, Jr., the first criminal of note to be executed largely on the basis of **handwriting analysis**. In 1979, the profile of forensic odontologists was boosted when bite mark testimony was allowed in the trial of serial killer Ted Bundy. In 1990, testimony about **DNA**, with its seemingly incontrovertible statistical claims about DNA matches, was admitted into **evidence** for the first time. Judges, juries, and members of the public accepted the testimony of forensic scientists with little question.

Skeptics, however, have demanded proof—in the form of clinical trials, publication, peer review, and measurement of error rates—that what forensic experts practiced was science and not pseudoscience. In the early years of the twentieth century, these skeptics performed a valuable service. They exposed the pseudoscientific claims of phrenologists, who asserted that the shape of the **skull** was indicative of mental faculties and character, so that criminal tendencies could be measured with a pair of calipers. Similarly, early handwriting analysts had little in the way of science to back their claims, and their analysis often shaded off into graphology, a pseudoscience that attempts to assess personality through unique handwriting characteristics. In the 1920s, toolmark examination was all the rage; in a rape trial, one examiner testified with apparent breathtaking scientific accuracy that to find an exact match of the knife blade used in the crime, "every one of the hundred million people in the United States" would have to have "six hundred and fifty quadrillion knives each." In the 1930s, efforts were made to link criminal tendencies with particular **blood** types, but the claims were abandoned when they were rejected by the scientific community as pseudoscience.

The skepticism that scuttled these pseudosciences was given renewed life in the aftermath of *Daubert v. Merrell Dow Pharmaceuticals*, a 1993 U.S. Supreme Court case that interpreted the 1975 **Federal Rules of Evidence** as they pertained to the admissibility of expert testimony, including that of forensic scientists. Under the so-called Daubert standard, judges were required to act as gatekeepers for scientific testimony and to demand that the testimony of forensic scientists (and other experts) has a valid, reliable, and relevant foundation.

Arson investigators, for example, have long searched for signs of chipped concrete at fire scenes. Their assumption is that an **accelerant** such as gasoline causes concrete to "fragment," but laboratory tests have called this assumption into question, casting doubt on the validity of this mainstay of arson investigation science. Similarly, many defendants have been convicted of crimes based on visual comparisons of hair **fibers**. However, 26 of the first 74 prisoners to be exonerated by DNA evidence in the 1990s had been convicted largely on the basis of a supposed match between their hair and hair follicles found at the crime scenes. In 1997, a Vancouver, Washington, man was convicted of **murder** largely on the strength of a Dutch expert's claim that he was 100% confident that an ear print found at the crime scene was made by the defendant, even though no peer-reviewed studies confirm the validity of ear print comparison. As of 2005, **ear print analysis** is still used in Europe, and the European Commission is conducting research in hopes of supporting or denying its validity. The **FBI** asked the National Academy of Sciences (NAS) to conduct an examination of voice-print technology, which is premised on the theory that a spectrograph can produce a unique pattern for an individual's speech, but the NAS concluded that the theory had not been validated. Firearm **identification** has come under similar scrutiny because while some of the marks found on a crime scene bullet are unique to the individual gun, other marks are shared by bullets fired from the same model of gun. Further, different brands of bullets can take on identifying marks differently, even though they have been fired from the same gun. In the early 2000s, research was under way to give firearm identification testimony more precision, especially in measuring error rates.

The judiciary began to show similar skepticism in 1999. Massachusetts Federal District Court judge Nancy Gertner assumed the role of gatekeeper that year when she refused to allow a forensic handwriting expert to testify as to the authorship of a stick-up note and restricted the expert to noting points of similarity between the note and the accused robber's handwriting. Said Gertner, "one's handwriting is not at all unique in the sense that it remains the same over time, or uniquely separates one individual from another." In 2001, a federal court in *United States v. Saelee* said that the testing that has been done on handwriting analysis "raises serious questions about the reliability of methods currently in use." In 2002, a federal judge in Philadelphia refused to admit a fingerprint comparison based on his belief that its techniques had not been scientifically validated (he later reversed this decision). The controversy this aroused followed on the heels of a February 1999 report issued by the **National Institute of Justice**, the research arm of the U.S. Justice Department, saying that the "theoretical basis" for fingerprint comparison "has had limited study and needs a great deal more work." A new study of the science behind fingerprint comparison was scheduled to begin in early 2005.

Although judges and others are demanding more scientific evidence from forensic scientists, few are willing to dismiss these branches of forensics as pseudoscience altogether. Many judges are, however, less shy about branding as pseudoscience some other branches of forensics, including forensic **animation** and forensic **odontology**.

A new branch of forensics, forensic animation, creates computerized illustrations of the events of a crime. The technology was first used in a 1984 New York car accident case. In 1992 it was used to convict a San Francisco man of murdering his brother. It has also been used in product liability and baby-shaking cases. By the early 2000s, over a hundred firms were specializing in the creation of forensic animations. Typical of these was a 72-second animation used to convict a Scranton, Pennsylvania, man accused of shooting his wife. The video broke down the crime second by second, illustrating the angle from which the shots were fired, where they entered the body, and the like. Judges like forensic animation because of its efficiency; a video can show in minutes what might take a day or more to establish with traditional witness-stand testimony. Prosecutors like it because it brings a crime to life in a way that such phrases as "posterior exit wound" uttered by dour scientists do not. Others dismiss the technology as a form of pseudoscience for at least three reasons. First, the animation creates an aura of accuracy and precision, similar to the 650 quadrillion knife blades mentioned above, about the reconstruction of events that is often based, at best, on human analysis and interpretation of physical evidence. Second, the animation fills in blanks in the sequence of events that cannot really be known. And finally, noting that in functioning as executive producers of such videos, many attorneys admit it is possible to manipulate camera angles or lighting to achieve a desired effect that may mislead a judge or jury.

Also coming under severe fire is bite mark evidence offered by forensic odontologists. These experts originally limited their efforts to identifying crime or disaster victims through dental records, but after gaining recognition as a division of the **American Academy of Forensic Sciences** in 1970, they began to branch out into criminal investigations. Relying on low-tech tools like putty to make impressions of bite marks and plaster casts of a suspect's teeth, as well as such high-tech tools as image-enhancing software to make bite mark features more visible, they have testified at hundreds of trials, often involving such crimes as rape, murder, and child abuse, where bite marks are often found on the victims. Some have gone so far as to say that bite marks are as good as fingerprints for identifying a criminal. However, says David Faigman of the University of California Hastings College of Law, "Bite marks probably ought to be the poster child for bad forensic science." He and others point to numerous cases in which convictions have been won after forensic odontologists testified with high certainty that bite marks identified defendants who were later exonerated by DNA evidence. Noting that the field lacks a firm research base, they point to studies in which forensic odontologists in controlled settings arrived at false conclusions anywhere from a quarter to two-thirds of the time and sometimes even failed to identify marks caused by something other than a human bite.

The American Academy of Forensic Sciences, founded in 1948, serves to promote accurate scientific practices within the **forensic science** community through education, professional association, and with its peer-reviewed publication, the *Journal of Forensic Sciences*.

SEE ALSO Animation; Expert witnesses; Federal Rules of Evidence; *Frye* standard; Handwriting analysis; Odontology; U.S. Supreme Court (rulings on forensic evidence).

Psychiatry

Forensic psychiatric evaluations are crucial to many civil and criminal court decisions. Psychiatrists are requested to assess the level of criminal and legal responsibility of defenders in cases of fraud, embezzlement, **murder**, physical aggression, disputes for child custody, and other crimes and court proceedings. In some countries, when a person decides to write a will, his or her mental sanity has to be established in order to prevent disputes among heirs about the legal validity of the will based on allegations of the author's mental health at the time the document was written. Other roles of forensic psychiatry involve studying the psychiatric risk factors for criminal behavior among the population, to evaluate inmates for probationary release, and to research the neurobiological aspects of psychopathic personalities and the risk they may pose to society.

Psychiatry is the field of medical sciences that studies mental diseases and behavioral disorders associated with biological causes. Congenital (present at birth), hereditary, or acquired psychosis, mania, and schizophrenia can often lead to violent or self-destructive behavior and deviant patterns of social interactions. In contrast to psychiatry, **psychology** investigates behavioral, emotional, and cognitive disorders. Psychology also studies the unconscious mechanisms underlying life experiences and mental illness. Both psychiatry and psychology study the development of personality from birth to adulthood, and the psychological (emotional and cognitive) and social or interpersonal developmental needs of each phase of life. However, the medical diagnosis and treatment of psychosis and other psychiatric disorders is the exclusive domain of the psychiatrist, whereas the counseling and cognitive re-education of patients suffering from nonpsychotic disorders, such as neurosis, behavioral problems, and emotional traumas, is usually the role of the psychologist.

Neuropsychiatry or the clinical application of the findings of neuroscience to the diagnosis and treatment of psychiatric disorders has yielded a better understanding of the biological bases of violent and criminal behavior associated with some psychopathologies, as well as a number of new effective diagnostic techniques. Since the 1970s, many neuroscience studies have shown that the brain structures and neurochemistry can be modified during infancy and childhood by the repetitive exposure to traumatic experiences or to neglect. Whereas less than 1% of any given population may present hereditary psychosis, these studies have shown that children born with a healthy brain can be neurologically damaged by chronic exposure to maternal neglect, child abuse, or a violent environment, even if the child is not the direct target of the violence. The brain adapts to such situations by undergoing detrimental and often permanent changes in its structures and neurochemical functions that often lead to psychosis and violent behavior, or to self-destructive patterns and other psychiatric pathologies. Such knowledge is leading many psychiatrists to work in the early detection of children at risk in order to prevent further damage through early diagnosis and treatment of abused children. Forensic psychiatry is therefore, crucial to the evaluation of children victimized by domestic or social violence and/or neglect, and for informing courts and social agencies on the therapeutic needs and available treatments in this vulnerable age group.

Forensic psychiatry differs in nature from clinical psychiatric practice because it aims to prove a fact in court, and is subjected to scrutiny and cross-examination by opposing parts. It requires a wide range of specific studies and adequate techniques as well as a special **training** in order to enable the psychiatrist to act as an expert examiner and witness in court. The psychiatric examiner supplies prosecutors, judges, probation boards, and police investigators with expert diagnosis on the mental state of defenders, convicts, and suspects. Such forensic diagnosis will constitute **evidence** to be considered by judges and/or by the court.

Expert psychiatric evaluation may be divided in three categories: transversal (or horizontal) evaluation, retrospective evaluation, and prospective evaluation. Transversal evaluations aim to establish whether the defendant is suffering in the present from a psychiatric disorder that would acquit him of civil or criminal responsibility. However, an insanity diagnosis implies in many cases the compulsory reclusion to a psychiatric hospital and treatment. If the psychiatric offender poses serious threat to himself and to other people's lives, he can be committed to a mental institution for life. Transversal evaluations are usually requested by the defense or by the prosecution before the trial or in the initial phases of the trial, and are obligatory by law in many countries. Retrospective evaluations require great expertise and technical preparation from forensic psychiatrists in order to infer the mental condition and legal responsibility of the defender at the time he committed the crime. Prospective evaluations, or risk assessment, consist of evaluations based on the present and past history of a convict, or a defendant to determine future risk of recidivism (repeated criminal behavior). It is usually carried out by a multidisciplinary team when prisoners are being assessed for probation, or by the forensic psychiatrist alone to enable the judge to determine the length of a new sentence in cases of repeated offenses.

Another field of forensic psychiatry involves researching the incidence of crime in the population, and is known as crime epidemiology. One such study sponsored by the National Institute of Mental Health (NIMH) was completed in 2002. An entire generation of boys in the city of Dunedin, New Zealand, was periodically evaluated from birth through physical, psychiatric, neurological, and psychomotor tests. In 2002, the group donated **blood** for genetic tests, including those who had a record as juvenile offenders in recent years or were serving sentences for violent crimes. It was found that in addition to having been victims of serious abuse or neglect during childhood, a subpopulation among the delinquent group had a genetic mutation that affected the regulation of a chemical messenger in the brain. Although this subgroup represented only 12% of the delinquents, they accounted for 44% of convictions for violent crimes.

The adoption of psychiatric diagnostic guidelines by some countries in the past 20 years, which are regularly updated to include new scientific advances, are essential for modern forensic psychiatry. The process of forensic psychiatric evaluation can be generally described as requiring interviews with the examinee, clinical physical examination, neurological and endocrine tests, neurological and functional diagnostic tests, neuropsychological assessments, and interviews with third parties. Based on the results of these various tests, forensic psychiatrists issue expert reports and prepare evidence for presentation in court. In the United States, a forensic psychiatric diagnosis is based on the *Diagnostic and Statistical Manual of Mental Disorders*, developed by the American Psychiatric Association. In many other countries the World Health Organization (WHO) guidelines are used, such as the *Clinical Descriptions and Diagnostic Guidelines* and the *Diagnostic Criteria for Research.*

Advancements in neuroscience and the establishment of objective criteria for psychiatric diagnostics as well as the clear and detailed description of the etiology (causes) and ethology (progression) of psychopathologies (serious mental disorders) were important to forensic psychiatry, as these advancements rid the profession of the controversial character often attributed to forensic psychiatry in the past. The APA system adopts objective formulations, similar to those used in other medical specialties. Diagnostic techniques introduced or improved in the last two decades, such as functional brain magnetic resonance **imaging** (fMRI), PET scans, and computer tomography, allow the identification of structural asymmetries and functional abnormalities of the brain associated with some mental illnesses. The same is true for new laboratorial neuroendocrine tests, which give insight into brain chemistry. The advances of neurosciences and the better understanding of brain chemistry gave forensic psychiatry a new scientific status as an objective science, using clear diagnostic parameters and criteria. Therefore, allegations of insanity by defenders can now be proved or disproved on the basis of solid scientific evidence.

SEE ALSO Brain wave scanners; Criminal profiling; DNA typing systems; Epidemiology; Expert witnesses; Forensic science; Genetic code; Nervous system overview; Psychology; Psychopathic personality.

Psychological profile

A psychological profile is a tool that can help crime investigators by telling them the kind of perpetrator they are seeking. The development of psychological **profiling** began in the Federal Bureau of Investigation (**FBI**) Behavioral Science Unit during the 1960s in an attempt to understand violent criminal behavior. Although psychological profiling has been used in the pursuit of **serial killers**, it is also applied to the investigation of **product tampering**, poison pen letter writing, serial bombing, serial rape, kidnapping, **arson**, and single murders.

A psychological profile is built through **evidence** from the scene of the crime, which is integrated into psychological theory. Forensic researchers have built a body of knowledge based upon interviews with criminals and data from a wide range and number of crimes. It is important that the profiler has access to all the information about a crime, from witness statements and analysis of **physical evidence** to **photography** and **autopsy** findings. A perpetrator does not leave behind just physical evidence like fingerprints at the scene when he or she commits a crime. Also left behind clues are clues about behavior and personality which are revealed by a study of the scene and all the evidence connected to it.

Victimology, the study of the victim, is an important part of psychological profiling. The investigator wants to know what attracted this perpetrator to this victim and what the relationship was between them. This may shed light on the motivation for the crime which can reveal much about the personality of the perpetrator and maybe the fantasies driving them.

The perpetrator's *modus operandi* (**method of operation** or M.O.), which describes the tools and strategies used to carry out the crime, can be very revealing. It demonstrates some of the suspect's behavior that, in turn, is linked to their personality. Forensic **psychology** has revealed three main types of offenders. The organized offender plans the crime, sometimes in great detail, bringing tools and taking them away again. The type of offender will take care not to leave evidence behind and will also hide or dispose of the body. The organized offender is usually of average to high intelligence with a stable lifestyle. They normally tend to be married and employed. The disorganized offender often leaves a mess. They don't plan or bring tools; instead they use whatever is to hand to carry out their attack. This type of offender lives alone or with a relative, may be unemployed, of lower intelligence, and have a history of mental illness. Their attacks are often accompanied by considerable violence. The third category is the mixed offender, who shows mixed characteristics of the first two types. While their approach may be carefully planned, the assault itself may be frenzied, showing a person losing control over deep-seated urges and fantasies.

The psychological profile of a criminal can be very revealing of their habits, employment, marital status, mental state, and personality traits. A profile works best if the offender displays some form of mental disturbance such as employing torture or mutilation. Some take a trophy away from the victim, possibly an item of no obvious value but of deep symbolic significance to the perpetrator. They may also use a signature, which is a behavioral sign such as positioning the corpse in a certain way or tying a ligature with a complicated knot. This, again, can reflect a specific personality quirk which may be very revealing to the profiler.

Psychological profiling first proved its worth in the capture of Richard Trenton Chase, the so-called "Vampire of Sacramento," who murdered a woman and drank her blood in 1978. Concerned at the brutality of the crime, the FBI called in the profilers. They noted the disorder at the scene and, from a study of body type and mental temperament, concluded the murderer was white, thin, undernourished, and in his mid-twenties. As a disorganized type, he'd be unemployed and live alone. They also guessed he would kill again and, unfortunately, three days later he did. He murdered three people in their own home, stole the family car and then abandoned it. The second **murder** provided more information to refine the profile. Chase was soon found, living locally. His appearance was just as the profile had suggested. He had a history of mental illness, admitted the crimes, but did not see he had done wrong. He told his interrogators that his own blood was turning to sand, so he had to become a vampire. The profile saved many lives, for Chase had more murders planned and marked down on a calendar found in his room.

SEE ALSO Criminal profiling.

Psychology

Psychology is the science of the mind. An appreciation of what is happening of the mind of a criminal and why he or she acts as she does can be an important part of any investigation. A forensic psychologist (or psychiatrist, if they are medically qualified) can carry out a number of functions, such as assessing the mental stability of a suspect, building a **psychological profile** of the perpetrator and victim, and trying to understand the motivation for a crime.

Psychological tests can be useful in learning more about a suspect and their behavior. Standardized personality screening tests, of the kind that are sometimes also used in recruitment, can reveal the suspect's basic personality type. The tests are lists of questions to be checked which elicit responses about behavior, emotion, social skills, and beliefs. One common personality test includes the Minnesota Multiphasic Personality Inventory (MMPI), which can reveal if someone is suffering from a mental disorder such as anti-social personality disorder.

The psychologist may also use more subjective tests known as projective tests, which reveal more about inner conflict, fantasies, and thought processes. In the widely used Rorschach inkblot test, the suspect is shown a series of abstract inkblots and asked to describe what he sees. Another approach is to ask the subject to draw something like a house or a frightening scene. This can be very revealing of the suspect's fantasies and may be in complete contradiction to what they actually say to the psychologist.

The third kind of psychological test that may be administered is a cognitive test that measures the suspect's intelligence, mental competency, thought processes, and ability to understand his or her behavior. A common example is the Wechsler Adult Intelligence Scale. Less structured interviews will also be carried out, where the suspect may be encouraged to talk about their family, childhood, relationships, and problems. The psychologist will lead up to a discussion of the events that brought the suspect in for **interrogation** and try to find out how they feel about what happened. Of course, many suspects lie, but a skilled psychologist will be able to sort out the truth from the fiction by analysis of the subject's body language.

SEE ALSO Profiling, screening; Psychiatry.

Psychopathic personality

For both forensic **psychiatry** and legal purposes, the correct diagnosis of psychiatric disorders in criminal offenders is crucial to establish legal and criminal responsibility. Psychopathic personality disorder (PPD) is a psychiatric disorder. The majority of patients with a psychiatric disorder do not commit crimes. For that matter, although psychopathic personality disorder shows a high prevalence among criminals, it does not imply that all carriers of the disorder will necessarily become involved with criminal activity. Conversely, all criminals do not have a psychiatric disorder. An estimated 1–4% of individuals among the general population present some degree of the symptoms described for psychopathic personality disorder.

Psychopathic personality disorder is a chronic psychiatric condition with specific manipulative and exploitive behaviors that persist for many years. The cause of PPD is unknown, although genetic factors and a history of child abuse are thought to play a role. The condition affects more men than women, and often, persons with psychopathic personality do not seek treatment unless ordered to do so by a court. The diagnosis of psychopathic personality is most often made by a forensic psychiatrist.

Perhaps the main characteristic of PPD is the inability to feel remorse. The American psychiatrist and neuroscientist Bruce Perry defines remorse as a painful emotional reaction that results from the realization of how much suffering the individual has caused to another person. Remorse, therefore, implies the capacity to empathize with the pain one has caused another person. People with psychopathic personality disorder have no such capacity. They can repent or intellectually recognize they were wrong, when they are caught, especially if such recognition brings some advantage to his or her situation. However, repenting is a rational exercise, and not an emotional event, according to Perry. People with PPD are often highly intelligent and have able manipulative skills, but often have poor emotional intelligence and are unable to understand or consider other people's feelings. In essence, they are predators, often presenting a cunning intuitive perception of other's psychological fears and weaknesses, which they exploit for self-benefit. Persons with PPD are not solely found among criminal ranks; often they are present at the workplace, in social circles, and in the political scenery. Swiss psychiatrist Karl Jung (1875–1961) made an interesting psychological assessment of Hitler in the late 1930s, describing characteristics belonging to Hitler which resemble the main criteria for PPD: superficial charm, grandiose sense of self worth, keen manipulative skills, lack of realistic long-term goals, irresponsibility, lack of remorse or guilt, callous lack of empathy, poor behavioral control, self-centered and self-important feelings, blaming others for his failures, predatory attitudes, easily-frustrated, impatient, and ambitious.

People with psychopathic personality disorder who do not commit crimes are likely to have troubled relationships at home and in the workplace, due to their destructive personality characteristics and need to manipulate and control others. They have the ability to undermine self-esteem and self-confidence in others. They feel superior to others and consider themselves above the rules that regulate society. Their main aim is self-gratification, even when they pretend to be caring and concerned with the well being of others. Self-image and self-interest are a high priority for people with these characteristics. They often lie, abuse, steal, cheat, and are unscrupulous in business partnerships and commercial transactions. Appearing fearless, they may put at their lives and the lives of others at risk during thrill-seeking activities. Many white-collar criminals share characteristics with this personality group, and often elude authorities.

Violent psychopaths who end up in prisons are usually less intelligent or have little education, and began criminal activities as juveniles. Violent psychopaths may have a childhood history of torturing small animals and/or of repeated acts of vandalism, systematic lying, thefts, violent behavior towards smaller children, and defiant attitude with parents, teachers, and other authority figures.

In contrast with other psychiatric offenders, criminals with psychopathic personality disorders have a clear understanding that they are breaking the rules. They are convinced, however, that rules exist only for those who are inferior to themselves. Breaking the rules without being caught is a means of proving their superiority. Rehabilitation programs usually provide little benefit to criminals with psychopathic personality disorder, as they do not view incarceration as deserved punishment, and they have no remorse for their actions or wish to alter their behavior.

SEE ALSO Criminal profiling; Criminology; Hitler Diaries; Psychiatry; Psychology.

Psychotropic drugs

Determining the presence of various drugs in samples, including **blood** and urine, is an important facet of **forensic science**. A variety of analytical techniques can be used, depending upon the drug being tested. Eyewitness information concerning the behavior of the victim or suspect, and physical aspects of the investigation scene (i.e., presence of syringes, open liquor bottles, or the smell of marijuana), can guide the law enforcement officer or forensic investigator in recommending particular drug tests.

Psychotropic drugs are forensically relevant. The drugs are a loosely defined grouping of agents that have effects on psychological function and include antidepressants, hallucinogens, and tranquilizers.

They are all compounds that affect the functioning of the mind through pharmacological action on the central nervous system. Psychotropic drugs are widespread in today's society and encompass both prescription psychiatric medications and illegal narcotics, as well as many over the counter remedies. Because these compounds affect human behavior, there is much suspicion, misunderstanding, and controversy surrounding their use. Sedative drugs first appeared in the late 1800s. They were followed by **barbiturates** and **amphetamines** in the early 1900s. But it was drugs such as chlorpromazine hydrochloride (Thorazine) and lithium, introduced in the 1950s, that dramatically affected psychiatric medicine. Medicine essentially recognizes four main psychotropic drug categories: antipsychotics, mood stabilizers, antianxiety agents, and antidepressants.

Antipsychotics include chlorpromazine, which was released in 1954 for the treatment of schizophrenia. Originally designated as a major tranquilizer, it was also found to be effective in subduing the hallucinations and delusions of psychotic patients. Since then, other antipsychotics, including haloperidol (Haldol) and clozapine (Clozaril) were developed for the treatment of various kinds of psychosis.

Mood stabilizers were first recognized following Australian psychiatrist John F. J. Cade's 1949 discovery of the beneficial effects of lithium on manic-depressive disorder. Patients with schizophrenia, however, did not respond to lithium, leading psychiatrists to a degree of diagnostic precision that was previously not possible. Recently, some antiepileptic medicines—valproic acid (Depakene) and carbamazepine (Epitol, Tegretol) have also been used to treat manic-depressive disorder.

Barbiturates were widely prescribed before the 1960s to relieve anxiety, but were found to be highly sedating and addictive and did not always work successfully. Chlordiazepoxide (Librium) and the other benzodiazepine agents developed from the 1960s to the 1980s rapidly replaced barbiturates.

Antidepressants are possibly the most widely used psychotropic drugs in the United States. In any given six-month period, about 3% of adult Americans experience severe depression. For the millions whose depressed mood becomes a clinical syndrome, though, psychotropic therapy is one way to relieve the symptoms. The tricyclic imipramine hydrochloride (Tofranil), developed during the late 1950s and introduced during the early 1960s, was the first of the now-available antidepressants and still is often prescribed. Research has progressed considerably since then and current theories attribute depression to psychological causes (low self-esteem, important losses in early life, history of abuse) and biological causes (imbalance of **neurotransmitters**, including serotonin and dopamine; disruptions in the sleep-wake cycle) as well as social factors. The various classes of antidepressants—tricyclics, MAOIs, serotonin-specific agents—and individual drugs—including nefazodone (Serzone), mirtazapine (Remeron), venlafaxine (Effexor), and bupropion hydrochloride (BuSpar)—target the biological causes. At present, the selective serotonin reuptake inhibitors (SSRIs) hold center stage, and fluoxetine hydrochloride (Prozac) is in the spotlight. The result of years of focused research and design, fluoxetine was rapidly accepted and prescribed to millions within a few months after its introduction in December 1987. As of 2005, long-term effects of SSRIs and potential elevated risks of suicide in young people taking SSRIs are under study.

Though much of the research and understanding of psychopharmacology comes from the field of medicine and **psychiatry**, there are, of course, other areas where psychotropic drugs have been used, ranging from illegal recreational use to the possibility of applying them as agents of "mind control." The Central Intelligence Agency (CIA) Crime and Narcotics Center monitors, reviews, and delivers information about international trafficking in illegal drugs and international organized crime to the nation's leaders and law enforcement agencies. Former Director of Central Intelligence William Webster created what became today's DCI Crime and Narcotics Center in April 1989. The center is staffed by people from the 13 agencies making up the US Intelligence Community, including the CIA, as well as from law enforcement agencies. The Crime and Narcotics Center's staff are responsible for estimating the amount of illegal drugs, mainly coca, opium poppy, and marijuana, produced around the world. They also assist law enforcement agencies to break up drug and organized crime groups and help law enforcement agencies detect and capture illegal drug shipments.

Psychotrophic drugs are potentially useful in the **interrogation** of suspects. One such drug is sodium pentothal, more commonly known as **truth serum**, which is used as a sedative and anesthetic during surgery. It depresses the central nervous system, slows the heart rate, and lowers blood pressure. Patients on whom the drug is used as an anesthetic are usually unconscious less than a minute after it enters the veins. Because of its effectiveness as a sedative, it was also one of the first of three drugs to be used by the U.S. prison system during executions. In milder doses, the drug affects people such that they often become more communicative and share their thoughts without hesitation. Despite its name, however, sodium pentothal will not make a person tell the truth against their will, but a recipient is only more likely to lose inhibitions and therefore, may be more likely to volunteer the truth.

SEE ALSO Interrogation; Truth serum.

Puncture wound

A puncture wound is the piercing of the body by a sharp-tipped object. It can be as trivial as pricking a finger with a needle or drawing pin, or as serious as the fatal penetration of the heart or lungs with a knife. Puncture wounds tend to have more depth than width, which distinguishes them from cuts, where the reverse is true. In a forensic context, the most significant kinds of puncture wounds are stab wounds, which are often fatal.

A stab wound can be homicidal, suicidal, or accidental and **autopsy** can often shed light on the manner of death in such cases. Many different weapons can be used to inflict stab wounds. Typically, a knife is used but screwdrivers, fragments of **glass**, hat pins, or hypodermic needles may also cause stab wounds. The weapon need not even be held by an assailant. In some accidents, people sustain broken ribs which puncture the lungs, or fall on broken glass or spiked railings.

During an autopsy, the pathologist will look at the location, depth, and track of puncture wounds. He or she will try to work out from what direction the weapon entered the body, the track it took, and the damage caused. X rays can be useful in establishing the track of the wound and may also be indicative of the dimensions of the weapon. It is also important to examine any damage to clothing; the direction of any tears and **blood** patterns may reveal something of the victim's position relative to the assailant.

Relatively little force need be applied to the weapon to build up a penetrating pressure on its pointed end. Once the weapon has penetrated the victim's clothes, then the body itself offers relatively little resistance to its penetration, unless it impacts on bone. Weapons that break into bone will have been applied with considerable force. Often, the tip of the weapon is left behind in the victim's body and, if the pathologist retrieves it, they will have a valuable piece of **evidence**.

Wounds that enter an organ are known as penetrating and if they also pass out the other side they are known as perforating. Much of the bleeding in a stab wound is internal. Indeed, a trivial looking puncture of the skin may conceal a very deep and possibly fatal wound. Cause of death is usually massive hemorrhage. Most deaths by stabbing are homicidal in nature and common sites for the wounding are the heart, abdomen, back, and throat. The pathologist will want to deduce as much as possible about the circumstances of the event by the analysis of the nature of the stab wounds.

SEE ALSO Knife wounds; Wound assessment.

Q

Quality control of forensic evidence

When an item of **evidence** that could be crucial to securing a conviction appears in court, judge and jury want to be sure that it really is relevant to the crime. The only way of fulfilling this requirement is to make the concept of quality central to everything the forensic investigator does with the evidence, from collecting it to presenting it in court. This striving for quality is not confined to **forensic science**; it is found in most other industries, from pharmaceuticals to aerospace. The underlying goal is to offer products and services to the public that are safe and effective. In forensic science, quality of evidence is important because if first-rate evidence is not submitted in court, the guilty may go unpunished or, equally, an innocent person may lose their liberty.

The terms quality control (QC), and quality assurance (QA) are often used interchangeably. What is more, their meanings may differ from place to place and between different kinds of activity. Put simply, QC covers all the different activities done to fulfill quality requirements for a product or service. In forensic science, this might cover the need to run **control samples** when doing a **DNA** analysis or to keep records of exactly what was done in the microscopic examination of a hair sample. The term QA is a broader one, covering the overall system of dealing with evidence and includes issues such as staff training and qualifications and the laboratory environment. A disorganized laboratory, with no clear chain of command, cannot reasonably be said to be providing good QA. In this article, the term QA/QC will be used to cover all aspects of quality in forensic investigation.

The idea of quality began with medieval craftsman who organized themselves into guilds dedicated to making products of a high standard. Products that reached the quality standards of an inspecting committee would receive a special quality mark. Master craftsmen began to add their own quality marks to their products to guard their reputation and standards. Customers who bought products bearing inspection and master craftsman marks were assured of the quality of their purchase. It was in the twentieth century that the concept of quality was broadened to include many more products and services, including forensic science. The medieval quality marks have evolved into a more general idea of standards, which are procedures, metrics (measurements), behaviors, or whatever is needed in a particular activity to guarantee a quality output.

Standards vary from place to place, so there is a need for some kind of international reference. After all, the result of DNA **identification** should not vary depending on the country or laboratory where it was done. If the defense orders a second opinion, then it merely confuses matters if the second lab follows a different procedure from the first one. The ISO (International Organization for Standardization) 9000 series is a set of international standards on quality management and QA/QC, which was established in 1987 and is constantly being updated and revised. A lab dedicated to forensic investigation can be registered to ISO 9000 standard, which gives proof of the quality of its work. Another important idea in the improvement of quality is benchmarking. This involves a search for a benchmark, an example of best practice or the best way of doing something, and comparing current practice with the benchmark. Quality is an evolving concept, with organizations and individuals continually being challenged to reach ever-higher standards. In science, methods and equipment are changing all the time, and laboratories and their personnel must keep up and adapt. For crime investigation, this can only be a good thing, for it means enhancing the court's confidence in the evidence being presented.

In the context of forensic investigation, QC/QA covers scientific, legal, and ethical aspects of the work of both laboratory scientists and the police scene-of-crime officers. Forensic science involves many different disciplines, from **pathology** and chemistry to engineering and **entomology**. Whatever the nature of the evidence, however, its preservation from deterioration or contamination is paramount. **Trace evidence**, in particular, is vulnerable in this respect. Protective clothing at the scene and restricted access can help preserve the evidence that is present. After that, proper and securing packaging is essential. Once in the laboratory, the evidence must be correctly stored, which may involve refrigeration or protection from moisture, and it must never be left unattended or unsecured in case of tampering or theft.

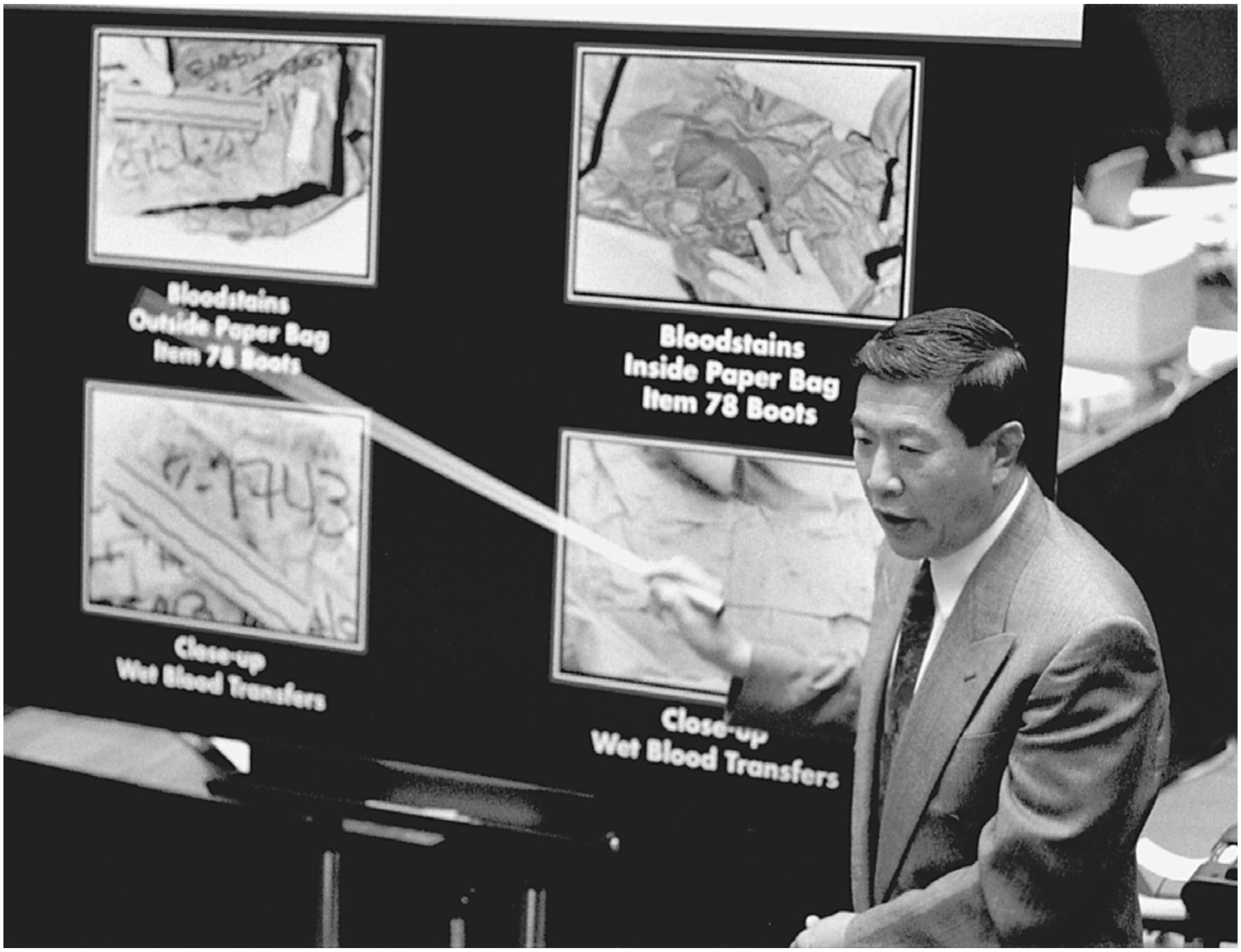
When it comes to laboratory investigation of the evidence, there will be Standard Operating Procedures (SOPs) and Standard Methods (SMs) that must be followed. These are written instructions as to how to carry out a given task using properly tried and tested methods. These SOPs and SMs will change over time, as new methods, equipment. and evidence emerge. A court would, rightly, not be impressed to discover that a forensic laboratory was still carrying out, for example, **fingerprint** analyses according to a method from the 1950s.

A wide range of equipment, including spectrometers, **microscopes**, **cameras**, and gas chromatographs is used in the forensic laboratory. An important part of QA/QC is ensuring all this equipment is properly used by staff that have received correct training. The equipment must also be properly and regularly calibrated, that is, run with reference samples to ensure its correct operation. It must also be regularly maintained and replaced or upgraded if faults occur.

Quality standards apply as much, if not more, to the people working in the forensic laboratory as to the equipment and methods they use. First, the person must have the appropriate scientific qualifications for the job. Requirements may vary, but each person should have a written job description including their responsibilities, duties, and skills required. The manager of the laboratory will have had several years of experience of forensic work. Technicians will have qualifications appropriate to the type of work they are carrying out. Everyone's work needs to be supervised and audited, both internally and externally. Because forensic science is such a rapidly evolving discipline, it is essential that there be provision for continuing education for everyone employed in the laboratory. This might include the opportunity to take a higher degree and will certainly involve taking courses to learn new techniques from time to time and keeping up with the professional literature to increase awareness of developments. In addition, an important part of being a forensic science professional is to be prepared to testify in court. This may involve fierce cross-examination and the individual must be objective and confident enough to defend their work as well as making the principles and detail involved accessible to the judge and jury.

Everyone working in a forensic laboratory must do all they can to take a scientific, objective, approach to their work, just as one would in any other laboratory setting. This means being unbiased, prepared to repeat experiments, using control and reference samples, and keeping accurate records of procedures carried out and results obtained. Over and above this, there are special requirements for forensic investigators relating to ethical and legal aspects of the work. Perhaps the most important requirement here is an awareness of the importance of the **chain of custody** of evidence. This means that it must be clear to the court exactly what has happened to the evidence from the moment of its collection to its presentation in the courtroom. Everyone who handled the evidence in any way must sign for it and record what they did with it. Only with an unbroken chain of evidence can the judge and jury be sure of the relevance of the evidence to the crime under investigation.

Not only must the evidence itself be properly handled and accounted for at all times, careful records must also be kept of all operations carried out on it. At one time, these would have been hand written. Now, however, there are many computerized laboratory information handling systems. The forensic laboratory should be using a recognized and



A defense witness forensic scientist uses a pointer as he describes how blood stains were transferred from evidence items to the paper bags they were carried in during the O.J. Simpson double-murder trial in 1995. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

acceptable system and all personnel should be trained in its correct use.

People who choose to work in forensic science generally do so because they have a keen interest in the subject and are motivated to help solve crimes and see justice done. However, it is not unknown for a forensic investigator, maybe under the stress of his or her workload or maybe for more sinister reasons, to lose or destroy evidence, make mistakes, or even to falsify results. The QA/QC system should allow for the rapid detection and correction of this kind of incident.

Laboratories doing forensic work can apply for accreditation by an independent third party, which is also seen as an important part of QA/QC. In the United States, this accreditation is carried out by the American Society of Crime Laboratory Directors through their Laboratory Accreditation Board. A satisfactory evaluation and on-site inspection of the organization, staffing, and facilities of a laboratory can lead to accreditation. After this, a full re-inspection will be carried out every five years. Many laboratories in the United States have been accredited in this way and similar schemes apply in other parts of the world, such as the United Kingdom. Forensic science cannot stand still when it comes to quality; the discipline must always be striving to improve.

SEE ALSO Disturbed evidence; Evidence.

Questioned documents

In 1795 an Englishman named William Henry Ireland made an astonishing claim: that he had in his possession a manuscript of the play *Kynge Leare,* written in the hand of William Shakespeare himself. Such a discovery would have been invaluable, for no manuscript version of any of Shakespeare's plays is known to exist. A year later, however, Edward Malone was able to refute Ireland's improbable claim. In examining the manuscript he discovered twenty distinct paper watermarks among its leaves. Surely, Malone concluded, by the time he had written *King Lear*, Shakespeare would have been financially secure enough to be able to purchase a single batch of paper on which to write. The hodge-podge of different papers in the Ireland manuscript could be explained only as the work of a forger, who would likely raid a variety of old manuscripts for paper that would appear authentic, which is exactly what happened. In 1805, Ireland confessed that the manuscript was a forgery and that indeed he had obtained the paper by paying a bookseller to tear pages out of old manuscripts.

Malone was not the first questioned document examiner. In 1681, a French monk named Jean Mabillon (1632–1707) published *De Re Diplomatica*, which outlined a science he founded called diplomatics, or the analysis and verification of documents. Neither Mabillon nor Malone could have known that their efforts would eventually evolve into a branch of **forensic science** called questioned document examination (QDE). In Malone's day and later, a document examiner relied primarily on a good set of eyes, a microscope, and perhaps rudimentary chemical tests, but as new scientific tools emerged in the twentieth century, the field evolved into a complex specialty, demanding from its practitioners a high level of **training** and scientific knowledge.

To that end, in 1913, prominent questioned document examiner Albert S. Osborne invited a select number of colleagues from around the United States and Canada to join him to discuss problems and share research in QDE. For three decades Osborne, whose *Questioned Documents* (1910) and *The Problem of Proof* (1922) are regarded as classic books in the field, continued to meet informally with his colleagues until they formally founded the American Society of Questioned Documents Examiners, the field's leading professional organization, in 1942.

The term "questioned document" refers to any handwriting, typewriting, signature, or mark whose authenticity is in dispute. The types of documents that come under the examiner's purview include wills, contracts, letters, threatening letters, suicide notes, ransom notes, photos, lottery tickets, passports, voter registrations, drivers licenses, checks, tax returns, sales receipts, torn pieces of paper (such as matches torn from a matchbook), photocopies, carbon paper, charred paper, faxes, and the like. Although typically such documents are paper, examiners can be called on to examine any surface on which marks or writing appears, including, for example, walls, blackboards, or rubber stamps. In one noteworthy 1989 case, an apparent kidnapping and **murder** of a young girl, document examiners were called on to examine the plastic garbage bag in which the victim was found. Minute markings created by the heat-seal process used in manufacturing such bags enabled investigators to determine that the bag was manufactured on the same machine within seconds of other bags found in the parents' house, key **evidence** that resulted in the conviction of the girl's mother for murder.

Questioned document examination is a catch-all term for a field that encompasses a number of subspecialties, some of which overlap and any of which could play a role in the investigation of a crime. These include: (1) **handwriting analysis**, which attempts to show whether a questioned document came from the same hand as a document known to have been written by a particular person; (2) historical dating, which uses such techniques as carbon-14 dating to determine the age of a document; (3) typewriting analysis, which can trace the origin of a document to a make and model of typewriter and to an individual typewriter, a technique used in the investigation surrounding Unabomber Ted Kaczynski; (4) fraud investigation, which follows money trails and often relies on questioned document examination to demonstrate criminal intent; (5) paper and ink specialists, who use chemical and other methods to identify and date different types of paper, ink, watermarks, copy machines, printer cartridges, and the like; (6) forgery specialists, who use lighting, spectography equipment, and the like to determine whether a document or parts of a document have been erased, changed, or otherwise doctored; and (7) forensic stylistics, in which examiners look at linguistic style, grammar, and word choice, to determine whether a person was the likely author of a document. A new and evolving subspecialty is (8) **computer crime investigation**. This subspecialty uses some of the same techniques as typewriting analysis, examining ink cartridges, paper alignment, the alignment of images produced by printers, and fiber analysis of paper, as well as discovery of hidden, protected, temporary, or encrypted computer files, recovery of deleted files, analysis of unallocated space on a computer disk. Any of these subspecialties can merge under the general heading of questioned document examination.

While many state crime labs have questioned document units, the Federal Bureau of Investigation (FBI) often serves as the lead investigative agency or provides technical expertise because of its enormous resources. The FBI's reference files include information drawn from previous casework; thus, evidence such as a threatening note can be compared with other threatening notes that were part of earlier investigations. Examples include the Anonymous Letter File, the Bank Robbery Note File, and the National Fraudulent Check File. The agency's standard files are banks of legitimate documents used for comparison with questioned documents. Examples of these include the Checkwriter File, the National Motor Vehicle Certificate of Title File, the Office Equipment File, and the Watermark File. Watermarks have proven invaluable in many cases to show that a document could not have been written when it was alleged to have been written because the watermark did not exist at the time.

QDE has played a major role in the investigation of cases involving murder, forgery, counterfeiting, art crimes, gambling, kidnapping, organized crime, fraud, con games, theft, **arson**, burglary, serial murders, and sex crimes. The majority of cases in which the FBI Questioned Documents Unit (QDU) becomes involved require handwriting analysis. A typical FBI case arose in 1956, when a one-month-old child was kidnapped from his Long Island home. In the baby's carriage, investigators found a ransom note torn from a notebook purporting to be from the child's babysitter. FBI investigators called in to examine the note discovered distinguishing characteristics in the way the writer formed 16 letters of the alphabet. Of particular interest was the writer's lowercase *m*, which looked much like a sideways *z*. Investigators searched through nearly two million documents looking for similar writing until a Brooklyn, New York, probation officer found in his files documents written by a 31-year-old auto mechanic with the same peculiar *m*. After the FBI determined that the suspect was indeed the writer of the ransom note, he was arrested, tried, convicted, and executed in 1958.

Other questioned document cases have gained national and even international notoriety. In 1976, document examiners examined the infamous "Mormon Will," a holographic will allegedly written by reclusive billionaire Howard Hughes. According to the terms of the will, which had been mysteriously delivered to the offices of the Mormon Church, the bulk of the estate would pass to the church, but $156 million would go to one Melvin Dummar of Gabbs, Nevada. For months, Dummar claimed that he was a beneficiary under the will because a bum he had picked up in the desert and driven to Las Vegas was in fact Hughes, who was rewarding him for his kindness. Eventually, document examiners determined that the will was a hoax. In a similar case, in 1983, after *Stern* magazine in Germany began publishing portions of a set of diaries purportedly written by Nazi dictator Adolf Hitler, document examiners at Germany's Federal Archives, using ink and paper analysis, determined that the diaries were forgeries created by an artist and petty criminal named Konrad Kujau.

Questioned document examiners bring to bear a number of high-tech tools, many of which are manufactured by the UK firm Foster and Freeman. The firm's ESDA^2 is named after the process it uses, called electrostatic detection, to render visible indented writing, such as writing that appears only as indentations on the next sheet of paper in a pad. The Video Spectral Comparator 5000 is used to examine questioned documents in the visible and near infrared regions of the light spectrum and can determine the presence of indented writing, make obscured writing visible, and differentiate inks and papers by their optical properties.

An invaluable tool has been the company's FORAM 685–2, which uses surface enhanced resonance Raman **spectroscopy**, or SERRS, to compare ink samples as small as 5 microns. Raman spectroscopy, developed in 1928 by Indian scientist Chandrasekhara Raman, has a wide variety of applications in law enforcement. It is used, for example, to identify explosive materials and to detect the presence of **illicit drugs**. Librarians and archeologists also use it to determine the chemical makeup of ink or paint found on ancient documents. Armed with this technology, a document examiner can measure the vibrational structure of molecules by exciting them with photons and examining the light the substance emits when its molecules "de-excite." More specifically, the technique directs light from a monochromatic **laser** down an optical microscope to a sample. The sample absorbs the light, but when it re-emits the light, the light is at a different wavelength. This re-emitted light is fed to a diffraction spectrometer, which records the spectrum and displays it on a computer. The light spectrum is a kind of fingerprint that identifies the substance from which it was emitted, for example, a specific kind of ink on a questioned document.

SEE ALSO Art forgery; Computer forensics; Document forgery; Handwriting analysis; Hitler Diaries; Howard Hughes' will; Spectroscopy; Typewriter and printer analysis.

R

Radiation damage to tissues

Some forensic **evidence** is easy to detect. Gunshot and **knife wounds** and the burns inflicted by chemicals or fire are obvious examples. However, other causes of injury or death are not as easily detected, at least in their early stages. An example of the latter is exposure to radiation. While exposure to a high level of radiation can cause rapid death and massive burning of the skin, the exposure to less immediately harmful levels of radiation cause subtle internal changes in the body. Knowledge of these changes can be useful to a forensic investigator.

Certain types of radiation exposure may cause mutations (**DNA** damage and genetic alterations) or accelerate the types of mutations that occur spontaneously at a very low rate. Ionizing radiation was the first mutagen that efficiently and reproducibly induced mutations in a multicellular organism. Direct damage to the cell nucleus is believed to be responsible for both mutations and other radiation-mediated genotoxic effects like chromosomal aberrations and lethality. Free radicals generated by irradiation of the cytoplasm are also believed to induce **gene** mutations even in the non-irradiated nucleus.

There are many kinds of radiations that can increase mutations. Radiation is classified as ionizing or non-ionizing depending on whether ions are emitted in the penetrated tissues or not. X rays, gamma rays, beta particle radiation, and alpha particle radiation (also known as alpha rays) are ionizing forms of radiation. An example of non-ionizing radiation is sunlight, more specifically the ultraviolet component of the visible light spectrum of wavelengths.

Critical lesions leading to mutations or killing of a cell include breaks in the DNA strands, damaged bases (the building blocks of DNA: adenosine, thymine, cytosine, guanine) and sites where a base is deleted. Large chromosomes can also be deleted when cells damaged by radiation are replicating. Except for large deletions, most of these lesions can be repaired to a certain extent, and the lethal and mutagenic effect of radiation is assumed to result principally from incompletely or incorrectly repaired DNA. This view is supported by experimental studies, which showed that mice given a single radiation dose, called an acute dose, develop significantly higher levels of mutations than mice given the same dose of radiation spread over a period of weeks or months, allowing time for DNA repair.

Biologically, the different effects produced by the different types of radiation involve the way energy is distributed in irradiated cell populations and tissues. For example, alpha radiation ionizations occur every 0.2–0.5 nanometers (nm), which leads to an intense localized deposition of energy. Accordingly, alpha radiation particles will travel only about 50 nm before expending of their energy. Primary ionization in x rays or gamma radiation occurs at intervals of 100 nm or more and traverses centimeters into tissues. This penetration leads to a more even distribution of energy as opposed to the more concentrated or localized alpha rays.

Thus, in a forensic examination, the pattern of radiation damage can be a clue to the type of radiation that was involved.

SEE ALSO Chromosome; DNA; Dosimetry; Radiological threat analysis.

Radiation, electromagnetic radiation injury

An important facet of a forensic investigation is the determination of the cause of the injury or death. This may not always be self-evident, since some causes of trauma do not leave readily apparent external clues. This is especially so when the harmful agent originates at some distance from the scene. One example is electromagnetic radiation.

Any nuclear explosion 25 miles (40 km) or higher above the ground produces a high-altitude electromagnetic pulse (HEMP), a short-lived, overlapping series of intense radio waves that blanket a large swath of ground. Electromagnetic bombs have also been developed and tested.

These radio waves can induce electrical currents in metallic objects and so cause damage to electrical and electronic equipment, including electrical power grids, telephone networks, radios, and computers. Since the basis of human **physiology** is the transmission of electrical impulses, disruption of the passage of currents in the body can have debilitating or even dire consequences to cardiac and neurological functions.

The electromagnetic pulse from a nuclear explosion consists of a series of overlapping radio pulses. When a nuclear weapon detonates, large numbers of gamma rays (high-energy photons with wavelengths less than .1 nm) radiate outward from the burst point. Many of these collide with atoms in the Earth's atmosphere, knocking electrons free. These free electrons are created almost simultaneously in a large volume of the atmosphere surrounding the explosion, and travel rapidly away from the burst point in all directions. Because any charged particle crossing magnetic field lines experiences a force at right angles to its direction of motion, the Earth's magnetic field forces these electrons to follow curved paths. Because charged particles following curved paths emit electromagnetic waves (synchrotron radiation), the explosion-liberated electrons spiraling through the Earth's magnetic field emit a strong radio pulse. Additional pulses, of longer duration but lower magnitude, are subsequently caused by scattered neutrons and gamma rays (radiation that has made one or more bounces, rather than following a straight radial path from the burst point) and by the expansion and ascent of the ionized nuclear fireball through the Earth's magnetic field. The electromagnetic pulse caused by the latter effect, termed the magnetohydrodynamic EMP or HD-EMP, is of low intensity but long duration, and is thought to be a particular threat to power transmission lines.

Two other forms of electromagnetic pulse may be caused by nuclear explosions. The first is generated inside electronic devices by the passage of ionizing radiation (e.g., neutrons and gamma rays) directly into metallic cases, circuit boards, semiconductor chips, and other components, where it can cause brief electrical currents to flow by knocking electrons loose from atoms. This effect is termed systems-generated electromagnetic pulse (SGEMP). The other form of EMP—source-region EMP or SREMP—occurs when a nuclear weapon explodes at low altitude. In this situation, a highly asymmetric electric field is produced in the vicinity of the burst (e.g., within a radius of 3–8 km) having intensities that are much greater than those produced by the high-altitude electromagnetic emission.

SEE ALSO Electrical injury and death; Electromagnetic weapons, biochemical effects.

Radiological threat analysis

Many countries have stocks of radioactive materials arising from nuclear weapon and nuclear power programs. Therefore, there is an ongoing threat of release of significant amounts of radiation into the atmosphere either by accident or by sabotage. Since the World Trade Center attacks of September 11, 2001, fears that terrorists might steal material from a nuclear facility to build a bomb have grown. Experts are now trying to analyze and take precautions to deal with such threats.

Radiological threat analysis starts with assessing and managing the potential dangers of nuclear sites and activities and reducing their vulnerability to accident or attack as far as is possible. Sites where large amounts of material are stored, a nuclear power station, for instance, need to be protected by the police or the military. Security should be tight, but must not interfere with the activities of the site, which may be making a significant contribution to the country's energy supply.

Potential radiological threats are of three kinds. A group may actually steal a nuclear weapon, they may steal radioactive materials or they may attack or sabotage a nuclear installation. There have been no known instances of the first scenario, but plutonium and highly enriched uranium have been known to go missing and may have fallen into the hands of terrorists. There have also been several cases where people have tried to break into nuclear installations but none of them have led to serious harm. Indeed, the perpetrators of the World Trade Center bombing of 1993 threatened to target nuclear installations in a letter to the *New York Times*. Experts have tried to analyze various scenarios such as the sabotage of vulnerable areas, like the control room or electricity supply, inside nuclear installations. These exercises have led to new approaches to tightening up security.

One important finding that has emerged from forensic radiological threat analysis is that no nuclear installation in the world could currently withstand an air strike. Since September 11, officials consider this fact a significant vulnerability. The special hazards presented by nuclear reprocessing plants have also been highlighted by scientific analysts. Nuclear transport trains, which carry plutonium for hundreds of miles in countries like France, are also potential targets for a radiological threat. Such transportation should be minimized, if not eliminated, wherever possible. The analysts must always keep one step ahead of the terrorists, trying to imagine the worst-case scenario of what they might do and then taking steps to prevent it.

SEE ALSO Chemical and biological detection technologies; Chemical Biological Incident Response Force, United States; Chemical warfare; Radiation damage to tissues.

Rape kit

A rape kit, also known as a sexual assault **evidence** kit (SAEK), is a collection of biological evidence taken from a rape or sexual abuse victim after an assault. The kit, which varies by state and situation, aids in arresting and convicting a suspect. It should be collected within 72 hours of the attack, with complete retrieval often requiring up to four hours. The victim's informed consent is necessary for a rape kit to be used.

Once the rape kit is opened, the "chain of evidence" must be maintained. Evidence cannot be left unattended. The recommended contents of a rape kit typically include: instructions and check-off sheet; large paper sheet; filter paper; small paper bags; cotton-tipped swabs; small cardboard boxes; comb; wooden splints; envelopes; red-topped and purple-topped tubes for **blood** sample collection; history and physical documentation forms; patient discharge information form; patient's clothing; fingernail scrapings, broken fingernail pieces; hair strands; oral swabbing; pubic hair; vaginal swabbing; vaginal washings; cervical smear; rectal swabbing; blood samples; and microscope slides.

To begin the process of collection, a nurse individually bags each article of the victim's clothing to be submitted to the investigating police officer or directly to the crime laboratory. Items of clothing are placed in paper bags, not plastic bags, as plastic may promote bacterial growth on blood or **semen** stains. Clothing can be collected up to one month after the assault, provided the items have not been laundered.

The pubic hair region is combed to recover any foreign hair that may have been deposited by the assailant. The comb is then placed in an envelope that is sealed and initialed. The patient is examined for visible blood or seminal stains. If the nurse observes such stains, a gauze pad is moistened, the stain is collected on the pad, the pad is allowed to air dry, and then it is placed in one of the plastic bags. The area swabbed is documented. Ten to fifteen pubic hair **control samples** are taken from the victim. A representative hair sample is also obtained, preferably pulled and not cut from the victim.

A set of swabs is used to prepare two vaginal and cervical smears on the microscopic slides. The speculum used to examine the cervix should be lubricated only with saline, since K-Y jelly may be spermicidal and may interfere with wet mount procedures and forensic evaluation. The slides are sprayed with a cytological fixative and allowed to air dry for three to five minutes before being labeled.

The condition of the hymen and any perineal trauma are noted. If a Wood's lamp (an ultraviolet light lamp) is available, the patient's thighs are examined for fluorescing semen stains (urine and pus may also fluoresce) and any positive areas swabbed. If genital anal contact is indicated, anal smears for **sperm** are collected. Lastly, a blood sample needs to be obtained from the victim for later typing.

Head of the Connecticut State Police Forensic Laboratory hands out new kits for the collection of evidence in sexual assault investigations at the end of a training class in the use of the kits in October 2004. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

If any blood, hair, or foreign tissue is observed on the fingernails, the nurse will scrape under the nails with the wooden splints over a clean white paper. If blood is present, the nurse will clip the nails. Oral samples are obtained by swabbing the mouth twice. Sperm have been recovered from the oral cavity up to six hours after an assault, even if the teeth were brushed or mouthwash was used. A second **saliva** sample is collected on the filter paper disk to determine characteristics (such as **secretor** status) of the victim.

Throughout the examination, the person is observed for signs of trauma outside of the genital region. The most commonly injured extragenital areas are the mouth, throat, wrist, arms, breasts, and thighs. The presence, size, and location of bruises, lacerations, bite marks, and scratches are documented. If the patient consents, the areas of trauma are photographed. If consent is refused, diagrams are used to accurately portray the physical condition of the victim.

Those responsible for collecting a rape kit are trained to recognize the psychological impact of the examination. Although the examination experience itself is generally not physically painful, it can be experienced by victims as psychologically humiliating. For many rape victims, the collection of a rape kit can be experienced as a second source of victimization.

The collection of a rape kit does not mean that the kit will be processed. Historically, many states have not possessed the financing to process every rape kit that was turned into evidence. In response, some states have changed their statute of limitations for rape prosecution, allowing for longer statutes when **DNA** evidence is uncovered.

SEE ALSO Blood; Bloodstain evidence; Body marks; DNA databanks; DNA typing systems; Fibers; Fluorescence; Hair analysis; Physical evidence; Saliva.

Reconstruction, accident SEE Accident reconstruction

Reconstruction, crime scene SEE Crime scene reconstruction

Reference sample

Analysis of forensic samples can often involve the use of sophisticated instruments. While the presence of even minute quantities of a compound can be detected, the data can be suspect and legally inadmissible unless it can be demonstrated that the instrument was functioning properly. In a proper sample analysis, various quality control procedures need to be included along with the samples. One critical aspect is the inclusion of a reference sample.

A reference sample is a sample that is comprised of a similar matrix as the forensic sample. For example, if a forensic sample is a water-based solution, the reference sample must be a water-based solution. In addition, a reference sample contains a precisely defined amount of a target compound or microorganism.

Analysis of a reference sample should yield, within defined limits, the quantity of the target agent. If the analysis precision is faulty, then the reliability of the equipment and/or the operator is questioned.

For example, a microbiological reference sample will contain a defined number of living bacteria (such as ***Escherichia coli***). The sample is rapidly shipped to the laboratory and must be analyzed within a defined time (typically 48 hours). The results are sent back for evaluation and determination of the laboratory's performance.

Reference samples are commonly used in accreditation procedures, which are designed to verify that a laboratory is competent to perform the analyses. Achieving and maintaining accreditation adds credibility to a laboratory's performance and makes it less likely that the legal admissibility of sample analyses will be questioned.

In the United States, the American Board of Forensic Technology maintains a laboratory accreditation program in forensic **toxicology**. Proficiency testing involves the analysis of reference samples for the detection, **identification** and quantitative analysis of alcohol, various drugs, and **toxins** in biological matrices including urine and **blood**.

Other reference samples are available, depending on the analytical capability of the lab. Examples include **DNA** and metal ions.

Other countries have their own reference sample programs. For example, the Standards Council of Canada oversees the reference sample-mediated accreditation program that includes the six Royal Canadian Mounted Police forensic laboratories located across the country.

Laboratories that participate in reference sample-mediated accreditation programs are required to analyze a determined number of samples each year. This schedule ensures that the lab's equipment and personnel are continually proficient.

SEE ALSO Analytical instrumentation; Control samples; Quality control of forensic evidence.

Kathleen J. Reichs

AMERICAN
FORENSIC ANTHROPOLOGIST, WRITER

Kathleen J. Reichs is a professor of **anthropology** at the University of North Carolina, Charlotte. In addition, she investigates up to 80 cases a year as forensic anthropologist for both the State of North Carolina and the Province of Quebec, Canada, the latter a position offered to her because she is one of the few certified forensic anthropologists fluent in French. Forensic anthropology is the application of the science of physical anthropology to the legal process. In her professional capacity, Reichs identifies bones and analyzes fracture patterns, bullet wounds, and stab marks in cases where she is called in by a pathologist. Reichs is also the author of a series of bestselling novels featuring protagonist Temperance Brennan, a female forensic anthropologist.

Reichs was born in Chicago, Illinois. She received her Ph.D. from Northwestern University. An internationally recognized forensic anthropologist, in the capacity of her work she has testified at the United Nations Tribunal on Genocide in Rwanda, helped identify remains from mass graves in Guatemala, and performed forensic investigations at Ground Zero in New York. She has also examined the remains from the Tomb of the Unknown Soldier. Additionally, she has taught **FBI** agents at the Federal Bureau of Investigation laboratories in Quantico, Virginia how to detect and recover human remains.

Writing under the name Kathy Reichs, she draws on her experience as a forensic scientist to create her forensic thrillers, which began with *Deja Dead* in 1997. Protagonist Temperance "Tempe" Brennan's work parallels that of her creator. The fictional stories spend a great deal of time explaining the processes used in forensics.

"The hard part was interweaving the science, making it brief enough so that it isn't boring, and doing it totally without jargon," Reich related in an interview. "I tried to make it accurate," the author also explained, "not just grisly or sensational. I wrote it to give people the feel of what it's like to do this kind of work." Reichs described the difference between her own work and the investigation undertaken by Tempe, saying, "While I do go out to exhumations if we get a tip, I would never pursue the investigation in the way that she does. I stay in the lab."

Reichs has published seven forensic novels and three technical books.

SEE ALSO Anthropology; Literature, forensic science in.

Rudolph Archibald Reiss

7/8/1875–8/8/1929
SWISS
CRIMINALIST

Rudolph Reiss is considered one of the pioneers of **criminalistics**, or the analysis and interpretation of **physical evidence** gathered from crime scenes. His groundbreaking work at the beginning of the twentieth century created advances in forensic sciences. Reiss also contributed to the development of the forensic institute of the University of Lausanne, which is among the world's prominent forensic education facilities.

Rudolph Archibald Reiss was born in Hechtsberg, Germany, about 400 miles southwest of Berlin. He was the youngest of ten children. He attended different schools in Germany until he graduated from high school. As a child, he was frequently in poor health, and moved with his family to Lausanne, Switzerland in August of 1893 in order to improve his physical condition. Reiss began his studies in chemistry at the University of Lausanne and in June 1898, obtained his doctoral degree in chemistry.

Reiss was also interested in photography from a young age. While studying in Lausanne, he actively participated in photography clubs and contests. He also co-founded the *Revue Suisse de Photographie* (Swiss Photography Review). This attraction to photography was crucial to the development of his forensic career. In 1899, the University of Lausanne appointed him to lead the photography laboratory of the university.

In 1909, the *Insitut de Police Scientifique* (Institute of Scientific Police) at the University of Lausanne was founded. This first university level forensic school provided the highest quality of teaching in forensic sciences. While other subsequently founded schools did not survive World War I and World War II, this school endured the wars because it was located in neutral Switzerland. It is now called *Ecole des Sciences Criminelles* (School of Criminal Sciences) and is still one of the world-leading university forensic **institutes**.

In 1911, Reiss published the *Manuel de Police Scientifique. Vol. I Cambriolages et Homicides* (Manual of Scientific Police. I. Burglaries and Homicides), which presents techniques used by the scientific police at the time to investigate, collect, and analyze **evidence** related to burglaries and homicides. Reiss held as his goal to publish *Volume II. Faux* (Volume II. Counterfeits), *Volume III. Identification* (Volume III. Identification), and *Volume IV. Organisation de la Police Criminelle Moderne* (Volume IV. Organization of Modern Criminal Police). Unfortunately, his engagement in the ongoing Serbian war throughout the following years prevented him from accomplishing his goal.

Countries such as France, Germany, Russia, and Brazil invited Reiss to present at conferences and to help with the development of forensic sciences. Reiss spent three months of 1913 in Sao Paulo, Brazil, teaching forensic sciences to police investigation personnel. Then, in 1914, the Serbian government requested Reiss' help in order to investigate the war crimes committed by the armies of Austria-Hungary against the Serbian people. Reiss responded in such haste that he forgot to advise the University of Lausanne about his departure. In 1915, the Serbian government requested his services again and, with the support of the university, Reiss returned to Serbia. During Reiss' absence, funding for the Institute of Scientific Police was threatened, as the university wanted to downgrade it. Reiss immediately responded from Serbia and wrote several letters to support the status of the teaching facility. In 1919, Professor Reiss resigned from the University of Lausanne. First, he explained that he had been absent for so long from the university that it would not be fair for his substitutes to be subordinated again. Second, Reiss' affinity with the Serbian cause conflicted with the neutrality policy of Switzerland. Swiss Criminalist Marc Bischoff replaced him as the director of the Institute of Scientific Police. Reiss died suddenly in 1929 while in Serbia.

Reiss contributed to the development of police organizations in Switzerland and in many other countries. Reiss was also one of the participants of the International Congress of Police, which eventually evolved into **Interpol**.

Reiss developed many techniques used by the forensic community to investigate crimes of all kinds. He advanced the use of photography to document crime scenes and forensic evidence. Finally, his teaching allowed several police agencies around the world to develop their own criminal investigation divisions and to solve crimes using science.

SEE ALSO Fingerprint.

Remote sensing

Remote sensing is broadly defined as the act of obtaining images or data from a distance, typically using a manned spacecraft, a satellite, or a high-altitude spy aircraft. The term was invented in the 1950s to distinguish early satellite images from aerial photographs traditionally obtained from fixed wing aircraft. As such, remotely sensed images can be considered to be one kind of **geospatial imagery**. Although the application of unclassified remote sensing images to civil and criminal investigations has been limited, they have proven to be useful for documenting international atrocities in areas that are otherwise inaccessible to outside observers.

Sufficiently detailed satellite imagery has been used to document international crimes such as possible genocide in the Darfur region of Sudan and the existence of concealed mass graves in Iraq. In Iraq, potential gravesites were identified with the help of satellite image and aerial photograph interpretation and then investigated in more detail using ground-penetrating radar and other methods. A total of 270 mass graves were reported, of which 53 had been confirmed by early 2004, with some 400,000 bodies discovered. Features such as mass graves are generally not directly visible. Instead, analysis reveals features such as otherwise inexplicable areas of freshly moved earth or signs of heavy construction equipment used to excavate the graves. Comparison of publicly available Landsat satellite images obtained in 2003 and 2004 was also used to document the burning of 44% of the villages in the Darfur region of Sudan during a period of civil strife, which some observers believe amounted to genocide. Burning was inferred in areas where the albedo, or amount of radiation reflected by the ground surface, had changed significantly during the times at which the two images were obtained. This was accomplished by using a computer algorithm to calculate albedo from the satellite data, then subtracting one albedo map from the other to calculate the change. This kind of mathematical operation on entire maps or digital images, as opposed to single numbers, is known as map algebra.

Modern remote sensing satellites provide panchromatic grayscale images (popularly known as black and white) and multispectral images in which channels representing discrete bands of the **electromagnetic spectrum** are combined. The most common multispectral images consist of some combination of red, green, blue, and near infrared bands. Hyperspectral sensors can produce images composed of dozens or hundreds of bands. Using information about the spectral reflectance characteristics of different kinds of **soils**, rocks, and plants, image analysts can fine tune the ratios of bands in multispectral and hyperspectral images to identify specific targets.

Image resolution has historically limited the use of satellite images, particularly those that are unclassified and easily available, in criminal and civil forensic work. The *Landsat 1* satellite launched by the United States in the early 1970s, which provided the first publicly available satellite images, had a maximum resolution of 80 m. Therefore, objects smaller in size than several hundreds of meters could not be analyzed because objects must be many times larger than the maximum resolution in order to be clearly shown. *Landsat 7*, launched in 1999, had maximum resolution of 15 m for its panchromatic band, 30 m for its multispectral bands, and 60 m for its thermal infrared band. Although imagery with maximum resolution of 10 m or more can be useful for regional investigations, it is generally not useful for detailed forensic investigations of activities that have occurred through time on individual parcels of land. A new generation of commercial satellites such as the *Quickbird* satellite launched in 2001, however, has 0.61 m panchromatic resolution and 2.44 m multispectral resolution. The commercial IKONOS satellite, which was launched in 1999, has a maximum resolution of 1 m for color imagery. Although no images have been released as of early 2005, many intelligence experts believe that the most recent KeyHole surveillance satellites operated by the United States have a resolution of about 2 cm (0.02 m).

The resolution of panchromatic images is higher than that of multispectral or hyperspectral images because panchromatic information requirements are lower. In a panchromatic digital sensor, each light-sensitive photosite responds to all colors of light. In a multispectral sensor, however, the same number of photosites must be divided among each of the spectral bands. A multispectral sensor with infrared, red, green, and blue bands but the same number of photosites as a panchromatic sensor would have a resolution only 1/4 as high as the panchromatic sensor. This explains, for example, the ratio of 4 between the panchromatic 0.61 m resolution and multispectral 2.44 m resolution of the *Quickbird* satellite. In some cases, multispectral images can be combined with brightness information from more detailed panchromatic images. The apparent effect is a sharper image, although the resolution of the multispectral layer is not actually changed.

SEE ALSO Digital imaging; Geospatial imagery; Satellites, non-governmental high resolution.

Robert K. Ressler

AMERICAN CRIMINOLOGIST

Former Supervisory Special Agent and Federal Bureau of Investigation (**FBI**) criminologist Robert K. Ressler was with the FBI's elite Behavioral Sciences Unit (BSU) for sixteen of his twenty years with the Bureau. Ressler served on active duty in the United States Army for ten years, and then remained in the Reserves until his retirement at the Rank of Colonel, with thirty-five years of service. While in the Army, he served in the Military Police Corps and was a criminal investigation officer with the Criminal Investigation Division (CID) in Washington, D.C. Ressler attended graduate school at Michigan State University and earned a master's degree. A Special Agent in the FBI's Lansing, Michigan, office who eventually became the Assistant Director of the FBI's Training Academy in Quantico recruited him. When the Academy opened in 1972, the BSU was established. Special Agents Howard Teten and Pat Mullany were the pioneers in developing the BSU's metatheory and psychological approach to criminal behavioral **profiling** that was to strongly influence both the FBI and the worldwide **forensic science** community for the remainder of the century. Mullany and Teten formed the original FBI profiling and crime scene assessment team. As the profiling program began to gather momentum, more agents were recruited for training. When the FBI's Training Academy opened in 1972, the Unit was officially established. Ressler was recruited into the BSU in 1974, and was initially involved as a training instructor for new Academy students.

Ressler remained with the BSU for the next sixteen years, until his retirement from the Bureau in August of 1990. During that time, he was responsible for creating many programs leading to the development of the National Center for the Analysis of Violent Crime. He was the catalyst and director of the FBI's first research program concerning violent criminal offenders, and, as such, interviewed and collected data on thirty-six serial and sexual murderers. The program resulted in the publication of two textbooks: *Sexual Homicide: Patterns and Motives* (1988) and the *Crime Classification Manual* (1992). Ressler is credited with having originated the term "serial killer."

In 1985, he became the first Program Manager for the Violent Criminal Apprehension Program (VICAP). The goal of VICAP was to gather all possible information about both solved and unsolved homicides, concentrating on those that were random, involved abduction and/or were serial in pattern. Added to the database was information about unidentified corpses for whom the manner of death appeared to be homicide, and missing persons for whom foul play was strongly suspected. The database was could be accessed and added to as a crime-solving tool, by law enforcement agencies, both within the United States and internationally.

Since his retirement from the FBI, Ressler has continued to play an active role in the world of forensic science. He is a criminologist in private practice as well as a popular international lecturer and public speaker. He continues to consult with law enforcement agencies, and to testify as an expert witness on both civil and criminal cases. Robert Ressler is the Director of the Virginia-based Forensic Behavioral Services, a training, lecturing, expert witness, and consulting agency. His particular areas of interest remain **criminology**, criminal personality profiling, sexual assaults, workplace violence, crime scene analysis, hostage negotiation, homicide (especially serial and sexual murders), and threat assessment.

SEE ALSO Civil court (forensic evidence); Criminalistics; Criminal profiling; Serial killers.

RFLP (restriction fragment length polymorphism)

RFLP, or restriction fragment length polymorphism, is a molecular biological technique used to compare **DNA** from two samples. Special enzymes that cleave the DNA in specific locations are used to digest strands of DNA. Mutations within the DNA result in strands of different lengths. **Electrophoresis** is then used to separate the strands according to their length. RFLP is used as part of DNA fingerprinting, to detect genetic diseases and to determine genetic relationships between species.

The DNA molecule is made up of a sequence of four smaller molecules called nucleotides. The four nucleotides are adenine (A), guanine (G), cytosine (C), and thymine (T). The sequence of these nucleotides is extremely important, as it determines the structure of all of the molecules in an individual. Differences in individuals result from small variations, called mutations, in the sequence of DNA. There are a variety of types of mutations in DNA. Insertions are regions of DNA where nucleotides have been added to a sequence. Deletions are regions where nucleotides have been removed. In vertebrates (animals with a backbone), there are regions of DNA that contain many repetitions of the same sequence. Two families of these repeats are found quite often in DNA: variable number of tandem repeats (VNTRs) and short tandem repeats (STR). Point mutations may also occur in DNA. This is simply the replacement of a single nucleotide by a different one.

A special type of protein called a restriction enzyme, or a restriction endonuclease, can recognize specific sequences of nucleotides on DNA and then cleave the DNA at these locations. For example, the restriction enzyme HaeIII recognizes the sequence GCGC and it cleaves the bond between middle cytosine and guanine. Bacteria naturally produce restriction enzymes and they use them to cleave the DNA from foreign organisms. Over 90 different restriction enzymes have been isolated from different species of bacteria. Each of these enzymes cleaves DNA between different, and specific, sequences of nucleotides.

When performing RFLP, the target DNA is usually subjected to polymerase chain reaction, which produces millions of copies of strands of DNA identical to the original. This amplified DNA is then combined with a set of restriction enzymes, which cleave the DNA in specific locations. For example, consider the strand of DNA from one individual with the sequence GCGCAAGGC-GAATTCGCGC. The restriction enzymes HaeIII and EcoRI are both added to the mixture. As discussed, HaeIII cleaves between C and G on the sequence GCGC. EcoRI recognizes the sequence GAATTC and it cleaves the bond between the adenine and the thymine. The resulting strands from this RFLP would be GC, GCAAGGCGAA, TTCGC, and CG. Next, consider a sample of the same region of DNA from a second individual. This individual has a point mutation so that their DNA sequence is GCGCAAGGC-GAATTCGCCC. After exposure to the same restriction enzymes, the resulting strands of DNA would be GC, GCAAGGCGAA and TTCGCCC.

After exposure to the restriction enzymes, the two mixtures are transferred to a gel and electrophoresis is performed. In gel electrophoresis an electrical current is transmitted through the gel causing the fragments of DNA to migrate through the gel according to their electrophoretic mobility. This distance is roughly proportional to the inverse of the fragment's length. As a result, shorter fragments migrate farther from the origin as they move through the gel.

After the gel is run, the DNA is labeled using a radioactive probe and the gel is exposed to x-ray film, which changes color in the presence of radioactivity. The locations of the fragments of DNA show up on the film as bands. Different samples can be loaded onto the gel in different lanes so that the banding patterns can be compared side-by-side. In the example above, if the digested DNA is loaded into two lanes on the same gel, three bands will appear in both lanes but the pattern will be different. Both lanes will have a band very far from the origin containing the small sequence GC and a band close to the origin containing the sequence GCAAGGCGAA. Both lanes will also have a third band between these two. However, the band from the first individual will be farther from the origin than the band from the second individual, because it is shorter.

In cases where the DNA under consideration contains VNTRs or STRs, restriction enzymes that do not cut within the VNTR or STR sequence are used. The resulting gel has bands closer to the origin that represent fragments with more repeats and bands farther from the origin for fragments that contain few repeats.

The applications for RFLP are many. DNA fingerprinting uses the presence of STRs at thirteen different locations on the chromosomes. The lengths of these STRs are detected using RFLP analysis. Several genetic diseases are detected using RFLP analysis including cystic fibrosis, Huntington's chorea and sickle-cell anemia. In particular, sickle-cell anemia is caused by a single mutation of a single nucleotide: thymine is replaced by adenine. This mutation occurs at a point in the DNA sequence that is recognized by the restriction enzyme MstII in a person without the disease. The RFLP from a person suffering from sickle-cell anemia will have a long band instead of two shorter ones because the cleavage by MstII will not occur. Finally, mutations in DNA between species are often investigated using RFLP analysis. Species with more different banding patterns are suspected of being less closely related than species with more similar banding patterns.

SEE ALSO DNA banks for endangered animals; DNA fingerprint; DNA sequences, unique; Mitochondrial DNA analysis; Y chromosome analysis.

Dieter Max Richter

AUSTRIAN
FORENSIC SCIENTIST

In 1900, Dieter Max Richter made two important contributions to the world of **forensic science**. First, he adapted the Austrian Nobel Prize winning immunologist Karl Landsteiner's (1868–1943) technique for **blood** group typing for use on bloodstains. His second major contribution to the world of forensic science was his application of the scientific method; it was the first time that performance validation experiments were used to adapt a technique specifically for use within the field of forensic science.

With Landsteiner, Richter studied the agglutination of blood that occurs when one person's blood is brought into contact with that of another. They found that the blood of a person with type A would be agglutinated by anti-A **serum**; the blood of a person with type B would be agglutinated by anti-B serum; and the blood of an individual with type O blood would not be agglutinated by either anti-A serum or anti-B serum. Eventually, it was learned that blood types follow predictable distribution patterns: O is most common among indigenous peoples and Latin Americans; type A is most prevalent among Europeans and Caucasians; and B is most common among African Americans and some Asians.

When the pair had firmly established their methodology for typing and grouping human blood, they began to work with blood serum and other bodily **fluids** such as **saliva**, **semen**, and vaginal secretions, and were able to replicate their earlier work. They found the blood serum of some people could agglutinate the blood of others. From his earlier work, Landsteiner had devised the idea of three mutually incompatible blood groups, and labeled them A, B, and C (later referred to as O). Eventually, a fourth group, AB, was added. Landsteiner and Richter used the same methodology employed in the blood group typing of human blood, blood serum, and other bloodstains, with equally reliable results. By so doing, they opened up the world of forensic science to the use of old **evidence** to make new **identification**, or to gain new knowledge about a crime, a crime scene, a victim, or a perpetrator.

SEE ALSO Blood spatter; Blood, presumptive test; Bloodstain evidence.

Ricin

Ricin is a highly toxic protein that is derived from the bean of the castor plant (*Ricinus communis*). The toxin causes cell death by inactivating ribosomes, which are responsible for protein synthesis. Ricin can be produced in a liquid, crystal or powdered forms and it can be inhaled, ingested, or injected. It causes fever, cough, weakness, abdominal pain, vomiting, diarrhea, dehydration, and death. There is no cure for ricin poisoning, and medical treatment is simply supportive.

Ricin comes from castor beans, which produce castor oil, a component of brake fluid and hydraulic fluid. One million tons of castor beans are processed each year and the resulting waste mash contains 5–10% ricin. The 66,000 Dalton protein can be purified from the mash using **chromatography**. Once purified, ricin is a very stable molecule, able to withstand changes in environmental conditions.

The protein composed of two hemaglutinins and two **toxins** (RCL III and RCL IV). The toxins are made up of an A polypeptide chain and a B polypeptide chain, which are joined by a disulfide bond. The general molecular structure of ricin is similar to other biologically produced toxins, such as botulinum, cholera, diptheria and tetanus.

The B portion of ricin binds to glycoproteins and glycolipids that terminate with galactose on the exterior of cell membranes. The toxin is then transported inside the cell by endocytosis. Once inside the cytosol of the cell, the A portion of the molecule binds to the 60S ribosome, stopping protein synthesis. A single molecule of ricin can kill a cell.

An image released by the Federal Bureau of Investigation shows a small metal vial of ricin found in a threatening letter addressed to the Transportation Department discovered at a U.S. Postal facility in Greenville, S.C., in October 2003. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

Ricin poisoning can occur by dermal (skin) exposure, aerosol inhalation, ingestion, or injections and the symptoms vary depending on the route of exposure. If ricin comes in contact with the skin, it is unlikely to be fatal, unless combined with a solvent such as dimethyl sulfoxide (DMSO). Aerosol inhalation can cause fever, chest tightness, cough, nausea, and joint pain within four to eight hours. Respiratory cell death can prelude respiratory failure. If ricin is ingested, it can cause severe lesions in the digestive system within two hours of exposure. It may cause abdominal pain, nausea, vomiting, and bloody diarrhea. Eventual complications include cell death in the liver, kidney, adrenal glands, and central nervous system. Injection of ricin causes local cell death in muscles, tissue, and lymph nodes. Ricin poisoning causes death generally within three to five days, although a victim may survive after the fifth day.

There is no cure for ricin poisoning, although a vaccine is currently under development. Treatment for dermal exposure includes decontamination using soap and water or a hypochlorite (bleach) solution, which deactivates Ricin. In case of aerosol inhalation, treatment is the administration of oxygen, intubation, and ventilation. Ingestion of ricin is treated with activated charcoal.

The most famous case involving ricin is the **assassination** of the Bulgarian dissident, Georgi Markov. In 1978, Markov was working in London as a British Broadcasting Company (BBC) correspondent. As he was walking across Waterloo Bridge, a man jabbed the tip of an umbrella into Markov's right thigh, murmured an apology and slipped away into the crowd. Markov died four days later. After the collapse of the Soviet Union, the new Bulgarian government admitted that their Secret Service had been responsible for the murder. The KGB produced the murder weapon: an umbrella modified to inject a 1.7 mm platinum pellet filled with ricin into Markov's leg.

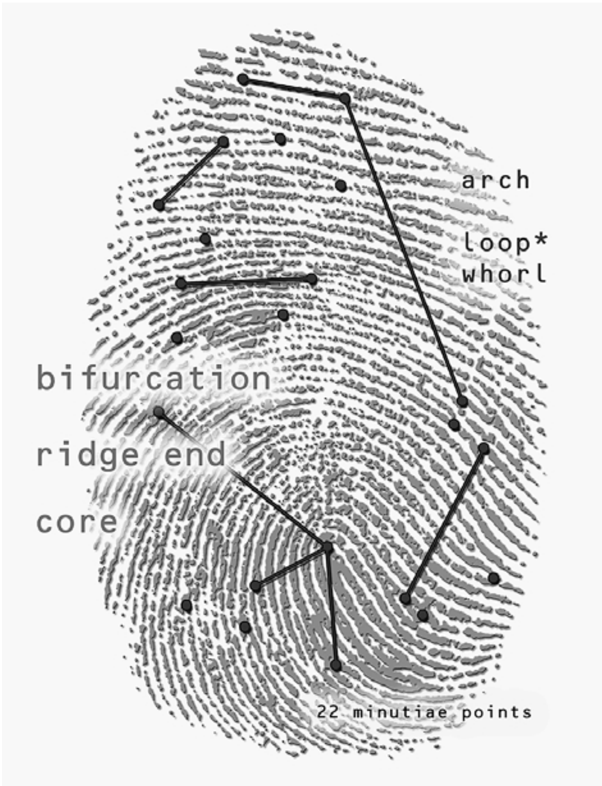
SEE ALSO Pathogens; Toxicological analysis; Toxins.

Ridge characteristics

Humans have characteristically ridged skin on their fingertips, palms, and soles. This roughened skin makes it easier to grip things and, up close, it appears as patterns of tiny ridges and furrows. The fingertips, palms, and soles can sometimes create a transfer of these patterns when they come into contact with surfaces and objects. The most important of these transfers are fingerprints, made when the tips of the fingers and thumbs make impressions. Fingerprints have long been used for forensic **identification** purposes thanks to features within their patterns called ridge characteristics or minutiae.

All fingerprints fall into one of three basic overall patterns, the arch, the loop, and the whorl. However, the ridges themselves form a wide variety of patterns within these basic three types. **Fingerprint** experts describe various ridge characteristics. For example, ridge endings refer to an abrupt cessation of ridge. A bifurcation occurs when a ridge splits into two. A dot is a very small segment of ridge. There are also combinations of ridge characteristics, such as the island that is two bifurcations together. When a control fingerprint, either taken from a suspect or obtained from a database, is compared with one from the scene of a crime, the investigator will look at the ridge characteristics.

The control and the sample fingerprint are placed in the same orientation and a search is made for ridge characteristics that match. Each person has a unique pattern of ridge characteristics and it is this mark of identity for which the investigator must search. The number of ridge characteristics that must match to allow identification remains debatable. For many



Identifying characteristics of a fingerprint. © DIGITAL ART/CORBIS

decades, investigators had to match a minimum of 12 ridge characteristics in a control and sample fingerprint to be able to say they came from the same finger. Now, however, it is accepted that having a fixed minimum is not appropriate in all cases and it is best left to the experience of the investigator to make the decision on identification. Of course, he or she should be prepared to defend this decision in court.

SEE ALSO Fingerprint; Fingerprint analysis (famous cases); Latent fingerprint.

Rigor mortis

Rigor mortis, from the Latin for "stiffness of death" is the rigidity that develops in a body after death. This rigidity may begin shortly after death—within 10–15 minutes—or may not begin until several hours later, depending on the condition of the body at the **time of death** and on environmental factors, such as moisture content of the air and particularly temperature. A colder temperature promotes a slower onset of rigor mortis.

Knowledge of the progression of rigor mortis can be very useful for a forensic investigator in a determination of the time that has lapsed since death.

Typically, rigor mortis affects facial muscles first. Spreading to other parts of the body follows. The body will remain fixed in the rigid position until **decomposition** of tissue begins, about 24–48 hours after death.

Rigor mortis occurs because metabolism continues in muscles for a short while after death. As part of the metabolic activity, adenosine triphosphate (ATP) is produced from the metabolism of a sugar compound called glycogen. ATP is a principal energy source for muscular activity. As long as ATP is present, muscles continue to maintain their tone. As the store of glycogen is exhausted, ATP can no longer be made and its concentration decreases.

One of the consequences of ATP depletion is the formation of abnormal links between two components of muscle tissue, actin and myosin. The leakage of calcium into the muscle cells also contributes to the formation of abnormal actin-myosin links. The abnormality produces the stiffening of the muscle, which persists until the links are decomposed.

SEE ALSO Autopsy; Coroner; Fluids; Death, mechanism of.

Ritual killings

Ritual killings are relatively unusual, but sometimes bear some of the hallmarks of a serial killing, such as mutilation of the corpse or some kind of special positioning. Many ritual murders involve the idea of human sacrifice, usually for religious reasons. The term religion is, however, used quite loosely in this context, as it can include belief systems such as satanism and vampirism. There may also be cultural, psychological, and psychosexual elements to a ritual **murder**. The hallmark of a ritual killing is **evidence** of acts not necessary to bring about death. For example, bite marks, excessive violence, and sexual assault may be found in connection with a ritual killing.

Human sacrifice is a feature of some, but not all, occult belief systems. The word occult means hidden and by its very nature, this kind of ritual killing can be hard to investigate. Violence motivated by religion may not be a crime in the eyes of the perpetrator, but it is treated no differently from any other murder in

Rigor mortis sets in to the body of a victim of a fuel tanker explosion in 1978. The tanker was delivering propane to a Los Alfaques campsite in the Tarragona Province of Spain. More than 150 people, mainly tourists, died and 500 people were injured.
© RICHARD MELLOUL/SYGMA/CORBIS

the eyes of the law. Research into motivation for ritual killings has shown that the practice is thought to lead to transformation, self-deification, and healing. Many people also believe that satanic human sacrifice is done as a way of drawing down dark forces. Investigators may assume that those involved in human sacrifice are simply mentally disturbed and hiding behind a belief system that seems to justify their actions. Yet understanding the beliefs that led to the crime, however distorted they appear, may actually be helpful in solving it and aid in the prevention of future occurrences.

Many ritual killings have involved teenage perpetrators drawn into satanic cults. In 1997, 16-year-old Luke Woodham of Pearl, Mississippi, killed his mother and then went to school with a rifle, killing two classmates and wounding seven more. Woodham had been instructed by his peers in a satanic group that murder was a way of achieving their purposes. The jury rejected an insanity defense and he was sentenced to a life term for each murder. In another case, three teenage girls in Italy murdered a nun, having formed their own satanic group. There have been other murders, in both Europe and the United States, involving young people who have been in satanist groups.

In vampirism, there is a belief that drinking blood and practicing cannibalism can help the individual to achieve power and immortality. There have been a number of ritual homicides committed in the vampire tradition, some of them involving teenagers. For instance, 17-year-old Michael Hardman broke into the home of 90-year-old Mabel Leyshon in Anglesey, Wales. After killing her by stabbing, he arranged her body with the legs propped on a stool and placed two candlesticks on her body and a candle on the mantelpiece. He then removed her heart and drained blood from her leg to drink in a vampire ritual, thinking these actions would render him immortal. When police searched his bedroom, they discovered a large amount of vampire-related books and Internet material. Hardman, known as the "Vampire Boy Killer," was sentenced to a minimum of 12 years in jail in 2002.

The above cases of ritual killing involve young people who appeared to be dabbling in the occult rather than being committed to it. Often they acted alone or in a small group. There are others who are committed to a belief system, or pretend to be for the purposes of committing the crime. It can be difficult to distinguish between the two motives. For example, Richard Trenton Chase, the so-called "Vampire of Sacramento," murdered a woman and drank her blood in 1978. Psychological profilers noted the disorder at the scene and concluded the murderer was white, thin, undernourished, and in his mid-twenties. As a disorganized type, he'd be unemployed and live alone. They also guessed he would kill again, which he did. Trenton had a history of mental illness and admitted the crimes, but did not see he had done wrong. He told his interrogators that his own blood was turning to sand, so he had to become a vampire.

Another case of a killer incorporating some ritual elements into his crime was the Night Stalker, Richard Ramirez, who terrorized Los Angeles between 1984 and 1985 with a rampage of rape and murder. He would try to make victims declare a love of Satan. At his conviction for 13 murders in 1989, he raised a hand with a pentagram design on it and shouted, "Hail Satan." It is widely believed that killers like Ramirez use belief systems like satanism as a cover or justification for their crimes. Whether or not they are also mentally deranged is debatable.

Even more difficult for forensic psychiatrists are those cases where a murder has been committed by a true believer who considers murder to be a sacred act of sacrifice. Such deaths tend to occur outdoors in a designated sacred area on a significant date. Generally such acts are blood rituals involving a knife. Depending on the belief system involved, the killing may involve a rapid slitting of the throat or be slower and more tortuous. The blood may be drained from the corpse, which will be an unusual finding at **autopsy**. Mutilation post-mortem, along with sexual abuse, carving symbols into flesh, and dismemberment, are not uncommon in such killings.

A recent case of murder, committed by apparent true believers, involved the discovery of the mutilated torso of a young boy found floating in London's River Thames in 2002. The body was found close to seven half-burned candles. An autopsy showed hallmarks of a ritual killing and the body had been dismembered in a manner consistent with a human sacrifice. There was a name on the sheet in which the candles had been wrapped and African experts suggested the signs were consistent with a ritual homicide of the kind sometimes carried out in Nigeria to bring good luck to the perpetrators. It may be that the boy was sacrificed to an ancestor god of the Yoruba people, Nigeria's second largest ethnic group. Orange shorts, orange being the color associated with the god, were placed on the corpse.

Genetic testing, including **mitochondrial DNA analysis**, suggested the boy came from West Africa, probably Nigeria or a nearby country such as Togo or Benin. The boy was circumcised, which commonly occurs after birth in West Africa, but later on as a passage to adulthood in Southern Africa. Analysis of stomach contents and bone chemistry further revealed that the boy could not have been brought up in London. Forensic examination of the cuts where the head and limbs had been severed from the body suggested the expert use of very sharp knives. The flesh had first been cut down to the bones, which were then slashed with a single blow from a weapon like a butcher's meat cleaver. The body was then held while the blood was drained from it.

Investigators believe that those involved in this case included a magician or priest who would have carried out the ritual. The limbs may have been kept as magical trophies. The orange shorts have been traced to Germany, suggesting the boy was brought into Britain by a common route used in human trafficking. It is a complex case and, so far, a so-called *muti* (the African Zulu word for medicine) killing (in which body parts are taken for use in traditional medicines) has been ruled out. The reason is that the boy's genitals were left intact. In a *muti* killing, the genitals are removed, because they are believed to be a powerful medicine. Forensic investigators assume that the killers were more interested in the boy's blood. A number of Nigerians were arrested in 2003 in connection with the murder. It appears the boy may have been kidnapped and brought to Britain purely for the purpose of carrying out this ritual murder.

In terms of conventional psychological **profiling**, the ritualistic aspects of a killing are sometimes rather similar to the signature of a serial killer. So far, the theory of psychological profiling has not been developed to distinguish the serial killer from the ritual killer. To do this, various cultural and religious aspects would have to be added to current psychological theory. Those who indulge in religious violence know it to be illegal but do not believe it to be wrong. Many killers who are mentally ill do not understand they have done wrong and may or may not believe their acts are illegal. Understanding the difference between these two groups is clearly challenging for

Skulls discovered by Nigerian police from religious shrines in forests are displayed at a Nigerian police station in 2004. Officials said that a secretive sect was believed to have carried out traditional ritual killings. AP/WIDE WORLD PHOTOS/SUN NEWSPAPER NIGERIA. REPRODUCED BY PERMISSION.

the forensic psychiatrist but is worthwhile in terms of appreciating the context of certain brutal murders.

SEE ALSO Autopsy; Serial killers; Trace evidence.

RNA expression patterns and time of death SEE Time of death, contemporary determination

Nicholas Romanov

Nicholas Romanov, also known as Czar Nicholas II, was the last in a line of the Romanov dynasty that ruled Russia for more than 300 years. Nicholas was forced to abdicate his throne at the beginning of the Russian Revolution of 1917. After a brief period of confinement, Nicholas, his entire family, and four servants were executed. The fate of their remains was questioned for nearly 80 years and involved both political and religious debate. A variety of forensic techniques, including **mitochondrial DNA analysis**, identified the human remains from a pit near Yekaterinburg in the Ural region of Russia as those of the murdered family.

Nicholas Romanov married a German Princess, Alexandra, with whom he had four daughters, Olga, Tatiana, Marie, and Anastasia, and one son, Alexis. His rule of Russia was fraught with domestic and international turmoil. Russia was poorly prepared for World War I and suffered heavy losses. In addition, Alexandra became closely allied with a mystic, Rasputin, who was seen as dangerous by many in the royal court. A series of riots intensified to the level of civil war and Nicholas was forced to abdicate in March of 1917.

After Nicholas was removed from the throne, he and his family were confined. In November of 1917 they were moved from Siberia to the town of Yekaterinburg. On the evening of July 16, 1918, the Romanov family, Alexis' doctor, and three servants were told to dress, as they were to be photographed for a family picture. A Bolshevik execution squad led by Yakov Yurovsky burst into the room, firing shots at the family and their servants. Bullets ricocheted off of jewels that were sewn into the bodices of several of the women. Those who did not die quickly were bayoneted.

The bodies were taken to a spot called Four Brothers, north of Yekaterinburg. They were undressed and the valuables were removed, including about 40 kg of jewels. The bodies were dropped into a deep mine shaft. After word of the killings spread throughout the town, Yurovsky decided to move the bodies to try to better conceal them. Two of the bodies were allegedly set on fire, but this was found to be too time consuming, so the rest were doused with sulfuric acid and buried in a shallow pit about 20 km north of Yekaterinburg.

In 1978 Geli Ryabov, a filmmaker, and Alexander Advonin, a local expert on the executions, decided to try to find the bodies of the Romanov family. They contacted Yurovsky's son, who had a report that his father had written about the murders. It described the location to where the bodies had been moved. Ryabov and Advonin located the burial site on May 30, 1979, and secretly removed two of the skulls. Because of the political situation in the Soviet Union at the time, the two men were unable to provide any further insight into the assassinations, so they reburied the skulls one year later. When the Soviet Union changed its policies to allow for more open exchange of information, Ryabov told the story of the find in 1989. In 1991 Prime Minister Boris Yeltsin called for an official investigation into the origin of the remains.

Approximately 1,000 bones were collected from the burial site. They were reconstructed to form nine bodies, five of which were female and four male. The male skeletons were those of adult men, which suggested that the body of Alexis, who was 13 at the time of his death, was missing. Also missing was the skeleton of one of Nicholas' daughters, though there remained some discrepancy as to which daughter. A Russian team of scientists used a forensic technique called superimposition to identify the skeletons. This technique involves comparing photographic images with skeletal remains to try to link physical features with bone structure. The Russian team concluded that Marie was absent. Using dental comparisons and by study of various bone fragments, a team of scientists from the United States concluded that Anastasia was missing.

In 1992 Pavel Ivanov, a Russian molecular biologist, and Peter Gill of the British Forensic Science Service performed both nuclear and mitochondrial **DNA** (mtDNA) analyses on the skeletal remains. **STR (short tandem repeat) analysis** showed that the skeletons belonged to two parents and three female children and four other unrelated people. Prince Philip of England was maternally related to Alexandra and his mtDNA exactly matched the DNA from the skeleton believed to belong to Alexandra.

Results of the mtDNA analysis from the skeleton believed to belong to Nicholas were more difficult to interpret. Nicholas' younger brother Grand Duke Georgij was not alive and the suggestion of exhuming his remains was not an option in 1992. One of Nicholas nephews, Tikhon Kulikovsky, refused to cooperate with the investigation. Eventually, two of Nicholas' distant maternal relatives, Xenia Sfiri and the Duke of Fife, offered to contribute samples of their DNA to the study.

Like nuclear DNA, mitochondrial DNA is made up of a long sequence of four different nucleotides. Mitochondrial DNA analysis compares the sequence of nucleotides in two regions of mtDNA that are highly variable between different people. The mtDNA sequence of Xenia Sfiri and the Duke of Fife matched that of Nicholas except for one single nucleotide. The sequence of mtDNA from bone analyzed from the skeleton believed to belong to Nicholas had a thymine at position 16169, and the mtDNA sequence from Nicholas' relatives had a cytosine at that location.

Additional samples of bone from the skeleton believed to belong to Nicholas were then analyzed to try to reconcile the difference. About 70% of the bone samples contained cytosine at position 16169 and about 30% contained thymine at that location. This variation in mtDNA sequence is known as heteroplasmy and it is exceedingly rare. Some critics claimed that the bone samples must have been contaminated.

In order to convincingly establish whether or not the skeleton actually belonged to Nicholas, the Russian Orthodox Church ordered the body of Nicholas' brother Grand Duke Georgij exhumed in 1994. Analysis of mtDNA from the remains of Georgij resulted in the exact same heteroplasmy as was found in the skeleton believed to belong to Nicholas. Given the rarity of agreement of mtDNA sequence between two people, combined with the unusual occurrence of a heteroplasmy, the probability that the skeletal remains belonged to Nicholas were greater than 100 million to one.

After the source of the remains was established, Nicholas was given a funeral according to the traditions of the Greek Orthodox Church. On July 17, 1998, the remains of Nicholas were laid to rest in the St. Peter and St. Paul Cathedral in St. Petersburg. Two years later, the Church canonized Nicholas, along with his wife Alexandra, stating that their "meekness during imprisonment and poise and acceptance of their martyr's death" deserved great honor.

SEE ALSO DNA fingerprint; Exhumation; PCR (polymerase chain reaction); Skeletal analysis.

Rule of Sixes

The rule of sixes describes a method of determining the distance from which a shotgun was fired. In 1963, shotgun wounds were classified into three types based upon distance and penetration. The distances of six feet, less than six yards, and beyond six yards originally identified by firearm experts brought up the name "rule of sixes." At close range (less than six feet) a shotgun wound appears as a central hole. A blast fired from a distance of up to six yards leaves a central hole with satellite entry wounds. Beyond six yards, the wound appears as only a pattern of scattered shot, with no central hole.

In terms of forensic investigation, the determination of the gun's position is the specialty of both the **firearms** expert and the pathologist. If the gun is pressed close against the skin, all the little shots are concentrated in one place, leading to large wounds. At fairly close range, the shot begins to expand. At about two feet away, the wound begins to look like a large central hole with a few little holes surrounding the edge. Beyond four or five feet, the shot disperses and is more likely to make many smaller wounds and less likely to be fatal.

The wound itself can give important indications on the position of the gun. If the gun is pressed close against the skin, there is a small ring of soot, which is burned into the flesh and cannot be removed. The gun that was fired a few inches away leaves a large ring of soot, since it had the space to disperse and was not embedded. If the gun was held at an angle, the ring of soot will be distorted in one direction.

The distance at which the gun was still close enough to leave residue is called the intermediate range. Tattooing is a pattern of tiny orange-brown lesions on the skin made by a reaction to the gunpowder. It occurs before death, so is an indication that the person was alive at the time they were shot. If the victim was dead at the time of the shooting, there will still be powder marks, but they will be grey-yellow in color. Size and position of the soot can be used to determine the direction and distance of the gun. However, this is affected by the type and make of gun, so it is helpful to have that information first. As the gun gets further away, the area covered by soot becomes wider but the concentration becomes less dense. At long-range distance, no powder marks are generated. The only mark is the bullet hole.

Because distances are often unknown, the groups defined by the "rule of sixes" were reclassified in 1993 by pathologists according to the patterns of pellet scatter. Type I patients had >25 cm (10 inches) of scatter, Type II had <25 cm (10 inches) but >10 cm (4 inches), and Type III had <10 cm (4 inches). In terms of forensic **pathology**, pellet scatter proved to be a more accurate system, as well as more useful to physicians in determining patient treatment and recovery prognosis for persons with shotgun wounds. The term "rule of sixes," however, was kept.

SEE ALSO Firearms; Gunshot residue; Pathology; Wound assessment.

S

Sacco and Vanzetti case

The Sacco and Vanzetti case is widely regarded as a miscarriage of justice in American legal history. Nicola Sacco and Bartolomeo Vanzetti, Italian immigrants and anarchists, were executed for **murder** by the state of Massachusetts in 1927 on the basis of doubtful ballistics **evidence**. For countless observers throughout the world, Sacco and Vanzetti were convicted because of their political beliefs and ethnic background.

The Sacco and Vanzetti case began in South Braintree, Massachusetts, on April 15, 1920. Workers at the Slater & Morrill shoe factory were paid in cash. The money to be paid out that day, $15,773.51, was placed in two steel boxes, each secured by a Yale lock, and picked up by payroll guard Alessandro Berardelli and paymaster Frederick A. Parmenter for escort to the factory. The two guards began walking toward the shoe factory at 3 o'clock in the afternoon. Just as they passed two men leaning against a pipe-rail fence, the men attacked the guards. In the struggle that followed, Berardelli was shot four times, with the last shot coming as he had fallen to his knees. Parmenter was shot once in the chest and once in the back as he staggered and fell in the street.

The two attackers fired several other shots, apparently to signal accomplices. A dark-colored touring car, with three men inside, picked up the robbers and the payroll boxes. The car headed west, out of town. Berardelli was dead when the **medical examiner** arrived on the scene at 4 p.m. Parmenter regained consciousness long enough to make a statement that he did not recognize the gunmen. He then died at 5 a.m. the next day.

Eyewitness reports differed on almost every crucial part of the evidence. The description of the gunmen's builds, appearances, and clothes varied widely among the many people on the street that day. There was also disagreement about when the bullets were fired and who fired them. Some witnesses reported that a third robber had fired shots. Even the exact sequence of the crime varied among observers.

The police suspected anarchists, in part because anarchists at the time were engaged in a number of bombings and robberies. Michael Stewart, the police chief of Bridgewater, Massachusetts, had been assisting the Justice Department in rounding up Italian anarchists for deportation. One of the anarchists, Ferrucio Coacci, failed to report for deportation at the east Boston immigration station on the same day as the payroll robbery. Stewart concluded that the robbery and murders must have been committed by Coacci and his comrades, among whom were Sacco, Vanzetti, Riccardo Orciani, and Mario Buda. Stewart also considered them responsible for a botched holdup of a shoe factory in Bridgewater in December 1919.

Nicola Sacco (1891–1927) and Bartolomeo Vanzetti (1888–1927) both immigrated to the United States from Italy in 1908. Sacco found work as an edge-trimmer in shoe factories, while Vanzetti labored as a fish peddler. Both men were followers of Luigi Galleani, an anarchist who advocated revolutionary violence, including bombings and assassinations. On May 3, 1920, they learned that an Italian anarchist had died of a purported suicide while in federal custody. The dead man had been involved in a bomb plot with other anarchists, including Sacco and Vanzetti.

On May 5, 1920, Sacco and Vanzetti were either hiding Italian anarchist literature, including a bomb manual, or moving dynamite. Both men were carrying pistols and ammunition when arrested, and during their interrogation—initially about their radical activities, not the payroll robbery and murders—they told lies and gave contradictory statements to the police. The authorities concluded that the behavior of Sacco and Vanzetti meant that the men were guilty of something—presumably the payroll murders.

The trial of Sacco and Vanzetti for the South Braintree murders was held in Dedham, Massachusetts, from May 31 to July 14, 1921. Police believed that Sacco was one of the gunmen and that Vanzetti had been one of the three men seen in the getaway car. During the trial, 169 witnesses testified about 226 items of evidence. Sacco claimed to be in Boston on April 15 to arrange for passports so that he could return to Italy with his family. An Italian consul officer supported Sacco's statement. More than twenty witnesses, all of Italian background, testified that Vanzetti had sold them fish on the day of the crime.

The prosecution's chief expert, Captain William Proctor of the state police, did not hold that Sacco's Colt .32-caliber automatic fired the bullet that killed Berardelli (The remaining five bullets taken from the two bodies could not have been fired from the guns found on Sacco and Vanzetti.) Nevertheless, by prearrangement with District Attorney Frederic G. Katzmann, Proctor testified that the bullet in question was consistent with having been fired from the gun, meaning any Colt .32-caliber automatic, not necessarily Sacco's weapon. Katzmann also knew that the .38-caliber revolver found on Vanzetti at the time of his arrest could not have been taken from the slain guard, as the prosecution claimed. The guard's weapon was a .32-caliber revolver with a different serial number—evidence withheld from the defense.

The jury returned a guilty verdict on July 14, 1921. Each of the defendants was found guilty of first-degree murder. The weight of evidence—the weapons, ballistic tests, and eyewitness testimony—and the issue of consciousness of guilt were crucial in convicting Sacco and Vanzetti, but emotional factors were also heavily present. The presiding judge, a man who had requested to work on the trial because he hated anarchists, influenced the jury against the suspects with his instructions about the guilty behavior of the men. The prosecutor emphasized the Italian background of Sacco and Vanzetti.

A six-year struggle to save Sacco and Vanzetti followed the trial. Countless observers worldwide were convinced that political intolerance and racial bigotry had condemned two men whose only offense was that of being foreigners, atheists, and anarchists. Sacco and Vanzetti defenders eventually included radicals, trade unionists, intellectuals, liberals, and even some conservatives. Others were steadfast in their belief that the American system of justice could do no wrong and that the two subversives were guilty as charged, had been fairly tried, and deserved the maximum penalty.

The fate of Sacco and Vanzetti, however, was not decided in the arena of public opinion. Eight motions for a new trial in accordance with Massachusetts law were submitted to the trial judge. Several pertained to perjured testimony by prosecution witnesses and to collusion between local police and Justice Department agents. Another addressed a jailhouse confession by a convicted bank robber, Celestino Madieros, who claimed he and other members of the Morelli gang of professional criminals had committed the South Braintree holdup and murders. Each motion was denied. After the Massachusetts Supreme Court ruled that no errors of law or abuses of discretion had been committed, the judge sentenced Sacco and Vanzetti to death on April, 9, 1927.

In the face of mounting criticism of the legal proceedings and the impending death sentence, Massachusetts Governor Alvan T. Fuller appointed a committee on June 1, 1927 to review the case and advise him on the issue of clemency. The Lowell committee, named after its chair, Harvard University President A. Lawrence Lowell, ignored exculpatory evidence the defense had discovered since the trial while validating the prosecution's every step. Reporting its findings to Governor Fuller on July 27, the Lowell Committee declared that the trial and appeals process had been fair and advised against clemency. Governor Fuller followed the committee's recommendation. Despite continuing worldwide protests and demonstrations, Sacco and Vanzetti were electrocuted at Charlestown State Prison on August 23, 1927.

By this point, the case had become too controversial to quietly fade away. Scholars and scientists have spent the subsequent decades reexamining the evidence and the trial testimony. In the most current thinking about the case, Vanzetti is regarded as

Italian immigrants Nicola Sacco and Bartolomeo Vanzetti (middle, foreground) were accused of killing a paymaster and stealing about $16,000 in 1920. Many believed they were convicted and executed in 1927 because of their anarchistic beliefs. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

innocent of any involvement in the murders. The weight of opinion is that Vanzetti, although innocent, was willing to die to become a martyr for the cause of anarchy.

Less certainty exists about the innocence of Sacco. **Ballistics** tests in 1983 showed that the bullet that allegedly killed Berardelli came from the Colt revolver taken from Sacco at the time of his arrest. A panel of **firearms** experts concluded that Sacco was probably guilty either as a conspirator or a perpetrator of the crime. Another group of experts insists that there exists an overwhelming probability that a substitution of bullets took place and that Sacco was completely innocent. They contend that both Sacco and Vanzetti were innocent victims of a frame-up.

Forensic evidence in the Sacco and Vanzetti case has badly deteriorated in the passage of time. It is unlikely that anyone will ever be able to conclusively prove the guilt or innocence of the two anarchists at this late date.

SEE ALSO Ballistic fingerprints; Ballistics; Circumstantial evidence; Firearms.

Sagittal plane SEE Anatomical nomenclature

Saliva

A forensic investigation can involve the analysis of body **fluids**, including saliva, for **evidence** of **toxins** and both prescription and **illicit drugs**. Obtaining a saliva sample is far less obtrusive and

A staff research associate at the University of California-Davis veterinary genetics lab takes a swab of a spot of saliva off a sweatshirt worn by a victim in a dog attack case in 2002. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

cumbersome than obtaining a **blood** or urine sample, especially at the scene of an accident or crime.

Saliva is a clear liquid that is made and is present in the mouth, where it has a number of functions. It wets food and makes the food easier to swallow. As well, specialized proteins that are present in saliva trigger chemical reactions that begin to break apart chemical bonds in the food (the proteins are generically termed enzymes). This begins the process of digestion, whereby the food is converted to a form that can be utilized by the body to provide energy. For example, the salivary enzyme alpha-amylase initiates the breakdown of starch into its constituent maltose sub-units.

In addition to wetting the food, saliva also wets the tongue, which aids the various receptors on the surface of the tongue in differentiating the different tastes of foods. Washing of saliva over the surface of teeth, and the presence of antibacterial enzymes, helps keep teeth clean and helps lessen the chance of infections.

Saliva production lessens during sleep. The resulting build-up of bacteria on the teeth and in the mouth produces the characteristic objectionable morning breath. Even though production lessens during sleep, the production of saliva is a round-the-clock affair. Every day, 2–4 pints (approximately 1–2 liters) of saliva are produced. This large volume is secreted by three pairs of salivary glands located in the mouth.

Within each gland a cluster of cells called the acinus secrete the salivary fluid. The fluid contains water, electrolytes (minerals such as sodium, potassium, and calcium that are present in body fluids and cells, and whose concentrations are important in maintaining proper body function), mucus (a slippery, jelly-like substance that helps coat and protect cells) and the aforementioned enzymes.

From the acinus, the fluid collects in ducts within each salivary gland. Here, the composition of the fluid is changed. Most of the sodium is reabsorbed and potassium and bicarbonate ions are added. The latter is particularly important in ruminant animals like cows, since, when swallowed, it helps counteract the corrosive action of the large quantity of acid that is produced in the forestomachs.

From the collecting ducts, the saliva passes to larger ducts, which ultimately merge to form a single large duct, from which the saliva empties into the mouth.

Most animals, including humans, have three pairs of salivary glands that are located on either side of the mouth in three different locations. They differ in the nature of the saliva that is produced.

The parotid glands are located near the upper teeth, in a broad area underneath the earlobe. The secreted saliva is watery and reminiscent of the serum portion of blood; indeed, it is described as being serous. Submaxillary (or submandibular) glands are located on the floor of the mouth, underneath the back portion of the tongue. The saliva produced by these glands is a mixture of serous and mucus portions. Finally, the sublingual glands are located on the floor of the mouth in the region of the chin. Sublingual saliva is predominantly mucous in composition.

In addition to the three pairs of glands, hundreds of small glands called minor salivary glands are located in the lips, inside of the cheeks, and throughout the remainder of the mouth and throat.

Saliva can be of forensic significance because traces of drugs that are circulating in the body can be present in saliva. The composition of the saliva accurately mirrors the proteins that are present in both the blood and the urine. Thus, testing of saliva, which is easier and less obtrusive than obtaining a blood or urine sample, can be used to reveal the presence of prescription and illicit drugs.

Similar tests are being refined that will enable the detection of viral and bacterial infections as well as diseases such as cancer. These tests are based on the presence of signature proteins that are unique to the maladies, such as antibodies, from the microorganism or cancerous cells.

For example, an antibody-based saliva test for the human immunodeficiency virus (HIV; the accepted cause of acquired immunodeficiency syndrome) is available for clinical use. No home-use tests are officially approved as of yet, although a number of nonsanctioned and independently evaluated tests are available through Internet-based companies.

Promising preliminary research results published in February 2005 have shown that aberrant genetic material (deoxyribonucleic acid; **DNA**) and the messenger ribonucleic acid (mRNA) that helps process the genetic information into a protein from cancerous cells can also be detected in saliva. In the future, forensic analysis of saliva may help determine if the subject has (or did have) cancer.

SEE ALSO Barbiturates; Illicit drugs.

Sample control SEE Control samples

William C. Sampson

AMERICAN
CRIME SCENE INVESTIGATOR

Retired crime scene investigator William C. Sampson worked for the Miami-Dade Police Department for almost forty years, and is recognized as an expert in recovering latent fingerprints from skin. Using his experience and expertise, Sampson has consulted with and taught hundreds of law enforcement personnel on his innovative techniques. He has also written and lectured widely on the subject.

Sampson's career was spent serving the Miami-Dade Police Department, where he held posts as a training advisor, liaison to the department's crime laboratory, administrative supervisor, and crime scene investigator. He is a certified instructor by the Florida State General Police Standards Commission, and has worked as an adjunct professor at Miami-Dade Community College.

During the course of his career, Sampson made the discovery that the environment can affect the ability to obtain latent fingerprints from materials like skin and cloth. Previous to this, it was widely accepted that this type of **fingerprint** was unlikely, if not impossible, to obtain. Sampson experimented with manipulating the environmental ambient temperature and humidity and keeping the skin at a certain temperature, thus creating readable prints. He consulted with doctors, medical examiners, funeral directors, and even air conditioning companies. Working on his technique, he was able to yield a very high success rate, and as a result Sampson's work led to the **identification** and conviction of numerous perpetrators. Sampson has been teaching his techniques to law enforcement personnel across the country, and lecturing at many industry events and conferences. He has also written about developing latent fingerprints for trade publications such as the *Journal of Forensic Identification*, *The Print*, and *Evidence Technology.*

In 1995, Sampson, along with his wife and fellow forensic scientist Karen Sampson, formed

Subway passengers affected by sarin gas planted in central Tokyo subways by the Aum Shinri Kyo cult's are carried into St. Luke's International Hospital in Tokyo in 1995. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

KLS Forensics Inc. The company assists law enforcement agencies and provides training in many crime scene related topics.

Sampson was awarded the 1997 John A. Dondero Award from the **International Association for Identification**. He previously was the recipient of the Ford Foundation Award and the Miami-Dade Police Department's Distinguished Service Award. He is also a retired fellow of the British Fingerprint Society, and a member of the Florida division of the International Association for Identification.

SEE ALSO Careers in forensic science; Latent fingerprint.

Sarin gas

Sarin gas (O-Isopropyl methylphosphonofluoridate), also called GB, is one of the most dangerous and toxic chemicals known. It belongs to a class of chemical weapons known as nerve agents, all of which are organophosphates. The G nerve agents, including **tabun**, sarin, and soman, are all extremely toxic, but not very persistent in the environment. Pure sarin is a colorless and odorless gas, and since it is extremely volatile, can spread quickly through the air. A lethal dose of sarin is about 0.5 milligrams; it is approximately 500 times more deadly than cyanide.

Sarin, which has become infamous in contemporary times from its use in Iraq, and by the Aum Shinrikyo doomsday cult, was first synthesized in 1938 by a group of German scientists researching new pesticides. Its name is derived from the names of the chemists involved in its creation: Schrader, Ambros, Rudriger, and van der Linde. A pilot plant to study the use of sarin was built in Dyernfurth. Although they produced between 500 kg and 10 tons of sarin, the German government decided not to use chemical weapons in artillery during World War II. The Soviet army captured the plant at Dyernfurth at the end of the war and resumed production of sarin in 1946. The Russian government currently has about 11,700 tons of sarin.

Between about 1950 and 1956, the United States produced sarin. It is estimated to have stockpiles totaling 5,000 tons of the nerve agent stored in different parts of the country. Several other countries including Syria, Egypt, Iran, Libya, and North Korea have confirmed or suspected stocks of sarin.

Like other organophosphate nerve agents, sarin inhibits the break down of the enzyme acetylcholinesterase. Under normal conditions, this enzyme hydrolyzes the neurotransmitter acetylcholine. When sarin is present, the build up of acetyl-cholinesterase results in the accumulation of excessive concentrations of acetylcholine in nerve synapses. This overstimulates parasympathetic nerves in the smooth muscle of the eyes, respiratory tract, gastrointestinal tract, sweat glands, cardiac muscles, and blood vessels.

After exposure to sarin, symptoms begin within minutes. If a person survives for a few hours after exposure, he or she will likely recover from the poisoning. The first symptoms of sarin poisoning include a runny nose, blurred vision, sweating, and muscle twitches. Longer exposures result in tightness of the chest, headache, cramps, nausea, vomiting, involuntary defecation and urination, convulsions, coma, and respiratory arrest.

Atropine acts an antidote for nerve agent, including sarin. Atropine binds to one type of acetylcholine receptor on the post-synaptic nerve. A second antidote is pralidoxime iodide (PAM), which blocks sarin from binding to any free acetyl-cholinesterase. Both should be administered as soon as possible following exposure to the toxin. Diazapam can also be used to prevent seizures and convulsions.

SEE ALSO Toxicological analysis; Toxicology.

Satellites, non-governmental high resolution

High-resolution satellites, generally understood to be those with a spatial resolution of 2 meters (6.6 feet) or less, have the capability to provide forensic information from areas that are otherwise inaccessible to law enforcement officials.

Resolution is a measure of the ability of an image to depict detail. When used in reference to digital images such as those produced by **remote sensing** satellites, resolution generally refers to size of the pixels, or fundamental elements, comprising the image. A 2-meter resolution image consists of elements representing the average color or intensity of a 2x2 meter area of Earth's surface. Nothing smaller than 2x2 meters will be depicted as a distinct object. The smallest objects that can be clearly identified on an image, however, will be much larger than the resolution because many pixels are required to represent the characteristic shape or outline of an object. A 2-meter resolution satellite image might, therefore, show distinct images of buildings covering tens or hundreds of square meters, but not a small shed or automobile covering an area the size of a 2x2-meter pixel.

The best commercial satellites operating in 2005 had resolutions of 1 meter (3.3 feet) or less. However, intelligence satellites operated by the U.S. government were believed to have a resolution of about 2 centimeters (0.8 inches). Images with that resolution, however, have never been released for public use.

The first remote sensing satellites were built, launched, and operated by government agencies in the 1960s. In the interest of national security, images from these satellites were tightly controlled and generally inaccessible to civilian officials and forensic scientists. Imagery from the first Landsat satellites, launched by the United States in the 1970s, was publicly available but its low resolution (tens of meters) made it useful only for regional studies. After an attempt to privatize and eliminate government subsidies for the Landsat program in the 1980s, the United States passed the Land Remote Sensing Policy Act of 1992. This act emphasized the importance of satellite imagery, returned the Landsat program to government operation, mandated that its data be made available at cost, and included a provision for the licensing of commercially operated remote sensing satellites. At about the same time, the French government developed the SPOT (Satellite Pour l'Observation de la Terre) program and marketed its imagery through a subsidized corporation. Like Landsat imagery, however, SPOT imagery generally did not provide the resolution necessary for detailed forensic work.

The Landsat and SPOT satellites paved the way for a new generation of high-resolution commercial satellites that provide images detailed enough for forensic work. The commercial IKONOS satellite, launched by the multi-national Space Imaging consortium in 1999, orbits Earth at an altitude of 680 kilometers (422.5 miles) and provides panchromatic (black and white) images with 1-meter resolution. The *EROS A1* satellite, built by the ImageSat International consortium in Israel and launched from Russia in 2000, provides 1.8-meter (6-foot) resolution. Its successor, the *EROS B1*, will have 0.70-meter (2.3-foot) resolution when operable in 2006. The highest resolution commercial satellite imagery available in 2005 came from the *QuickBird* satellite operated by the Colorado company DigitalGlobe. QuickBird produces 0.62-meter (2-foot) resolution panchromatic images and 2.4-meter (7.9-foot) resolution color images. The panchromatic images, in particular, are detailed enough to depict individual automobiles, pieces of machinery, or ground disturbance associated with illegal activities.

Panchromatic images have higher resolutions (smaller pixel size) than color, or multi-spectral, images. This is because **digital imaging** sensors have a fixed number of photosites that respond to light. When a panchromatic image is made, each photosite senses the total intensity of light. When a multi-spectral image is made, in contrast, the photosites must be divided among the spectral bands being depicted. Thus, a color image consisting of infrared, red, green, and blue bands would have one-fourth the resolution of a panchromatic image from a sensor with the same number of photosites.

One particularly high profile application of commercial high-resolution satellite imagery was the search for debris from the space shuttle *Columbia*, which exploded over Texas in 2003. The *QuickBird* satellite was immediately redirected to cover the accident area, and the resulting images showed areas of broken trees and highly reflected debris. The detailed satellite images allowed accident investigators to better document the extent of the debris field and recover pieces of the shuttle.

High-resolution commercial satellite imagery is also invaluable in the aftermath of natural disasters such as the 2004 Indian Ocean tsunami. There, it was used to help guide relief efforts and provided important information for researchers studying the effects of tsunamis.

Other applications of commercial satellite imagery in **forensic science** are less exotic. Government officials in Arizona, Georgia, and Minnesota have used satellite imagery to detect illegal cotton cultivation, logging, and pollution. Because satellites pass over any given location no more frequently than every few days, they are best suited for the characterization of slow processes such as growing crops or persistent problems such as air or water pollution. For the same reason, it is unlikely that satellite imagery will provide images that catch thieves, kidnappers, rapists, or murderers committing crimes.

Like photographs and videotapes, satellite images can be manipulated and must therefore be authenticated for use in court. Prosecutors or plaintiff's attorneys must establish that any processing or enhancement techniques used on the imagery were properly documented and followed accepted professional standards, whereas defendant's attorneys may question the authenticity of imagery used against their clients. Although some manipulation must be done in order to transform digital information into a visible image, it is critical to establish that the manipulation did not distort or otherwise misrepresent the area being depicted in the imagery.

SEE ALSO Digital imaging; Geospatial Imagery; GIS.

Scanning electron microscopy

The scanning electron microscope (SEM) is an important tool in modern **forensic science** due to its wide range of applications. SEM allows the rapid analysis of elements that compose very small specimens and the conclusive determination of the origin of many materials that are crucial to the chain of **evidence**. Paint particles, **fibers** (both natural and artificial), bullet fingerprints, **gunshot residue**, counterfeit bank notes, forged documents, and **trace evidence** are all examples of specimens that can be analyzed using the scanning electron microscope. Scanning electron microscopy also renders detailed three-dimensional (3-D) images of extremely small microorganisms, 3-D anatomical pictures of insect, worm, spore, or other organic structures, and the analysis of gems and gem fragments.

Conventional **microscopes** use light and several lenses to magnify images, whereas SEM uses electron beams to sweep the surface of specimens, producing magnified images in black and white. In most SEMs, samples are placed in a vacuum chamber after being adequately prepared to conduct electricity. Once the sample is in the chamber, the air is extracted and an electron gun at the top of the chamber emits a beam of electrons, which passes through a series of magnetic lenses that condense the beam into an extremely fine focus, capable of sweeping nano spots on the sample surface. A scanning device near the bottom of the vacuum chamber controls the movement of the electron beam across the specimen, row by row. As the electron beam sweeps the surface, it excites electrons present in the atomic structure of molecules, causing some of them to escape from the surface. These escaping electrons, known as deflected secondary electrons, have specific energies that can be measured. As they are released from each area of the sample, they are collected and counted by a detector that sends their amplified signals. The various electronic energies produced are analyzed by computer software, and the resulting image is displayed on a computer monitor.

Some modern SEMs offer an additional advantage for forensic purposes because of new methods of biological sample analysis that do not corrupt the specimen, a major drawback with conventional SEMs. In conventional electron microscopy, biological samples have to be dehydrated and then coated with a material that conducts electricity, such as a thin layer of gold or carbon. Modern SEMs allow the adjustment of the internal pressure in the chamber to dissipate the electric charge that would otherwise charge the sample, thus dispensing with coating and dehydration. Examples of non-conductive materials that require special preparation in conventional SEMs are paper, paint, textiles, bone, hair, and **glass**.

Each chemical element consists of an atomic structure composed by a given number of particles in the nucleus and of electrons vibrating in different levels or shells around the nucleus, each at a specific distance from the nucleus. Electrons in different shells ("orbits") have different energies and the atomic weight of the nucleus determines the quantity of electrons of an atom. Atoms are usually neutral because all their positive and negative particles are in a state of dynamic electrical balance. However, when free atoms collide or when they are bound through molecular chemical reactions, some atoms gain or lose an extra electron, thus becoming positive or negatively charged (cations or anions). When the electron beam of a SEM hits the sample, it deflects two types of electrons from the sample: inelastic electrons and elastic electrons. Inelastic electrons are low-energy particles that give information about the topographic variations on the sample surface and are responsible for 3-D black and white images. They are also known as secondary electrons and most of them have charges inferior to ten electron Volts ($<$10 eV). Elastic electrons are those that collide with the electrons generated by the SEM (that are present in the beam). The collision of electrons produces specific energy quanta that are retained by the elastic electrons. By calibrating the microscope to different beam intensities, analysts can study several types of data provided by elastic electrons, such as the sample composition and crystallographic structure of the surface, the internal structure of semi-conductor materials, the distribution and energy levels of phosphorous compounds, and information about the elements and chemicals present in the several layers of the surface.

Forensic analytical tests such as scanning electron microscopy, spectrometers, **chromatography**, and x-ray dispersion aim at producing individualized evidence that allows the **identification** and origin of samples and the accurate interpretation of data in relation to a crime or a suspect investigation or to help explain an explosion, **arson**, or airplane crash. Modern scanning electron microscopy provides nondestructive analysis of both organic and inorganic samples. Another application of this method in forensics is the analysis and identification of dust particles in the air of indoor environments to either assess the air quality or to detect possible **pathogens** (disease-causing organisms) or hazardous substances. Mineral grains (such as carbonates, glass, quartz, or mica), biological materials (such as mold **spores**, pathogen spores, insect particles, skin cells, and rodent fecal dust), fibers (such as hair, textile fibers, carpet fibers, cellulose, and asbestos), and miscellaneous particles (such as metallic particles, paint, soot, rubber, and plastic) are all materials that have been used in forensic analysis done with scanning electron microscopy.

SEE ALSO Accelerant; Aircraft accident investigations; Analytical instrumentation; Arson; Artificial fibers; Ballistic fingerprints; Bomb (explosion) investigations; Document forgery; Fibers; Filaments; Hair analysis; Handwriting analysis; Ink analysis; Isotopic analysis; Minerals; Organic compounds; Paint analysis; Point-by-point analysis.

Scanning technologies

The forensic examination of an accident or crime scene can involve the direct visual observation of the surroundings. As well, **evidence** may be present or even hidden within objects. For detection of the latter, more specialized scanning technologies are necessary.

X rays are electromagnetic waves in the 10^{-8} to 10^{-11} meter (3×10^{16} to 3×10^{19} Hz) range of the spectrum. (Alternatively, x rays can, like all electromagnetic waves, be conceived of as particles termed "photons.") Because x rays have more energy than visible light, they can pass through solid objects that are otherwise opaque. However, they do not, in general, pass through them as if they were almost transparent, as air is to visible light; rather, when x rays encounter materials of different densities and compositions, they are absorbed and deflected from their original straight-line paths (scattered) to different degrees. This allows x rays to be used for **imaging** the interiors of many objects. The two commonest commercial applications of x-ray scanning technology are medical imaging of the interior of the body and security scanning of baggage and cargo. X rays also have a place in **forensic science**.

Projection radiography (also termed transmission imaging or fluoroscopy), discovered in 1895, is the oldest and simplest form of x-ray scanning. In projection radiography, a beam of x rays is directed at an object behind which a detector or x-ray sensitive surface (i.e., electronic-device array or photographic film) is placed. Volumes of different absorptive properties in the object absorb and scatter the incident x rays to different degrees, causing an x-ray shadow to be cast on the detecting surface. This shadow pattern is the x-ray image.

There are two essential limitations on projection radiography. Firstly, it can readily resolve only structures that contain strong x-ray absorption contrasts. In human beings, this means that the soft tissues are difficult, or impossible, to image. Secondly, all three-dimensional structure in the x-rayed object is collapsed or flattened onto the image plane, destroying information. Nevertheless, because of their speed, simplicity, and economy, projection-type x-ray systems are still commonplace in hospitals, and standard in security systems that examine cargo, baggage, and other inanimate objects.

Computed tomography (CT, also known as computerized axial tomography, CAT) was first made commercially available in the mid-1970s. CT combines projection radiography with computer processing to recover the three-dimensional information that is lost in a traditional two-dimensional x-ray. In a CT scanner, the object to be scanned (e.g., person or baggage item) is placed in a cylindrical or doughnut-shaped device. Inside the cylinder or doughnut is an x-ray source that is mechanically rotated entirely around the object. Also, the cylinder or doughnut is lined with detectors that measure the x rays that pass through the scanned object at all angles. By collating all the information that is gathered during a full revolution of the x-ray source, a computer can form a three-dimensional model of the irradiated volume of the object. This information can then be presented to the user on a video screen in any desired form; most commonly, a thin slice of the object is modeled, with the details of its structure imaged as a black-and-white cross section. To examine more of the object, the user looks at multiple slices.

"Backscatter" consists of waves that are reflected back from an obstacle. In backscatter imaging, x rays are beamed at a target object and a sensor co-located with the beam source records reflected (backscattered) waves. Since denser objects tend to create more backscatter, backscatter x-ray systems create a density-contrast image that reveals different information about objects' interiors than does transmission imaging.

Using specially constructed sensors it is possible to acquire transmission-type x-ray information that can be formed into stereoscopic images (that is, a left-eye, right-eye image pair that the user's brain combines into a three-dimensional impression). Because such an image has apparent depth but cannot be rotated, it is sometimes referred to as "2 1/2 dimensional."

While still in its infancy as an examination technique, stereoscopic x-ray scanning is quicker and cheaper than CT scanning, as it requires less computation and does not need to rotate the x-ray source around the object being scanned. Its limitations are that it provides neither fully rotatable three-dimensional knowledge of an object nor density data, both of which are provided by CT scanning.

The atomic orderliness of a substance affects the way in which x rays are diffracted (i.e., forced to mutually interfere) when passed through it. By recording the scattering patterns characteristic of specific compounds (e.g., drugs), and comparing these templates to patterns observed when scanning objects, a substance-specific detection system can be devised. This technique is now in the early development stage, and is not ready for deployment.

Several other techniques for imaging object interiors exist, including ultrasound, positron emission tomography (PET), nuclear magnetic resonance (NMR) imaging, nuclear quadrupole resonance (NQR) scanning, and neutron emission analysis. All, like x-ray scanning, have security, medical, or scientific applications; the question of which technique is best for any given application is decided based on physics (i.e., which imaging modalities can do a particular job) and, if more than one technique is usable for a given task, on economics (i.e., which imaging modality yields the minimum acceptable image quality for the least cost). For enhanced efficacy, airport security systems are now being planned that will combine complementary techniques to increase the probability of weapon or contraband detection. Such a system might combine x-ray scanning for suspicious-object detection with neutron emission analysis for chemical **identification**.

SEE ALSO Bomb detection devices.

Scene examination SEE Crime scene examination

Sculpting

Sculpting is a way of creating a three-dimensional reconstruction of the head from skeletal remains. It is useful for **identification** when traditional methods have failed to yield a result. Sculpting is carried out by a forensic artist. The forensic artist first makes a plaster cast of the **skull**. This is placed on a stand, facing horizontally, so that it can be tilted and turned in all directions as the artist works with it.

The head is built up by placing successive layers of clay on the plaster cast. The artist is guided during the reconstruction by tissue depth data tables. These are compiled from information of how deep a layer of flesh is over various parts of the human skill and how this varies with age, gender, and ethnic origin. Artificial eyes are placed in the eye sockets and hair can be added, either in the form of a wig or as clay layers. The artist may also add various items of clothing as appropriate as aids to identification. Full notes are taken throughout the process and the end product is photographed.

Manual sculpting of a head may take several weeks and is a skilled task. The end result is limited in that the face tends to be devoid of expression. Often, however, it is the expression, or range of expression, on someone's face that is the key to identification. There are now computer programs that can build not just the three-dimensional representation of the face, but also add expression. The program first makes a scan of the skull and then sculpts the face using the same tissue depth tables as the forensic artist. The end result is available much more quickly than it would be by manual processes.

The head can be animated by the computer program by using a virtual head that has simulations of the 24 muscles that control our facial expressions. The head can thus be given various expressions, which may provide additional information that will lead to a positive identification of a skull. If the forensic artist had to do this manually, several trips back to the workbench might be needed to create the different expressions. The program can also show the face with different hairstyles and hair colors. In the future, a computer program may also be developed to add a range of varying skin textures, to make the head come to life to an even greater degree.

SEE ALSO Composite drawing.

Secret writing

Forensic analysis often involves the examination of hand-written material, computer files, bank account and other account information, and other sources of data. Sometimes, the information needs merely to be retrieved for analysis, having been recorded in a straightforward and readily understandable way. However, information can be encrypted or even physically hidden so as to make its detection and deciphering challenging, even virtually impossible.

One such forensically relevant means of communication is known as secret writing. Secret writing is any means of written communication whereby written text can be concealed, whether it is enciphered/encoded or not. **Codes and ciphers** are sometimes mistakenly placed under the heading of secret writing, but this is accurate only if that expression is taken in its most general sense, as writings that are concealed in any way. Whereas codes and ciphers conceal the meaning of a message, secret writing conceals the actual message.

Techniques of secret writing include the use of invisible ink and carbon copies. Widely applied from ancient times until the early twentieth century, secret writing has been almost entirely eclipsed by more modern methods of concealing messages, such as microdots.

There has long been a desire to keep messages hidden from prying eyes. Indeed, secret writing dates from antiquity. Herodotus described a method of secret writing employed in the Persian Wars. As the Persian emperor Xerxes was preparing to march on the Greek city-states in 480 B.C., a Spartan expatriate name Demaratus learned of the plans and contrived to warn his compatriots. The problem was how to do so in such a way that the Persians themselves would not intercept the message, a challenge for which Demaratus contrived a clever solution.

As Herodotus recorded, Demaratus scraped the wax from a pair of wooden tablets, wrote his message on the wood beneath, then poured hot wax onto the tablets again. Of course the Spartans lacked the advantage of knowing that they were receiving a secret message, but according to Herodotus—who qualified his claim with the caveat "as I understand [it]"—Gorgo, the daughter of a citizen named Cleomenes, received a divine revelation. Thanks to the intervention of the gods, the Spartans realized that they had simply to scrape off the wax and read the message written on the wood beneath it. The Greeks thus began to prepare for the coming invasion, and routed Xerxes' navies at Salamis.

One form of secret writing known to many children from school projects involves invisible ink. This technique uses an acidic citrus juice; lemon juice is most often the preferred choice because it dries without leaving any evidence it has been applied. The juice takes the place of ink, and is applied using a fine stylus, or even an ordinary toothpick. After the juice dries, the acid remains on the paper, which it weakens. When the paper is gently heated, or examined under alternate illumination, the message becomes visible.

Other liquids for invisible ink include milk, which is mildly acidic, as well as white wine, vinegar, or apple juice. In the past, prisoners of war have used their own sweat, **saliva**, or even urine, all of which contain acidic secretions that adhere to the paper, weakening it, even after the water in those bodily fluids has evaporated. A slight variation on this technique is the use of a baking soda and water mixture as the invisible ink, and, after drying, applying grape juice concentrate with a paintbrush. The acid in the grape juice reacts with the baking soda (a base or alkali in chemical terms), exposing the message.

During the late nineteenth and early twentieth centuries, carbon copies provided a means of secret writing. This method involved a means not unlike the one still used today when signing a credit-card receipt. The back of the receipt is impregnated with graphite, a carbon allotrope (a version of a chemical element distinguished by molecular structure) also used in pencil lead. Therefore, when one signs the front of the receipt, the pressure transfers the graphite to the second page, leaving an impression as though one had written on it in pencil.

In a version utilized in the intelligence community, one piece of paper contains a special chemical that will be invisible when transferred to a second sheet. This makes it possible to inscribe secret writing on the back of an envelope, which can be mailed. Upon receipt, the message can be developed by exposure to water or heat.

The use of secret writing has declined since the middle of the twentieth century. Among the techniques that have become prominent is the microdot, or photographic image miniaturized to the size of a dot, which was actually developed in the mid-1800s.

Much more sophisticated is the technique of **steganography**, the concealment of information within other, apparently innocuous, data in a computer file.

SEE ALSO Codes and ciphers; Computer forensics; Decryption; Handwriting analysis; Linguistics, forensic stylistics; Questioned documents; Steganography.

Secretor

Secretor is the name given to the condition that a person secretes their blood-type antigens into **saliva** and other bodily **fluids**. It is also the name of the **gene** that causes this to happen.

Blood type (ABO) is determined by the presence of complex carbohydrates on the surface of blood cells that elicit an immune response in laboratory testing or in the case of bodily exposure by means of a blood transfusion. Blood type is a fundamental biological characteristic of an individual that does not change during their lifetime.

In forensic work, a person's blood type can be ascertained from very small traces of blood found at a crime scene. It is often possible, therefore, to know a person's blood type early on in an investigation based on this testing. The ABO blood system is not a complex information system; there are only three basic blood types, each of which can be further designated as Rh positive or Rh negative, yielding a total of six major blood types.

In some cases, no blood is found by the investigators, but there may be saliva or other mucus-containing bodily fluid that can be identified. If the person from whom the bodily fluid originates carries the dominant secretor gene, that individual will secrete the ABO antigens in mucus, and it is possible to infer the blood type from these fluids. Secretion of soluble blood type antigens is now know to be a function of the alpha(1,2)fucosyltransferase gene. Careful study of this gene reveals that the secretor gene is present in the vast majority of people tested, but nonsecretors carry a nonsense mutation in both copies of their secretor gene, rendering them silent. Approximately 75%–80% of Caucasians carry at least one copy of the secretor gene, and they therefore, secrete soluble antigens into bodily fluids. The secretor phenotype also is a fundamental biological characteristic of a person that remains constant throughout life. This is another piece of biological **evidence** that can be collected in trying to match a sample found at a crime scene with potential suspects.

Blood typing and secretor analysis are not highly informative systems of information compared with existing **DNA** technologies such as **STR analysis** because of the limited numbers of different categories into which all people can be placed. Nevertheless, they played a significant role in the collection and analysis of forensic specimens prior to the advent of more informative DNA systems, and they continue to play a small role today. These kinds of evidence are far more persuasive as negative evidence (to rule out a suspect) than as positive evidence (to confirm a suspect) because many people can match by random chance.

SEE ALSO Blood spatter; Crime scene investigation; Serology.

Semen and sperm

The presence of sperm and semen can be important to a crime investigation. The visual detection of semen can provide **evidence** in the case of a suspected rape. As well, the genetic material present in the sperm can be analyzed and used as a genetic fingerprint to identify a suspect.

In the male, semen is the fluid expelled during ejaculation. In addition to plasma, the semen ejaculate contains secretions from the seminal vesicles and other glands to support and nourish the living sperm cells (spermatozoa) contained within the semen. Sperm cells are haploid sex cells of the male. Unlike eggs (oocytes and the mature ovum) that are large, non-motile, and generally ovulated one at a time, sperm are tiny, motile, and produced in the millions. While a human sperm contains a relatively long tail (flagella), the volume of an entire sperm, tail and all, is only 1/85,000 of the mature ovum.

Motility of the sperm is due to the long tail, which is a modified flagellum. Cilia and flagella, from protozoa through humans, all have a similar structure that has been intensively investigated since first described in early electron microscope studies. Microtubules that run the length of the sperm tail are arranged in a ring of nine pairs surrounding a pair in the center. Ciliary dynein is associated with each of the nine microtubule pairs. It is the interaction of the dynein with the microtubules which causes flagellar bending and thus propulsion.

It is estimated that a quarter of a billion sperm are released in a single ejaculate of semen in a healthy male human. In addition to a nutrient function, the semen plays an important role in thermal and hydration regulation that promotes viable sperm cells. The semen also provides initial protection against the acidic gradient of the vagina and cervical region.

In a forensic examination, semen can be detected by the presence of the enzyme acid phosphatase. Because this enzyme is present elsewhere in the body, however, the test is not absolute proof of the presence of semen on clothing or in material recovered in a case of suspected sexual assault. But, detection of acid phosphatase is powerful **circumstantial evidence**, and indicates that further efforts should be made to investigate the possibility that semen is present.

The microscopic detection of sperm is much more conclusive. The chance of recovering intact sperm is less when a sample is older, due to **decomposition** of the biological material. However, samples that are analyzed soon after collection can be positive for sperm.

Semen can be visualized on clothing and other surfaces using an ultraviolet light. The semen fluoresces under ultraviolet illumination. This test has the advantage of being non-destructive to the scene of the investigation.

SEE ALSO Crime scene investigation; DNA; DNA profiling; Luminol; Rape kit.

September 11, 2001, terrorist attacks (forensic investigations of)

Forensic investigations can occur in relative obscurity or can be front-page news. A horrific example of the latter occurred in the aftermath of the terrorist attacks on September 11, 2001.

At 8:46 A.M. on September 11, 2001, American Airlines Flight 11, hijacked from Boston's Logan Airport with 92 people on board, crashed into the upper floors of the World Trade Center's North Tower in lower Manhattan, New York. Seventeen minutes later, United Airlines Flight 175, also hijacked from Logan and with 65 people on board, crashed into the South Tower. By this time, virtually the entire nation had tuned in to witness the after-effects on television of what at first seemed a terrible accident, but was quickly revealed as a terrorist attack. Over the course of the next 85 minutes, the South Tower collapsed, followed by the collapse of the North Tower. The incident, in which nearly 3,000 people died, ranks as the worst case of mass murder in U.S. history, the worst building disaster in human history, and the largest terrorist incident in the history of the western world.

Watches recovered from the debris of the World Trade Center are assembled in an evidence decontamination room on Staten Island in New York City. Debris from site was examined for evidence, property and remains of victims. © REUTERS/CORBIS

Terrorist hijacked United Airlines flight 175 flies into the South Tower of the World Trade Center in New York City during terrorist attacks on September 11, 2001. © ROB HOWARD/CORBIS

The forensic determinations that occurred in the aftermath of the tragedy were multi-pronged. Forensic inspectors sought to identify the dead and to determine the nature of the events that led to the collapse of the two buildings. Amid the carnage, investigators needed to observe the wreckage in an effort to find clues to the collapse of the buildings, while at the same time try to locate survivors.

On the same day, American Airlines Flight 77, departing from Washington, D.C.'s Dulles International Airport bound for Los Angeles, was hijacked and crashed into the Pentagon building in Washington, D.C. Another hijacked aircraft, United Airlines Flight 93, en route from Newark, New Jersey, to San Francisco, California, was also commandeered. The ultimate target of that hijacked plane remains unknown as its passengers fought back against the terrorists, crashing the plane in a field near Pittsburgh, Pennsylvania.

In the Washington and Pennsylvania crashes, the forensic investigations initially focused on **identification** of victims from clothing, dental **evidence**, **fingerprint** patterns, and analysis of genetic material. The goal was to ascertain the sequences of deoxyribonucleic acid (**DNA**) that can be as unique as a fingerprint.

A group of firefighters stand in the street near the destroyed World Trade Center in New York on September 11, 2001. © REUTERS/CORBIS

Later, forensic efforts were also geared toward determining the cause of the crashes, including searches to locate the **flight data recorders** that are a feature on aircraft, and analysis of the communications between the pilots and air traffic control personnel.

In New York, the forensic engineering work needed to proceed at the same time as wreckage was being cleared away. Because the priority was to uncover any survivors trapped beneath the rubble, steel beams and other rubble were removed from the site before investigators had an opportunity to inspect the structural remains on site in great detail. In retrospect, this hampered efforts to establish a cause of the towers' collapse. Ironically, one the forensic inspectors was able to assess the damage to some of the trade center's structure when a truck transporting the wreckage parked in front of his hotel.

Pieces of the structure that were recovered were instructive. For example, gouge marks on steel beams that were made by a wing and nose section of one of the planes indicated that the plane was traveling at a high rate of speed. In another example, beams were recovered with rivets still intact, which indicated that the buildings withstood the impact of the aircraft.

When the true scope of the loss of life became apparent, forensic efforts shifted to the identification of the dead. Indeed, DNA analysis was instrumental in identifying more than 1,600 victims. More than 800 of the victims were identified by their DNA alone.

As the identification of the victims came to a close, the longer term forensic engineering work continued. This work has continued until 2005, when reports on the cause of the buildings' collapse were issued.

A necessary part of the forensic engineering investigations involved the design and construction of the World Trade Center towers. Designed by architect Minoru Yamasaki—who, ironically, had a fear of heights—and engineered by Leslie Robertson and John Skilling, the 110-story towers soared 1,360 feet (415 m) above an open plaza, which made them the world's tallest buildings at the time of their completion in 1973. Whereas the Empire State

Building and other older skyscrapers drew support from an interior grid of steel girders, support for the trade towers came from the exterior and the inner core. Horizontal floor trusses joined the perimeter support structure to the central area, which the engineers envisioned as a great "tube" running through the building and containing not only its support structure, but also its utilities such as elevators. This design had two advantages. First, it made the buildings extremely stable—not prone to swaying in high winds as the Empire State did. And, it left much of the interior available as rentable space.

By the 1980s, New Yorkers had become accustomed to the trade towers, which punctuated the skyline as the ultimate symbol of American and international commerce. Then, in February 1993, just months before the towers turned 20, the towers became the target of a bombing by Islamic terrorists operating a van filled with **explosives**. In this, the first terrorist attack, six people were killed, but the structural integrity of the towers themselves was not threatened.

When Flight 11 crashed into the North Tower of the World Trade Center at 8:46 A.M., smoke and flames began to gush from the upper stories, and workers began to evacuate the lower floors. Some, however, chose to remain at their desks. For workers on the floors above the impact area, there was no choice but to remain in place.

For 17 minutes, it was possible to assume that what had happened to the North Tower was an accident; then, Flight 175 smashed into the South Tower. Once again, smoke and flames erupted from the heights of the building, and tenants down below began a slow, but steady evacuation while others—many with no choice—stayed where they were.

Seventeen minutes after the impact, with little warning, the South Tower, succumbed to the stress caused by the fire and began to crash from the top down. As it fell, it created a vast cloud of dust and ash above and filled the streets below with noise, heat, and terror.

Shortly thereafter, the North Tower began to implode, once again crashing downward from the top. The area around what had once been the World Trade Center became smoke, ash, and dust.

In late 2001, a team of investigators that included representatives of the American Society of Civil Engineers and the Federal Emergency Management Agency (FEMA) commenced a study on the structural collapse of the towers, the details of which they made public in April 2002. In August 2002, the National Institute of Standards and Technology (NIST) began its own study, scheduled to last two years. The actual timing was a bit longer, and findings of the study were released in April 2005.

The forensic analyses revealed that the aircraft impacts severed columns in each building, which distributed the weight of the upper floors onto the remaining columns. As the fires subsequently raged, these columns weakened to the point of buckling inward and eventually collapsed.

Thus, it was not the impact, but the heat from the burning jet fuel, that heated the temperature of the buildings' steel support structures up to 1,472°F (800°C), causing them to buckle and the floors to collapse downward. (Both jets were bound for Los Angeles and had almost a full tank of fuel on board.) The initial crash neutralized sprinkler systems, allowing the spread of the fire, which was fed by caches of paper and other flammable materials in the buildings' offices.

In another forensic aspect following the incident, forensic accountants began the task of tracing the perpetrators using financial records and other materials. These investigations led to the al Qaeda terror network as the perpetrators of the attack.

SEE ALSO Aircraft accident investigations; Architecture and structural analysis; DNA profiling; World Trade Center, 1993 terrorist attack.

Sequencing

Molecular techniques of analysis are a vital part of **forensic science**. Analysis of genetic material is instrumental in detecting pathogenic (disease-causing) microorganisms and in identifying a victim or implicating a suspect.

These molecular examinations rely on the determining of the arrangement of the building blocks of the genetic material. This determination is called sequencing.

Sequencing refers to the techniques used to determine the order of the constituent bases (i.e., adenine, thymine, guanine, and cytosine) of deoxyribonucleic acid (**DNA**), ribonucleic acid (RNA) or the constituent amino acid building blocks of protein.

DNA is typically sequenced for several reasons: to determine the sequence of the protein encoded by the DNA, the location of sites at which restriction enzymes can cut the DNA, the location of DNA sequence elements that regulate the production of messenger RNA, or to detect alterations in the DNA.

The sequencing of DNA is accomplished by stopping the lengthening of a DNA chain at a known base and at a known location in the DNA. Practically, this can be done in two ways. In the first method, called the Sanger-Coulson procedure, a small amount of a specific so-called dideoxynucleoside base is incorporated in a mixture with the other four normal bases. This base is slightly different from the normal base and is radioactively labeled. The radioactive base becomes incorporated into the growing DNA chain instead of the normal base, and growth of the DNA stops. This stoppage is done four times, each time using one of the four different dideoxynucleosides. This generates four collections of DNA molecules. Also, because replication of the DNA always begins at the same point, and because the amount of altered base added is low, for each reaction many DNA pieces of different lengths will be generated. When the sample is used for gel **electrophoresis**, the different-sized pieces can be resolved as radioactive bands in the gel. Then, knowing the location of the bases, the sequence of the DNA can be deduced.

The second DNA sequencing technique is known as the Maxam-Gilbert technique, after its co-discoverers. In this technique, both strands of double-stranded DNA are radioactively labeled using radioactive phosphorus. Upon heating, the DNA strands separate and can be physically distinguished from each other, as one strand is heavier than the other. Both strands are then cut up using specific enzymes and the different sized fragments of DNA are separated by gel electrophoresis. Based on the pattern of fragments, the DNA sequence is determined.

Several decades ago, sequencing involved scrutinizing the gels by eye. However, the marriage of powerful computational hardware and software to the sequencing process has automated the procedure.

The Sanger-Coulsom approach is the more popular method. Various modifications have been developed, and it has been automated for very large-scale sequencing. During the sequencing of the human genome, a sequencing method called shotgun sequencing was very successfully employed. Shotgun sequencing refers to a method that uses enzymes to cut DNA into hundreds or thousands of random bits. So many fragments are necessary since automated sequencing machines can only decipher relatively short fragments of DNA about 500 bases long. The many sequences are then pieced back together using computers to generate the entire DNA genome sequence.

Protein sequencing involves determining the arrangement of the amino acid building blocks of the protein. It is common to sequence a protein by determining the DNA sequence encoding the protein . This, however, is only possible if a cloned **gene** is available. It is still often the case that chemical protein sequencing, as described subsequently, must be performed in order to manufacture an oligonucleotide probe that can then be used to locate the target gene. The most popular direct protein chemical sequencing technique in use today is the Edman degradation procedure. This is a series of chemical reactions, which remove one amino acid at a time from a certain end of the protein (the amino terminus). Each amino acid that is released has been chemically modified in the release reaction, allowing the released product to be detected using a technique called reverse phase **chromatography**. The identity of the released amino acids is sequentially determined, producing the amino acid sequence of the protein.

Another protein sequencing technique is called fast atom bombardment mass spectrometry, or FAB-MS. This is a powerful technique in which the sample is bombarded with a stream of fast atoms, such as argon. The protein becomes charged and fragmented in a sequence-specific manner. The fragments can be detected and their identity determined. The expense and relative scarcity of the necessary equipment can be a limitation to the technique, though.

Still another protein sequencing strategy is the digestion of the protein with specialized protein-degrading enzymes called proteases. The shorter fragments that are generated, called peptides, can then be sequenced. The problem then is to order the peptides. This is done by the use of two proteases that cut the protein at different points, generating overlapping peptides. The peptides are separated and sequenced, and the patterns of overlap and the resulting protein sequence can be deduced.

SEE ALSO Analytical instrumentation; DNA sequences, unique; PCR (polymerase chain reaction).

Serial killers

Serial killers, those who kill more than once, pose a special problem for crime investigators because the their motives are often far less obvious than those of the person who commits a single homicide. Investigators describe three types of killer who commit multiple murders. The mass murderer kills several people at one time. Often these killers turn out to be disgruntled employees who show up at their places of work with shotgun in hand, bent on revenge. Spree killers often go on rampages with knives or guns, killing one person after another. Such people often have serious mental health problems. The serial killer, however, dispatches one victim at a time, with a time interval that may be as long as several years between each **murder**.

The "Washington Sniper" (aka, "Beltway Sniper" or "D.C. Sniper") killed ten people within a three-week period in the Washington, D.C., area in 2002. Originally thought to be a lone gunman, the killers turned out to be Gulf War veteran John Allen Muhammad and 18-year-old Lee Boyd Malvo, who were both convicted of capital murder. The media quickly labeled them "spree killers." Forensically speaking, however, they are probably more accurately described as a serial killers.

The serial killer tends to prey upon people at random. Usually, the attacker does not know the victims personally. The Federal Bureau of Investigation (**FBI**) Behavioral Science Unit developed the concept of psychological **profiling** in the 1960s to aid in the pursuit of serial killers and to let police know what kind of man (serial killers are nearly always men) is instigating the crimes.

Despite attempts by authorities to profile and find serial killers, some killers can continue killing and elude authorities for years. The so-called Green River Killer murdered at least 48 victims over a span of 16 years, from 1982 to 1998. The confessed murderer, Gary Leon Ridgway (now serving a life sentence), claimed that strangling young women was his "career."

Despite all the work that has been done on the **psychology** of the serial killer, forensic psychologists and psychiatrists are still far from understanding such people. Although it may be easier to comprehend someone who kills out of greed or revenge, the work of a serial killer is so far removed from normal behavior that most people have little understanding of his motives.

Many serial killers are psychopaths. Psychopathy, or anti-social personality disorder, is not considered completely curable. There is even debate by some scientists as to whether it is a mental illness at all. The hallmark of the psychopath is an extreme lack of guilt or empathy for others, which means the serial killer can carry out terrible crimes without emotional distress. Studies of serial killers in prison and evidence gathered from those who know them suggest that many of these murderers were the targets of physical, psychological, or sexual abuse in early childhood. This may lead them to build a world based on fantasy as a protective measure. These fantasies are then acted out in the course of a violent crime, often with a sexual context. The killer feels satisfied after the crime and then relaxes for a while. However, it is only a matter of time before the fantasies push them toward the next killing.

As the homicides mount, it becomes increasingly urgent for police to track down the killer. Also, as the killings mount, so too does the evidence, no matter how clever the killer may consider himself to be. As he continues, he may become careless or complacent, and the chances of his capture increase.

The forensic psychiatrist uses evidence from the crime scene to build a **psychological profile** of the serial killer. One categorization that has been found useful is to decide whether the investigators are dealing with an organized or a disorganized killer. If the crime scene suggests the murder was carefully planned and executed, then the killer may be a man of average to high intelligence who has a stable social network. He may be married with a family. He may also be employed. Living a "normal" life on the surface requires a degree of self-control, which manifests itself in the way the crime is carried out. Sometimes, though, the organized offender does lose control in the actual attack when the fantasy motivation takes over. In such cases, a violent or frenzied attack may occur, yet there may also be careful attempts to conceal or destroy evidence.

The disorganized offender leaves a mess at the crime scene. He may use any weapon that is available to strike out and makes little effort to cover his tracks. This lack of planning and control often suggests low intelligence. He is likely to be unemployed and may be a bit of a loner with few friends. The attack may be marked by excessive violence and could also include sexual contact with the victim after death. The disorganized serial killer often turns out to have a history of mental illness.

A number of other factors can be added to the profile. Many serial killers are young adults in their twenties or thirties. They tend not to cross racial lines. White killers tend to kill white victims; black killers tend to kill blacks. Many kill close to home the first few times, but then start to move farther away. Serial killers are eventually often highly mobile, which can make the logistics of catching them difficult.

Of particular interest to those investigating serial killers is what is taken from the scene or from the victim. In most crimes, the perpetrator will take items of monetary value, like cash or jewelry. They may also take evidence, such as a weapon. The serial killer often takes something known as a trophy or souvenir, of no obvious value except to him in his fantasy world. The item is known as a trophy if it is seen as a symbol of achievement and a souvenir if it is to remind the killer of the crime.

Trophies and souvenirs are an important part of the killer's *modus operandi* (**"method of operation,"** or M.O.), the name given to the particular tools and strategies that distinguish the killer's work. The M.O. includes factors such as the location of the crimes, the tools used, the time of day, the alibi, and any accomplices involved. The M.O. may, of course, evolve over time as the killer becomes more experienced. The investigators will be particularly interested in any details that are unique to that killer, such as leaving a note behind. They will also look for the signature of the crime. Trophies and souvenirs can be part of the signature, as can mutilating or having sex with the corpse, or placing the body in a certain position.

Victimology, the study of the victim, can be crucial in tracking down a serial killer. The investigators need to know what it was about that particular person that attracted the killer. Was the victim truly chosen at random or had the person been stalked previously? The killer may have been searching for the one person who fit his fantasy and, if a common link can be found between the victims, this may be very revealing. For instance, nearly all of the victims of serial killer Ted Bundy had dark hair parted in the center.

The location of the serial killer's crimes is also of significance. Geographical profiling is based on the premise that the killer will operate in a zone where he feels comfortable. This may be near home or, alternatively, far away from it, depending on his psychological make-up. Location is not just where the crime was committed, but is also where the victim was abducted and where the body was taken and left after the crime. Establishing a geographical profile can be challenging if the victim was a prostitute, for instance, or someone who might not be missed by relatives or co-workers for a while. The Yorkshire Ripper killed several prostitutes in the United Kingdom from 1977 to 1981, and the difficulty of tracking the victims' movements sometimes hindered the investigation. Sometimes bodies are dumped in remote places and may not be found for some time. In such cases, a forensic anthropologist may be called in to judge the times of death so the order in which victims were killed can be determined.

The world's most prolific serial killer was Dr. Harold Shipman, a British physician who took his own life in prison in 2004. He may have been responsible for up to 300 deaths, but the true figure will never be known as he always denied the killings. Prior to this, the so-called "Monster of the Andes," Pedro Lopez, held this dubious distinction, having been convicted of 57 murders in 1980. He may have killed many more; his victims were young girls in Colombia.

Despite his notoriety, Shipman was, in many ways, an unusual type of serial killer. His victims, many of whom were elderly women, met their end through morphine injections, one of the main methods of assisted suicide, which some believe to be a compassionate act. He was well known and liked in his community, and there was no obvious motive for the crimes. Some psychiatrists have suggested Shipman disliked older women, or that he was trying to re-enact the death of his mother. Others believed he gained pleasure from the power of life and death that he could exercise as a doctor. Shipman may have begun to kill patients very early on in his medical career, before he had even finished **training** to be a doctor. Initially, it was thought he began his career as a serial killer in 1974 when he first became a family doctor. This would put the number of deaths between 216 and 260. If, however, he began to kill almost as soon as he had the opportunity, then at least 24 more deaths, and maybe more, could have been at the hands of Shipman.

SEE ALSO Bundy (serial murderer) case; Psychological profile; Psychopathic personality.

Serology

Serology testing (assay) is largely used by forensic laboratories to analyze **blood** samples from suspects and bloodstains collected at the crime scene, in order to identify blood types of victims and assailants. The main objective of forensic tests, whether serological or other types, is to individualize samples through the **identification** of their sources.

Blood is the most common **physical evidence** in accidents, murder cases, and violent crime investigations. Besides blood, crime scene technicians may also find other stains and residues similar to blood in appearance at the scene, such as tomato sauce, red paint, or animal blood. To identify human blood, forensic scientists test samples at the crime scene with the chemical phenolphthalein, in an assay known as the Kastle-Meyer color test. Phenolphthalein releases hydrogen peroxide that reacts with an enzyme known as catalase in the blood. Catalase breaks down the hydrogen peroxide into water and oxygen, therefore releasing bubbles. However, as vegetables, animals, and some bacteria also produce catalase, this test only rules out the inorganic samples. Organic (plant or animal derived) samples are then collected for further serological analysis at the crime laboratory.

Body **fluids** such as blood, **semen**, **saliva**, and sweat, all contain **serum**. Serum is a liquid component of blood composed of water, trace minerals, several proteins including albumin, and immunoglobulins or antibodies. Albumin is the sticky protein that gives blood enough density for the water within it to remain inside the walls of arteries and veins. (Egg white contains high levels of albumin, which gives it the characteristic consistency.) When red and white blood cells are removed from blood, the resulting clear golden yellowish liquid is serum. Serology is therefore the study of the properties of serum. Serological tests have a wide range of applications in **medicine**, such as immunology and allergy assays, infection diagnosis, and blood typing. Serology can determine whether an individual was exposed in the past or if he is presently infected with a variety of **pathogens** (disease-causing organisms), such as hepatitis, measles, **anthrax**, syphilis, or HIV. Serology tests can also determine the presence of alcohol, illegal drugs, and poisons in the serum. Serological tests are also used in forensics to identify blood ABO groups, whose results, although not conclusive, may help to exclude or include suspects in the investigation process. If for instance, a suspect is blood type B and the samples from the crime scene are all types A and O, the suspect with type B blood can be excluded from the investigation.

Serology is such a convenient diagnostic tool because the **immune system** produces specific molecular tags in the blood for practically each foreign substance or invading microorganism. Each one specializes in binding to a specific molecule such as a viral, parasite, or bacterial protein, as well as to foreign substances such as poisons and drugs. For minutely small drug molecules against which the immune system is not very sensitive, special immune reagents were developed for the detection of drug abuse. An example is the Homogeneous Enzyme Immunoassays (EMIT), which is commercialized in kits ready for use.

To determine whether a blood sample is from a human or animal source, samples are tested with anti-human serum. This method was discovered by the German biologist Paul Uhlenhunth in the late 1870s. He injected protein from a chicken egg into a sample of rabbit's blood. After a few days, he extracted the rabbit's serum and mixed it with egg white, causing the separation of egg proteins from the solution to form a whitish clotting substance, precipitin. Precipitin is now a generic name for the resulting agglutinated complex formed when antibodies present in the serum of a species agglutinate the proteins in the blood of a different species. The forensic test consists of collecting the blood sample in a test tube containing serum from a rabbit containing antibodies against human blood, known as anti-human antibodies. If an insoluble complex of precipitin (clumping) occurs, the test is positive for human blood. This test can also be conducted using gel-electrophoresis, when a blood sample is put on a glass slide and covered by a layer of agar gel. The slide is positioned side by side with another containing the rabbit anti-human serum, inside a box filled with a solution that conducts electric current. As the current passes through, protein molecules are filtered into the gel and toward each glass slide. If precipitin is formed, the test is positive, and the blood sample is identified as human blood.

Electrophoresis is also used in typing the different groups of human blood, known as the ABO grouping system. After the discovery of antibodies and antigens (molecules to which antibodies bind), scientists identified four blood types among humans between 1875 and 1901. All human blood contains antigens in red cells that vary in type among individuals in accordance with inheritance (e.g., maternal and paternal inherited genes). Genes A and B (**chromosome** 9) encode enzymes that add specific sugars to an **antigen** at the ends of a complex sugar molecule (polysaccharide) that is present on the surface of erythrocytes (red blood cells). Individuals who inherit neither A or B genes have type O blood. As genes A and B are codominant (they do not dominate each other), individuals who inherit both genes (one from each parent) are type AB. The following other inherited combinations may occur: AA, BB, AO, BO, OO. Individuals AO or BO are respectively heterozygous type A and type B. AA or BB are homozygous types A or B.

Blood typing tests consist of mixing blood samples with anti-serum A on one side of the slide, and with anti-serum B at the other side. If the agglutination (clumping) occurs on both sides of the glass slide, the blood is AB. If it occurs only with anti-serum A, the blood is type A, or if it occurs only with anti-serum B, the blood is type B. If no agglutination occurs, the blood is type O. Because a person with type O blood does not present antigens to either A or

B antibodies, they can donate blood to most blood groups. Carriers of **gene** A that have antibodies against B antigens in their blood plasma, and vice versa, can only receive transfusions of the same blood type or from type O blood. Individuals with AB blood type can receive transfusions from all donors. Type O carriers however cannot receive blood from the other types because their plasma contains antibodies against A and B antigens.

Population prevalence of blood types is approximately as follows: type A is more common in Caucasians and Europeans; type B among Africans, African descendents, and South Asia populations; AB type is predominant in China, Japan, and Korea; and Type O is predominant in Native Americans, Aborigines, and Latin American populations, and is common in Middle-Eastern populations as well. A small portion of the world population carries a rare variation of AB type subgroups that present weak reactions or no reaction at all to antibodies.

Another breakthrough of significance for both medical and forensic sciences was the discovery by **Karl Landsteiner** in 1940 that 85% of the human population carries erythrocytes that express the Rh(D) antigen, or Rhesus disease antigen (a protein also present in Rhesus monkeys). Blood is designated as being either Rh positive ($^+$) or Rh negative ($^-$). If an Rh^- person receives blood from a donor who is Rh^+, his immune system will develop antibodies against the antigen, causing disease or death, depending on the quantity of blood transfused. There are thirty possible combinations between ABO groups and Rh factors. Approximately two thirds of all people have an O^+ or A^+ blood type, with all other types comprising the remaining third. These variations allow the number of suspects in a crime investigation to be narrowed.

Another singular characteristic of proteins and enzymes is the presence of discrete variations in a single base pair of the genes that encode them, known as polymorphisms (or multiple forms of the same gene). More than 1% of any given population has polymorphisms in specific genes. Specific polymorphisms are also more prevalent in certain populations. For instance, the CYP enzymes of the gene Cytochrome P 450 show a specific polymorphed version in 40% of the Asian population, whereas another polymorph is more prevalent among Caucasians and Europeans. Several other enzymes also present a known prevalence among races, and are therefore, useful in forensic testing.

Genetic screening for polymorphisms in forensic samples is very helpful when combined with blood type and Rh factors, because it sharply reduces the probability the existence of two persons with the same blood characteristics being involved with the same crime to very insignificant odds. In addition, other serological tests can also be used to estimate age, sex, and race of suspects, such as hormonal levels in blood and other fluids, as well as genetic analysis such as chromosomal typing (or karyotyping), and **DNA profiling**.

SEE ALSO Animal evidence; Antibody; Antigen; Blood; Chromosome; Circumstantial evidence; Crime scene investigation; Cross contamination; DNA; Epidemiology; Fluids; Hemoglobin; Homogeneous enzyme immunoassay (EMIT); Illicit drugs; Immune system; Luminol; Parasitology; Paternity evidence; Saliva; Serum; Toxicological analysis.

Serum

Serum, or **blood** serum, is a useful medium for a range of forensic analyses, as well as for laboratorial diagnostic assays, due to its biological contents. Pure serum, however, does not contain blood cells, platelets, or fibrinogen (coagulation factors). The sticky consistency of serum is due to albumin, a protein that provides the proper density for blood, and prevents it from leaking through cell vessel walls. The main function of serum is to moisten the surfaces of cell membranes and to transport to organs and tissues diluted water-soluble nutrients such as blood red cells (erythrocytes), hormones, fat-soluble nutrients (chyle), white blood cells, and antibodies present in the lymphatic fluid as it enters the blood circulation. Serum is also present in seminal fluid and lymphatic **fluids**, and exudates from wounds and blisters as a clear watery substance. The presence of these and other contents in serum allowed the development of several types of analytical assays (tests) useful for both clinical and forensic purposes, such as for detecting tumor markers, detecting antibodies for specific infectious agents, anti-doping tests, blood typing, and **DNA** tests. Serological tests are also used in postmortem **identification** of poisons or illegal drugs in the body fluids of corpses.

Blood plasma is formed by serum and lymphatic fluid, and contains suspended leukocytes (white blood cells), erythrocytes, coagulation factors, electrolytes (e.g., mineral ions), gases, proteins, glucose, water, and micronutrients essential for cells. Plasma may contain poisonous metabolites resulting from enzymatic transformation of drugs, poisons, allergenic substances, or environmental pollutants, known as exogenous metabolites. Additionally, serum transports endogenous toxic metabolites resulting from cellular and enzymatic processing of gases and nutrients, which are released in blood plasma to be excreted through urine, sweat, and feces. Serum and plasma contents can therefore be analyzed for various purposes: the forensic determination of environmental **toxins** in outbreaks of illness due to either water or food contamination, DNA screening for the identification of suspects and/or victims, paternity tests, and drug screening.

The most common serological immunoassays used by forensic technicians are: enzyme-multiplied immunoassay technique (EMIT), radio-immunoassay (RIA), fluorescence polarization immunoassay (FPIA), cloned enzyme donor immunoassay (CEDIA), enzyme linked immunosorbent assay (ELISA), gel diffusion analysis (immunodifusion), serum protein **electrophoresis** (immunoelectrophoresis), and Western immunoblotting. EMIT, RIA, FPIA, and CEDIA allow the screening of very small amounts of antibodies against all classes of drugs and the identification of specific drugs as well. As some small drug metabolites do not trigger natural **antibody** formation, specific **commercial kits** are used to recognize these potential antigens in suspects of drug abuse. Antigens are proteins and substances recognized either by the **immune system** as foreign to the host (such as viral and bacterial particles or allergens) or by an assay antiserum reagent. The following specific drugs can be detected in serum through the above immunoassay tests: benzoylecgonine, a cocaine metabolite, phentanyl, methadone, phenylciclidine, and propoxyphene. Additionally, the following classes of drugs can be identified: **amphetamines**, **barbiturates**, benzodiazepines, cannabinoides, and opiates. ELISA is more commonly used for HIV and hepatitis C diagnosis, although this method can also detect drugs in the serum or in urine. ABO blood grouping and Rh factor typing is usually performed through gel diffusion analysis (immunodiffusion) or serum protein electrophoresis, known as immunoelectrophoresis. These assays can also determine whether a blood sample has a human or animal origin. Serum proteins can also be sorted by immunoelectrophoresis, and the resulting protein complexes can be further screened for specific antibodies against HIV antigens or very small drug metabolites through the Western immunoblotting technique.

Another immunoassay technique, the antibody profile assay (APA), was developed in the late 1990s, and has proved to be useful in forensics. The test design is based on the fact that the serum of each individual contains a variety of antibodies, each one specific to a given foreign protein to which a host was exposed in different periods of life. Therefore, each individual has a unique antibody serological profile, consisting of all the different antibodies that he or she carries. At birth, babies have in their blood plasma only the antibodies received from the mother; gradually, each will develop his or her own particular antibody profile through exposure to infectious agents and other antigens during life. APA determines the unique set of individual specific antibodies (ISA) by embedding a paper strip containing antigenic proteins into blood samples, which causes specific immune reactions by the antibodies present in the sample. The strip is then stained to reveal a unique ISA pattern of bands that identifies the donor of the sample. Several hospitals use APA to identify newborns and their respective mothers.

The Wyoming State Crime Laboratory has collaborated with APA researchers in testing APA specificity for forensic application in identifying contaminated and tainted samples. The laboratory received ten blood samples and proceeded to subject them to all possible conditions found in crime scenes: tainting, contaminating, mixing the samples with other human or animal blood samples, urine, or gasoline, and putting them in upholstery, car hoods, and side walks. Researchers also exposed some samples to a variety of temperatures, ranging from −68°F (−56°C) to 140°F (60°C). The resulting 422 tainted samples were then returned to researchers for APA testing, and resulted in 91% correct identifications.

SEE ALSO Amphetamines; Antibody; Antigen; Autopsy; Barbiturates; Blood; Bloodstain evidence; Commercial kits; DEA (Drug Enforcement Administration); Death, cause of; FBI crime laboratory; Fluids; Homogeneous enzyme immunoassay (EMIT); Illicit drugs; Immune system; Narcotic; Paternity evidence; Pathogens; PCR (polymerase chain reaction); Poison and antidote actions; Rape kit; RFLP (restriction fragment length polymorphism); Saliva; Semen and sperm; Serology; Toxicological analysis; Toxins; Vaccines.

Sex determination

Sex determination is the process by which organisms develop as males or females. Some organisms reproduce only by asexual methods, and thus they may possess no system for sexual differentiation. For most species of plants and animals, however, sexual development is a basic element of the normal life cycle. In humans, sex is a fundamental characteristic that influences the development of many of the features of the body. This includes some obvious traits such as genital and breast development, but it also includes structures in the brain and other internal organs, the shape and mineral composition of bones, and a wide array of features observable at the cellular level.

The many clues, overt or subtle, that can be collected from careful examination of the bodies, organs, tissues, and even cells of the deceased remove much of the mystery of the sex of a victim whose remains are recovered from the scene of a crime, or the site of a fire, explosion or other disaster.

In humans, where there are two distinct sex chromosomes, the X and the Y chromosomes, it is the presence of the Y **chromosome** that specifies male development. More specifically, there is a **gene** on the Y chromosome called the sex-determining region of the Y chromosome (SRY) that causes male development. In fact, female development seems to be the default pathway, and in the absence of SRY, the urogenital tract develops as a female. The elementary structures for both male and female development are present in the early embryo, however, development of the female ductal system, called the Mullerian system, is inhibited by a substance produced by the early male embryo. Likewise, in females, the primordial male ductal system, called the Wolffian duct, degenerates as the Mullerian ductal system advances. The Mullerian ducts give rise to the fallopian tubes, uterus, and upper portion of the vagina. The Wolffian ducts give rise to the spermatic ducts and seminal vesicles which carry **sperm** from the mature testes during ejaculation. Although SRY, the primary sex-determining gene, is found on the Y chromosome, many of the genes responsible for development of both male and female reproductive structures and other sexual characteristics are found on the autosomes.

One of the earliest events in male development is the production of testis-determining factor within the sex cord cells. The sex cords begin to differentiate into Sertoli cells when SRY is present. The Sertoli cells secrete male-specific factors such as Mullerian inhibitory substance (MIS), which causes the female ductal system to degenerate. MIS also promotes the development of another male-specific cell population called Leydig cells, which produce testosterone. For female embryos, because of the absence of SRY, the sex cords develop along a different pathway to develop structures associated with the ovaries. As the embryo develops, hormones produced by the testes in males and the ovaries in females create a biochemical environment in which the more subtle elements of sexual development occur.

Sexual development is not always so straightforward in humans. Although people are usually considered either male or female, various disruptions can occur during sexual development and differentiation that give rise to atypical or mixed sexual development. These include sex chromosome abnormalities, where there are extra or missing copies of the sex chromosomes. This would include Turner syndrome, where females receive only a single X chromosome; Klinefelter syndrome, wherein males receive not only an X and Y chromosome but also an extra copy of the X chromosome; and a wide variety of other more rare numerical sex chromosome abnormalities where extra copies of the X and/or Y chromosomes are present. In addition, the SRY gene that is normally transmitted on the Y chromosome can become translocated to an X chromosome or an autosome, resulting in a reversal of sex. Also, when multiple cell lines are present, with different sex-chromosome allocations, individuals may develop both male and female characteristics. True hermaphrodites have both testes and ovaries, and may have both intact male and female external genital structures. Pseudohermaphrodites have external genital structures that are opposite of what would be expected on the basis of having either testes or ovaries internally. In addition, the development of the external genital structures can be incomplete, and it may initially be difficult to determine sex at birth. Occasionally, some of the male or female structures fail to form altogether for reasons that are not usually clear. In cases where external genitalia are ambiguous, it was common practice for many years to assign a female gender, and to perform surgical alterations to make the external genitals look more completely feminine. In recent years, it has been recognized that the sexual identity of genetic males after puberty is typically male regardless of whether the child was reared as a male or female, and thus more consideration is given to sex assignment now than in previous years.

Sexual determination is not always as straightforward in other species as it is in humans, and there are many different basic mechanisms by which sex is determined. In fruit flies *(Drosophila melanogaster)*, for example, sex is determined by the ratio of X chromosomes to the number of sets of autosomes. Normal females have a ratio of 1:1, usually having two X chromosomes and two complete sets of autosomes. Males typically have one X chromosome and two sets of autosomes for a ratio of 1:2. Any ratio greater than 1.0 will result in female sex development, and any ratio below 0.5 results in male development. In between 0.5 and 1.0, the pattern of development is intermediate, bearing some aspects of both femaleness and maleness.

In most species, female development is associated with the presence of two X chromosomes, and male development with the presence of an X and a Y chromosome. Females are therefore typically the homogametic sex, meaning that their sex chromosomes are identical to one another. Males are said to be the heterogametic sex, have two different sex chromosomes. In some species, most notably in certain birds and butterflies, the male is homogametic, and the female is the heterogametic sex. In these species, the male sex chromosomes are referred to as Z chromosomes, and the females are said to have a W chromosome and a Z chromosome.

Sex determination in plants is also variable. The male-associated structures in flowering plants are the stamen and pollen. Female associated structures are the pistil and ovaries. Most plants exist as hermaphrodites, producing both male and female structures, often in the same flower. Other plants may exist as male or female individuals, producing only male or female flowers. The common sexual differentiation schemes among plants that produce seeds encased in ovaries are dioecy and gynodioecy. In dioecy, plants can be either male or female. In gynodioecy, plants are either female or hermaphroditic. Sex determination in plants is often less genetically deterministic than in humans. That is, genetic factors may not sufficiently specify the sex of the plant. This results in male, female, or hermaphroditic development being somewhat dependent on environmental conditions.

Sex determination in animals can also be heavily influenced by the environment in some species. For example, sex-determination in some species appears to be primarily dependent upon temperature at the time of development rather than on the presence or absence of specific genes or chromosomes. In certain species of fish, sexual development can change over time with individuals functioning as females for part of the life cycle and as males for other parts of the life cycle. This can be influenced by the relative abundance of individuals of the same or opposite sex in the environment, even when the other individuals are separated by an insuperable barrier such as a glass partition in an aquarium. Environmental pollutants can also influence sexual development in many species.

Bacteria are generally considered to be asexual reproducers, however, ***Escherichia coli*** sometimes contain a plasmid called the F-factor that contains 30 or so genes in a small plasmid. The presence of the F-factor permits a bacterium to conjugate with another bacterium lacking the F-factor. During conjugation, copies of the F-factor are transmitted to recipient cells, converting them from F^- to F^+. This system is reminiscent of sexual systems in higher organisms.

There are many other unusual systems for sexual development and differentiation, and there seem to be as many exceptions as there are rules. For example, the parasitic wasp, *Habrobracon juglandis* can reproduce without a partner. This process is called parthenogenesis. Female wasps produce eggs at maturity and begin laying eggs regardless of whether there are males in the environment with which to mate. Both fertilized and unfertilized eggs hatch out and produce viable offspring. Eggs that are not fertilized contain only a single copy of each chromosome, a state that is called haploidy. Haploid offspring are male, and will produce sperm at maturity, and will mate with females to fertilize their eggs. The fertilized eggs receive two copies of each chromosome, one from each parent. This is called diploidy. Diploid offspring develop as females. Thus in this species, sex determination is dependent on the number of copies of each chromosome that are present at the time embryogenesis begins. When few males are present in the environment, most eggs will go unfertilized and the offspring will be haploid and thus male. When many males are present in the environment, most eggs are fertilized, giving rise to diploid offspring, which develop as females. While this system for sexual development is not common in nature, it illustrates one of the many innovative ways that sex can be determined in nature.

The benefits of sexual systems for reproduction are not very well understood in nature, but the presence of such elaborate and complex systems for development suggests that there must be benefits to sexual reproduction compared with asexual methods.

SEE ALSO Anthropometry; Chromosome; Gene.

Sexual dimorphism

The natural occurrence of physical differences between males and females is referred to as sexual dimorphism. Often, these physical differences are quite striking and obvious, such as the differences seen in humans where external genitalia at birth can usually be used to tell boys from girls unambiguously. As children develop and mature into adulthood, a whole host of other physical traits emerge such as body hair patterns, breast development, and a wide array of other growth characteristics. While it might seem self-evident that physical differences exist between males and females, some species, such as Quaker parrots, do not exhibit any outward differences, and cannot be sexed externally. Even avian experts must rely on genetic testing to sex these birds. Quaker parrots could, therefore, be described as sexually monomorphic.

The sex of an animal can oftentimes be determined by external physical traits such as overt differences in the appearance of the external genitalia. Dogs, for example, are sexually dimorphic at this level as one can easily determine gender from observation of external genitalia, even at a distance. Other species, such as hamsters, exhibit differences in external genitalia that are more subtle and require careful examination. Many birds may be sexed by the scientist, despite a lack of observable differences in external genitalia, because of striking differences in coloration patterns in the feathers.

In fruit flies (*Drosophila melanogaster*), it has long been recognized that the ratio of X-chromosomes to Y-chromosomes is the primary determinant of whether the embryo will develop as a male or as a female. Males can easily be discriminated from females based on external differences such as length and coloration patterns of the abdomen, and the presence of sex combs being limited to the foreleg of males. There are indeed differences in external genitalia of fruit flies, but these differences are far more subtle, making discrimination of gender on the basis of external genitalia impractical. There has recently been a revolution in scientific understanding of how sex-determination in fruit flies (*Drosophila*) generates sexual dimorphism in somatic tissues at the molecular level. The mechanisms for **sex determination** alter the activities of various signaling molecules and transcription factors within cells to direct various sex-specific elements of growth and differentiation.

In flowering plants, there are two dimorphic breeding systems that are fairly widespread among species that develop seeds within an ovary. The first system, called dioecy, involves males and females. Male expression in plants involves stamen and pollen production. Female expression involves production of the pistil and ovaries. The second and more common system, called gynodioecy, involves females and hermaphrodites (plants which express both male and female components). Hermaphrodites are individuals that produce both male and female sexual parts. Hermaphrodites are very common among plants. Conditions within the environment such as the availability of water or soil nutrients can alter the sexual expression in hermaphroditic plants, resulting in differences in the balance of male to female flowers over time.

The concept of sexual dimorphism can be applied at many different levels. Thus, while one might ask at the most basic level whether males and females are physically different and therefore distinguishable from one another, the question of sexual dimorphism can be applied toward specific traits, both internal and external. Differences in hormone levels betweens males and females constitute a kind of sexual dimorphism of their own at the biochemical level. Genetic differences betweens males and females, even prior to the rise of hormonal differences, can give rise to differences in both structure and function in the brains of vertebrate animals when comparing males and females. Even in cell **culture**, response to hormonal supplementation can be different in male and female neurons even when the neurons in culture are taken from the embryo prior to time that the testosterone surge masculinizes the male embryonic brain. This leads to differences in structural development as well as differences in the biochemical environment. One can even consider behavioral traits to be sexual dimorphisms if the patterns of behavior are consistently different between males and females.

Evidence of sexual dimorphism may be seen even in the circadian rhythms (daily physical patterns) of males compared with females in many species. Careful study of the development and the differences in circadian rhythms in male and female rodents shows that differences arise after the onset of puberty and require the presence of hormones produced by the testes or ovaries. Removal of the testes or ovaries in animals prior to the onset of puberty prevents the development of distinctive changes in circadian rhythms normally seen shortly after puberty, even when sex-specific hormones are applied.

In the most general sense, any aspect of physical structure, coloration, **gene** expression, **physiology**, biochemistry, or behavior that shows evidence of differences between males and females can be described as a sexual dimorphism. The existence of sexually dimorphic traits at so many different levels of function and development provides researchers with insights into the meaning of sex within nature.

SEE ALSO Anthropology; Biometrics; Gene; Physiology.

Sexual predation characteristics

By legal definition, a sexual predator is a person who has been convicted of or pled guilty to committing a sexually oriented offense, and who is likely in the future to commit additional sexually oriented offenses. Sexual predators present unique challenges to the forensic psychiatrist because their condition is often resistant to current treatments; they may or may not have a concurrent mental illness; and it is often difficult to properly place convicted sexual predators, whether within the prison population or in mental health facilities. Offenders can be classified as sexual predators in one of the following ways: (1) The offender is convicted of a sexually violent offense with a sexually violent predator specification, or (2) the sentencing court, after holding a sexual predator hearing (based on legal statutes) determines that the offender is a sexual predator. Offenders who are classified as sexual predators are bound by lifelong registration and verification requirements unless an additional hearing is held and a judge makes a decision to modify or to terminate classification of the individual as a sexual predator. Sexual predators are subject to local jurisdictional rules and requirements for neighbor and community notification, and they may be required to report their whereabouts to an officer of the court, or to a law enforcement agency, every 90 days.

According to the Federal Bureau of Investigation's (**FBI**) National Center for the Assessment of Violent Crime (NCAVC), while sexual predators do not always commit homicides, they do typically escalate their criminal sexual behaviors over time. Fantasy plays a key role in the lives of sexual predators, and they are reported (on the basis of extensive research and interviews with incarcerated and convicted sexual predators) to experience violent sexual fantasies well before they begin to act them out. Over time, they progress to the point of carrying out their imagined or fantasized scenarios with both willing and unwilling sexual partners. When sexual predators become lethal (that is, when they kill), they typically refine their means or methods of choosing, pursuing, abducting, and controlling their victims throughout a scenario that leads to the eventual sexual homicide.

It is quite common for sexual predators to report experiencing sexual pleasure, or achievement of sexual gratification, resulting from behaviors that would not generally be considered sexual, such as intentionally causing their victims to experience pain; mutilating or disfiguring their victims; collecting trophies such as articles of clothing or personal items belonging to the victim; taking tokens from the environment in which the crime was committed (in sexual homicides, the latter may be a piece of flesh or other body part); the manner in which the victim is left (bound or tied with the use of symbolic ligatures); or, in the case of **murder**, the manner in which the corpse is arranged or designed to be discovered.

Sexual psychopaths are a subcategory of sexual predators who are characterized as being far more likely to rape (and/or commit homicide) than simply to molest their victims. They are more likely to victimize both children and adults, rather than one or the other. Their criminal sexual predatory behavior, if they are motivated by thrill-seeking rather than by specific fantasies, may be directed into indiscriminate victim choice, not targeting one or a small number of victim types.

SEE ALSO Bite analysis; Blunt injuries, signs of; Bundy (serial murderer) case; Crime scene staging; Criminal profiling.

Shaken baby syndrome

Shaken baby syndrome (SBS) is a collection of findings used to describe the aggressive shaking, jolting, and jerking of an infant or young child primarily about the arms, chest, legs, or shoulders, and the strong impact trauma, or blows, on and about the head and **skull** of a baby. (Other names for shaken baby syndrome include shaken/impact syndrome, abusive head trauma, pediatric traumatic brain injury, shaken brain trauma, shaken impact syndrome, and whiplash shaken infant syndrome.) SBS is most often inflicted by biological fathers, stepfathers, male partners of biological mothers, and caregivers, but can also be inflicted by biological mothers.

Shaken baby syndrome is diagnosed by physicians (in cases of live children) and forensic scientists (those of dead children) when finding such problem areas as retinal hemorrhages (bleeding within the retina of eyes), intracranial hemorrhage (bleeding in and around the brain), increased head size (as a result of too much fluid in brain tissues), spinal cord damage, and broken and fractured ribs and bones. When brain damage is suspected, various diagnostic methods are used including computed tomography (CT) and magnetic resonance **imaging** (MRI) in order to show injuries to the brain. When such problems occur, more subtle symptoms are usually also present such as viral illnesses (such as influenza), infant colic (stomach aches and cramps), swallowing and feeding dysfunction, vomiting, lethargy (sluggishness), and irritability. Enough traumatic force used when shaking a baby can lead to brain damage, hearing loss, blindness, learning disorders, mental retardation, paralysis, seizures, and eventual death of the child.

Shaken baby syndrome, a type of child abuse, is investigated by law enforcement officials as a criminal assault in the United States and in many countries around the world. Such investigations are mostly performed by an expert who can distinguish between common childhood illness and injuries, and symptoms associated with SBS. It could also be investigated by professionals from local or state child welfare, social services, and public health care agencies due to the need to protect the child. Forensic experts must be called in when death has occurred in order to verify that the **cause of death** was shaken baby syndrome.

SEE ALSO Skull.

Shoeprints

Shoes create impressions at the scene of a crime called shoeprints and can be extremely informative to the forensic investigator. The sole of a shoe picks up various kinds of material as a person walks, and this is readily transferred to other surfaces, creating an impression that can reveal the pattern on the sole. Investigators look at soil, particularly around the potential entry and exit points of a crime scene, as well as carpet, linoleum, paper, and dust to try to detect shoeprints. If a shoeprint is found in a pool of **blood**, it can serve as incriminating **evidence**.

There are three kinds of shoeprints: patent, plastic, and latent. Patent shoeprints are clearly visible and come from tracking through a substance like paint or dirt and leaving some behind each time a step is taken. A plastic shoeprint occurs when a shoe sinks into a soft substance like snow or mud. Latent shoeprints are those that are not visible to the naked eye and often occur on a hard surface like **glass** or concrete. The techniques used for collecting shoeprints vary, but include dusting with special powders, electrostatic lifting, and making plaster casts. A photographic record is always taken as well.

Back in the laboratory, the forensic investigator will determine various characteristics of any shoeprints collected. The pattern itself can be linked to specific manufacturers and shoe types. Very few shoe soles are made of plain leather alone, and the patterns on a pair of trainers can be complex. The investigator will probably have access to a shoeprint database to identify the origin of a shoe. It may also be possible to determine the size of the shoe from the size of a sole, and this can help build a physical profile of a perpetrator.

Each individual has their own way of walking, which has an impact on the way their shoes wear down, and this will be evident in the shoeprint. It may be possible to determine if the perpetrator had a foot deformity or a limp from the way their shoes have worn down. As someone walks, the soles of their shoes also acquire a unique pattern of damage consisting of tiny cuts, scratches, and abrasions. Because no two people ever tread exactly the same route over a period of time, this damage pattern is unique to each shoe sole and can be powerful individualizing evidence.

To compare a shoeprint found at the scene of a crime with that from a suspect's shoe, the investigator has to create a print from the latter. One way is to coat the shoe sole with a light oil by pressing it into foam rubber impregnated with oil. The shoe is then pressed onto paper, creating an oily print that can be visualized with magnetic powder. If a plastic print is needed for comparison, the shoe will be pressed into a similar surface to the one in which the shoeprint was found. It is important to try to reproduce the mechanism by which the original shoeprint was made in investigating a suspect's shoeprint. The argument that both came from the same source—the suspect's shoe—then becomes much more convincing.

SEE ALSO Impression evidence.

Silencers

The forensic investigation of a crime that involved the use of a firearm is concerned with establishing the type of weapon used. This knowledge helps piece together the circumstances of the crime and can help apprehend those who committed the crime. These ballistic determinations can include obtaining **evidence** of the use of a silencer.

A silencer, intended to suppress sound, is an attachment to a firearm. Generally, silencers are a six- to twenty-inch steel, titanium, or aluminum alloy barrel addition designed to work with a particular weapon. Silencers have also been constructed from other materials such as plastic soft drink bottles.

Nicknamed "whispering death," these devices give a shooter the ability to strike a target with less risk of being noticed. Contrary to popular image, silencers do not completely muffle the sound of a gun, but instead lessen muzzle flash, reduce muzzle noise, and decrease recoil by delaying the escape of gases from the barrel of the firearm.

To an experienced forensic investigator, then relative lack of **gunshot residue** in a crime involving a firearm can be a clue to the use of a silencer.

Gunsmiths began experimenting with various designs to silence weapons in the nineteenth century. The first person to develop and market a silencer successfully was Hiram P. Maxim, the son of the similarly named inventor of the machine gun. In 1908 Maxim developed a silencer that delayed the release of gases, but he did not market the weapon until making a few improvements. The Maxim Model 1909, released in the year of its name, became the first efficient silencer to be marketed, but the Maxim Model 1910 became the most widely distributed silencer in the United States by capitalizing on an off-center design that allowed it to be used with a weapon's original sights.

Although the military value of silencers quickly became apparent to many observers, Maxim only had the goal of eliminating noise pollution. Many of the first buyers of silencers employed them for target shooting in basements and backyards so that the sound of firing would not disturb others. Silencers also found a market in pest control. Many silencers are still sold for use in eliminating rats, not so much to surprise the rodents, but to avoid the public relations problems associated with shots fired within heavily occupied areas.

The development of a supremely effective silencer has been complicated by many factors. The noise made by the discharge of a firearm has three components: 1) the sounds made by the movement of the parts of the gun; 2) the crack of a bullet passing through the atmosphere at a rate above the speed of sound; and 3) the release of high pressure gases breaking out of the barrel. Silencers only address the last concern, although the use of a heavy subsonic bullet rather than a high velocity bullet greatly adds to sound suppression. High velocity bullets make a noise of their own when traveling through the air outside of the silencer and the substitution of a slower bullet will slow the passage of the projectile through the air, thereby reducing ballistic noise. Silencers that fire regular supersonic ammunition are only a little quieter than those without suppressors. Subsonic ammunition has less power than regular ammunition making it effective only at shorter ranges of up to 600 feet (200 m). Silencers can be attached to most **firearms**, but they work best as components of purpose built or modified guns.

Silencers are now made for almost every firearm, from fully automatic submachine guns to big bore bolt-action rifles, and the popularity of these weapons is likely to grow.

SEE ALSO Ballistics; Crime scene investigation; Gunshot residue.

Simpson (O. J.) murder trial

The role of forensic scientists is paramount in gathering **evidence** for criminal court cases. In the end, however, the verdict rests with the jury. One of the most publicized and controversial court cases involved the double **murder** of Nicole Brown Simpson, 35, and Ronald Goldman, 25, at approximately 10 P.M. on June 12, 1994. Both were stabbed to death outside Nicole Simpson's Los Angeles condominium. The investigation was complicated by the fact that there were no eyewitnesses and no murder weapon was found. However, crime scene investigators did recover important evidence that linked Nicole's former husband, Orenthal James (O. J.) Simpson, the former football star, to the murders. This evidence was analyzed by forensic scientists and it was used to prosecute Simpson in an internationally watched and discussed court case.

The evidence that was retrieved at the scene of the crime was substantial. It wasn't immediately clear who committed the murders—even though Simpson was an early suspect—until five days after the murders. In front of a televised audience of millions of viewers, police cars, and helicopters, Simpson's white Ford Bronco drove in a 60-mile (97-km) chase across Route 405 in southern California. The car was driven by A. C. Cowlings, a friend and an ex-football player teammate, while Simpson sat in the back seat with a gun. Simpson had failed to show up for his arraignment on the charges of the double murder before the famous car chase. At the end of the car chase, with the Bronco pulling into his Rockingham Avenue estate, Simpson was arrested.

Deputy District Attorney Marcia Clark revealed the evidence to the court. There were hair samples that were found on Goldman's body after his murder. Forensic geneticists matched the **DNA** from the hair samples to DNA retrieved from O. J. Simpson. There was also a trail of bloody **shoeprints** near the murder scene that were estimated by the crime lab to be made by a man's shoe, size 12—the same size that Simpson wears. There was a pair of socks with bloodstains on it that was found in O. J. Simpson's bedroom. Geneticists extracted DNA from the socks and matched it to Nicole's DNA. **Blood** was also found on Simpson's Ford Bronco. After the DNA was extracted and tested, it was found to positively match DNA from both victims. Even blood found at the crime scene was found to have DNA that matched that of O. J. Simpson.

During the police **interrogation** of Simpson, it was discovered that he had a cut on his left hand. A leather glove that was found near both of the victims had blood on it. DNA samples from the blood matched that of both Simpsons as well as Goldman. A matching glove, with bloodstains on it, was also recovered on Simpson's own estate. Cumulatively, this striking evidence led the prosecution to believe that Simpson was guilty. His trial began the following January.

Simpson employed a group of competent, high profile lawyers that became known as "the dream team." They engineered a formidable defense (despite the overwhelming evidence against Simpson) that was focused on discrediting the Los Angeles police department. They claimed that the police failed to conduct a well-constructed, proper investigation. The prosecution launched its attack using O. J. Simpson's prior history of severe domestic violence and a platform for demonstrating both his motive and his capability of violence. There were other women, at one time involved with Simpson, who claimed to have been abused by him. The prosecution asserted that Ronald Goldman was murdered when he went to Nicole's condominium to return her eyeglasses and, in doing so, stumbled upon the murder. He was then allegedly murdered by O. J. Simpson.

For the defense, the strategy was targeted at police detective Mark Fuhrman, who arrived at Simpson's estate and first discovered the matching bloodstained glove on his property. The defense's case was strengthened by a variety of conversations that depicted Fuhrman as a racist based on previous racial remarks he had made. Attorney Johnnie Cochran proved to be a key player on Simpson's defense team. Jurors heard tape recordings of phone calls that Nicole made to 911 in 1989 and 1993 during altercations between her and Simpson. However, Cochran managed to refocus the court proceedings on Fuhrman, who he ultimately accused of planting the matching bloodstained glove on Simpson's property in order to frame the ex-football star for the double murders. It was implied that Fuhrman was motivated to frame Simpson because he was black.

Near the end of the trial, Cochran produced one of the gloves and requested that Simpson put it on his hand. It appeared to the jury that the glove did not fit Simpson appropriately, lending credence to Cochran's defense that the glove might have been planted. On October 2, 1995, a jury of Simpson's peers deliberated for only about three hours before reaching a verdict. On October 3, 1995, the jury acquitted Simpson of the double murder charges. The trial lasted nine months and the state of California rendered him not guilty. Many people throughout the country were shocked by the decision.

This case exemplifies the importance of the police department's handling of evidence and how police officers should conduct a criminal investigation. It also demonstrates that even with the most formidable evidence produced by the forensics scientists, it may not be enough to convince a jury beyond a reasonable doubt that an accused individual is guilty. Following this case, it became clear that top-notch **forensic science**, particularly the DNA analysis and the footwear impression examination determined by the Federal Bureau of Investigation (**FBI**) agents, must be accompanied by top-notch crime scene investigative collection of evidence. Detailed guidelines for the investigations of homicides, crime scene **processing**, and **arson** investigation have since been drafted by the National Institute for Justice. This includes the development of certification programs that specifically train police officers and crime scene technicians in the appropriate approaches to handle the evidence in a **crime scene investigation**.

The O. J. Simpson trial was controversial. The lack of agreement among experts on the reliability of any evidence in a criminal investigation can be crippling for the prosecution. This case also raised controversy regarding DNA evidence and the methods used for linking suspects to biological evidence found at the scene of the crime. An expert witness for the prosecution, Dr. Bruce S. Weir, testified regarding the methods used for the DNA analysis and how the evidence was examined for the case. Unlike a fingerprinting examination, where the methodology has not been demonstrated to be scientifically proven, DNA analysis is scientifically well tested and the methodologies are considered to be solid by most critics. However, how the evidence is obtained and handled can discredit the findings in a forensics DNA laboratory.

Also important in the O. J. Simpson murder case is the length of time that the evidence was collected. Some DNA from blood droplets that were found at the crime scene was determined not to be from the victims. O. J. Simpson's blood was drawn after this was determined (after the blood was collected during the crime scene investigation). The DNA from the blood droplets was compared to O. J. Simpson's DNA and found to match. By the order of events in this case and the fact that the DNA was already being analyzed by the forensics laboratory suggests that this blood could not have been "planted" by police officers after his arrest. In fact, the DNA analysis revealed that O. J. Simpson's blood DNA had matched the blood DNA found at the crime scene with the probability that only approximately one in 57 billion people could have the same type of match. Three different crime labs performed the same analysis and all three found a positive match.

When Dr. Henry Lee, a criminologist, testified that the blood may have been packaged inappropriately, the defense suggested that a sample switching occurred. The defense also claimed that the blood was degraded due to its storage in the lab truck. This was argued by the prosecution's DNA expert, Harlan Levy, who testified that the degraded DNA was not substantial enough to thwart proper DNA analysis and should not mitigate confidence in the results. If the DNA was mishandled due to the storage procedure, then the quality of the controls would also have been abrogated. Regardless of these credible points, the defense managed to convince the jury that the evidence was mishandled. This weakened the credibility of the genetics laboratory results. Moreover, the complicated and confusing testimony from the DNA experts may have confused and worn out the jury, who may not have had an appropriate understanding of the methodologies and scientific merit of these forensic tests.

The O. J. Simpson double murder trial brought forensic sciences and DNA fingerprinting techniques to the media spotlight. In the end, despite the overwhelming evidence in favor of the prosecution, the key to this case was that the jurors were not convinced that the blood samples were handled appropriately. This court case provided a framework for forensics experts to use to develop new ways to properly handle evidence and maintain a high level of quality control.

Civil lawsuits may be filed regardless of the outcome of an associated criminal prosecution or lack of prosecution. A victim can sue in a civil court even if the alleged perpetrator was found "not guilty" in a criminal court. In a civil trial that followed the criminal case, Simpson was found liable for the deaths of Nicole Simpson and Ronald Goldman (in civil court defendants are found liable rather than guilty). Much of the same forensic evidence that was used at the criminal trial was used in the civil trial. In a civil trial, there is a lower threshold for proof of liability. Moreover, Simpson was required to take the witness stand and offer testimony (something he was not required to do at his trial in criminal court). In the O. J. Simpson civil case, the verdict of liability was unanimous, and Simpson was ordered to pay penalties of roughly $8.5 million.

SEE ALSO Bloodstain evidence; Crime scene investigation; DNA databanks; DNA evidence, social issues; DNA fingerprint; DNA sequences, unique; DNA typing systems; Physical evidence; Quality control of forensic evidence.

Sinus print

A sinus print is a bony feature in the **skull** that can be used to make an **identification** of skeletal remains. To use a sinus print in this way, it is necessary that a skull be found among the remains and that ante-mortem skull x rays are available.

The sinuses are four pairs of air-filled cavities, surrounded by bone, at the side and top of the nose. They make the voice resonate and also lighten the bones of the skull. The frontal sinuses are found above the eyebrows and are bounded, at the top, by a scalloped ridge. Research has shown that the detailed shape of this bony ridge is an individualizing characteristic. The pattern is known as a sinus print and, like a fingerprint, it is unique to each individual. Identifications using sinus prints have been carried out since approximately 1921.

When skeletal remains are discovered, the forensic anthropologist, having first confirmed that they are human, will try to date them. Police will usually have a list of persons reported missing around that period of time. Should any of these have had a skull x ray for medical reasons, this will be part of their medical records and can be made available to the investigating team. An x ray is made of the skull and superimposed on the antemortem x ray. Should the sinus prints of antemortem and postmortem x rays match, this is powerful evidence of identity. If they do not match up, the missing person can be eliminated from the enquiry.

Identification from a sinus print may be confirmed by looking for other points of comparison in the antemortem and postmortem skull x rays. For instance, the side profiles of the skulls should also be compared. If there are teeth available with the discovered skull, then dental records can also help confirm identity. If there is no antemortem x ray, the skull may still be useful if there is a photograph of the missing person. In photo superimposition, the forensic anthropologist overlays a photographic transparency of the skull, scaled to match the angle of the head in the portrait. They will look for matches at points such as the chin, teeth, and eyebrow ridge. Lack of fit is usually very obvious. This technique is especially useful for disproving identity. However, it is not as powerful as the sinus print for establishing identity and can only be seen as a guide.

SEE ALSO Anthropology; Osteology and skeletal radiology.

Vittorio Siracusa

ITALIAN
FORENSIC SCIENTIST

In 1923 Vittorio Siracusa was the first to use the absorption-elution technique for the ABO **blood** group typing of bloodstains.

At a crime scene, when there appear to be spatters of dried blood, investigators must follow a logical process in order to identify the unknown substance. The first question to be answered is whether or not the material in question is blood. Once that has been established, it is necessary to determine whether the blood sample originated from an animal. When the unknown sample has been conclusively identified as a sample of animal blood, the next question to be answered is the species of animal from which it came. Assuming that the sample is found to contain blood, that the blood emanated from an animal, and that the animal is human, the next task is to type the blood. After successfully typing the human blood, the investigator will want to try to establish the age, race, and gender of the human blood source. The object of this series of investigative queries is to accurately identify the source of the blood in an effort to tie it to a particular suspect, or to link a perpetrator and a crime, or to link a series of crimes.

The absorption-elution test, promulgated by Vittorio Siracusa, has tremendous forensic utility, because it can be used to identify old and severely dried bloodstains. When a determination has been made that a particular stain contains human blood, but the stain is extremely dry, an absorption-elution test can be conducted. A small sample scraping is taken and compatible antiserum antibodies are added to it. The sample is then heated until it reaches the temperature at which the antibody-antigen bonds are broken. Known red cells from standard blood groups are then added to fragments of the sample, in order to see what causes it to coagulate, in order to determine basic (ABO) blood group type.

By developing the absorption-elution test for use on old or exceedingly dried blood, Siracusa made a lasting contribution to the world of **forensic science**. In fact, his test remains in popular use in contemporary forensic science investigations.

SEE ALSO Blood spatter; Blood, presumptive test; Bloodstain evidence; Microscopes.

Skeletal analysis

The human skeletal system is primarily composed of a supportive structure found inside the body called the endoskeleton. The endoskeleton is made up of either bone or cartilage. Bone is hard, calcified tissue of the skeleton found in vertebrates and consists of collagen, calcium phosphate, calcium carbonate, and is innervated by blood vessels. Analysis of an endoskeleton from the remains of an individual can provide information about the identity of the person that died, as well as information regarding physical characteristics about that person. This is particularly useful to forensics scientists, who are responsible for handling human remains during criminal investigations and determining the identity of a victim, the manner of death, and if a crime was committed.

Ascertaining the **cause of death** can be problematic because the integrity of the remains is often significantly compromised (decomposed) and the cause of death can be due to a myriad of reasons (fires, homicides, explosions, wild animals, poisoning, drowning, among other causes). Forensic anthropologists are often consulted in these difficult cases. They are experts who combine their knowledge and **training** in human evolution, human variability, human development, human genetics, and human osteology (the study of bones) to be used for criminal investigations or following natural disasters. Examinations of skeletal remains are often performed by forensic anthropologists.

There are three primary subspecialties recognized in forensic **anthropology** used for skeletal analysis: forensic osteology, forensic **archaeology**, and forensic **taphonomy**. Forensic osteology involves the study of human bones and includes understanding how bones form, disease states relating to bone, and distinguishing disease from trauma-induced alterations to the skeletal system. Forensic archaeology is the study of human remains at their site, and involves how to excavate human remains found in a potential crime scene. Finally, forensic taphonomy helps forensic scientists determine the skeletal alterations that transpired at the **time of death** and afterwards. These alterations can be analyzed by identifying diffuse or focal traumatic injury to the skeletal system, the rate, extent, and type of **decomposition** that occurs, and any environmental modifications that might be important.

Forensic osteologists usually become involved in the criminal investigation at the beginning of the search (as part of a team) for hidden or buried remains with the assistance of specially trained cadaver search and rescue dogs and law enforcement experts. Once the remains are located, osteologists and archaeologists excavate the remains and help to determine **evidence** relevant to the investigation. Bone collection must follow careful visual analysis of the crime scene to help understand the position of the body or, if buried, what types of tools were used on the body or for burying it.

Once the remains are removed from the site, they are cleaned and analyzed in a laboratory. Forensic osteologists can then apply radiographic techniques to compare skeletal remains to archived x rays, which could help identify the individual. These radiographic techniques are especially helpful if there is suspicion of foul play. If necessary, the skeleton is sectioned or cut and put onto a slide to be analyzed by a bone histologist, who may be able to make assumptions regarding the extent and type of damage inflicted on the bone.

Other techniques such as **scanning electron microscopy** can provide information regarding the extent of decomposition, which helps determine approximate time of death or the nature of the environmental affects on the bones. Scanning electron **microscopes** magnify images using electrons to create three-dimensional images. Bone samples can also be sent to other forensics experts for biochemical or trace element analysis, as well as for **DNA** analysis. Once laboratory tests are complete, the bones are usually casted (molded) and curated (preserved) using commercially available skeletal preservatives.

The race, age (at death), height, size, sex, and type of physique of a person can often be ascertained by examining their skeletal remains. Bone can also be analyzed for traits such as dental hygiene and habits such as smoking and frequent exercise. It is not possible, however, to determine the weight of an individual based on bone structure. Similar bone structures do not indicate similar fat cell size and distribution.

A laboratory that specializes in skeletal biology and forensic archaeology uses equipment such as x-ray machines, microscopes, bone casting supplies, peripheral x-ray bone densitometers (to determine bone density), ultrasonometer, cutting saws, calipers, mandibulometers (specialized calipers for the jaw), and other anthropology equipment. Collections of bones from **autopsy** specimens with known conditions such as arthritis, infections, fractures, cancer, and osteoporosis are also preserved in these laboratories, and aid in distinguishing trauma-induced bone changes from disease-induced bone changes. This distinction could provide critical information to a criminal investigation.

A forensic scientist must be able to analyze the skeletal system given different situations. For example, if a child suffers multiple fractures and dies due to related complications, the parents might be under suspicion for child abuse and homicide. Either the **medical examiner** or the forensic pathologist should identify the rare cases of multiple fractures in deceased children that involve a genetic-based cause of disease, such as osteogenesis imperfecta, where affected individuals are extremely susceptible to multiple fractures with little mechanical force.

Technological advances have paved the way for forensics sciences to gain a plethora of information from scantly detectable evidence in a crime scene. Even in cases where skeletal remains are scattered, contemporary techniques that use three-dimensional digital imagery can help remodel and restore the skeletal remains. Anthropometric (body proportion) measurements from a large enough sample size from a given population can be used for **computer modeling** programs to estimate body measurements. Three-dimensional facial reconstruction techniques can provide a visual representation of the victim. It is possible, based on the size and shape of an individual's **skull**, to estimate race and use computerized programs to help reconstruct what the individual looks like. These computerized models have begun to replace recreating the remains of a person using casts. However, in general, facial reconstructions cannot be used in a court of law as positive **identification**, as they can be subjective, unreliable, and difficult to reproduce.

In examining skeletal remains resulting from natural disasters, knowledge of how the natural surrounding environment participates in the decomposition of the skeletal system is important. For example, certain insects and microorganisms become involved in the decaying remains of an individual in a time-dependent fashion. When the body begins to decay, there are enzymes found in the digestive system that can liquefy the tissues, a process called putrefaction. Maggots are efficient at using rotting flesh for their energy requirements. By examining their life cycles, insect activity can sometimes reveal the time of death.

Additionally, trace amounts of DNA from bone remains can be recovered and analyzed by a molecular geneticist. DNA survival is greatest in dense bone, such as teeth, than in any other type of tissue. In fact, it has been possible to extract small amounts of DNA recovered from bones that are thousands of years old and perform DNA analysis by amplifying the DNA sequences with a technique known as **polymerase chain reaction**, or **PCR**. Bones from murder victims have been successfully identified almost a decade after the person died using comparative DNA typing and DNA markers. DNA markers from the bone sample are compared to DNA markers from samples from the possible parents of the victim. If enough DNA markers are analyzed and these markers match the parents, it is possible to conclude with a high level of certainty the identity of the victim. The degradation rate of DNA extracted from rib bones has also been used to determine the time interval since death of a victim.

In general, although it requires highly trained and specialized experts, skeletal analysis for forensic purposes can be useful and informative, especially in cases where bone is the only recovered evidence.

SEE ALSO Anthropology; Archaeology; Casting; DNA mixtures, forensic interpretation of mass graves; Odontology; Osteology and skeletal radiology; War forensics.

Skeletal system overview (morphology)

When death has occurred weeks or months before a body is discovered, **decomposition** removes much of the body **fluids**, muscle, and tissue from a corpse. What remains is the supporting skeleton. The arrangement of the bones in a skeleton, their condition, and markings that can be present (such as the scrape or gouging left by a knife blade) can tell a forensic investigator much about the deceased.

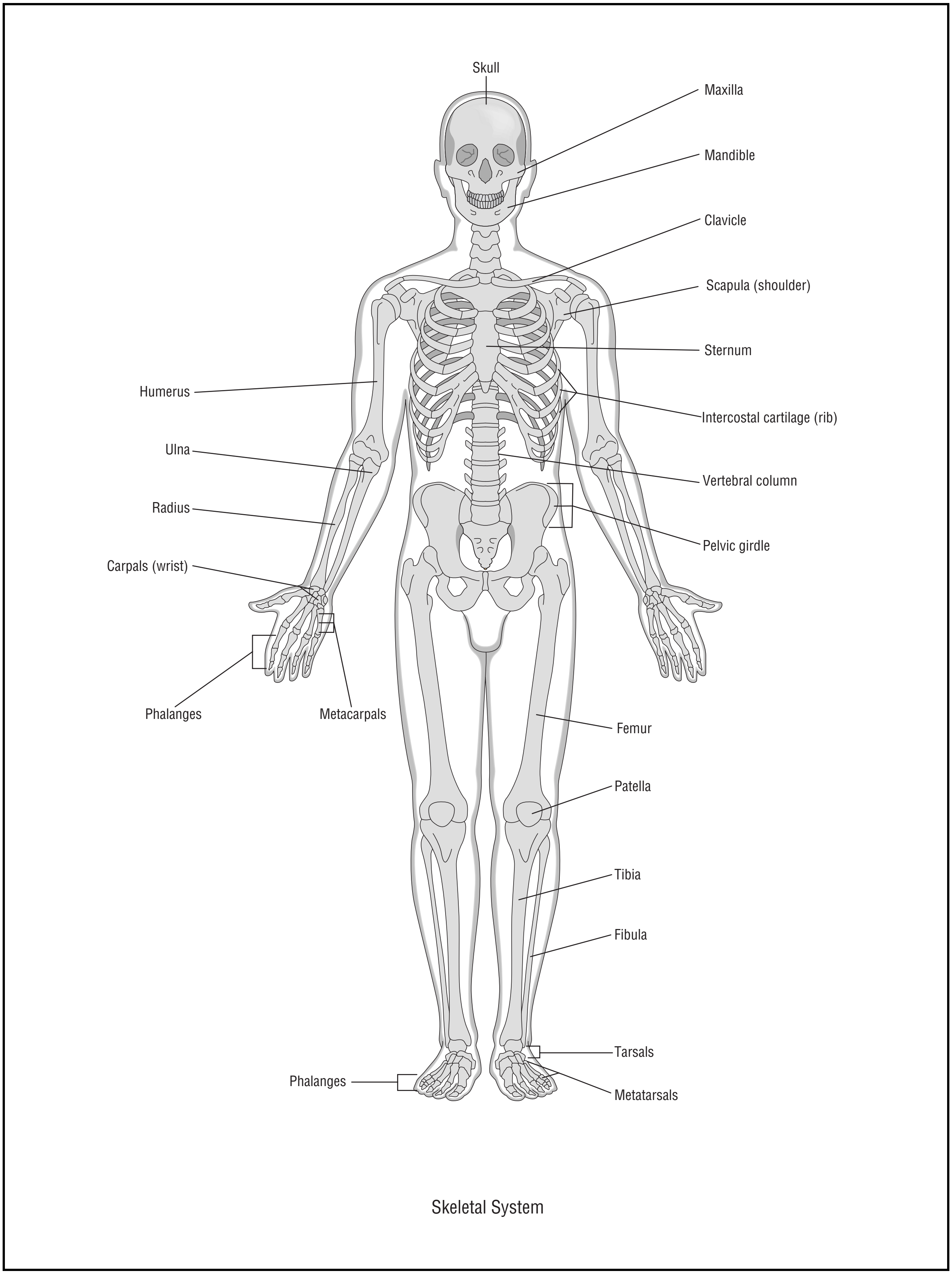
The bones of the skeletal system can be classified according to their shape and location. The types of bones categorized by shape—long, short, flat, and irregular—also provide evidence of their function. Long bones consist of an elongated shaft called the diaphysis. Each end of the diaphysis is an expanded portion of the shaft and is called an epiphysis. Examples of long bones include the femur in the thigh and the humerus in the arm. These bones function as levers when muscles contract, thus providing support to enable movement. Short bones often have equal dimensions, like those of a cube. Compared to long bones, short bones have a limited range of motion but are able to withstand force. Examples of short bones include the carpals in the wrist and the tarsals in the ankle. Flat bones are thin bones that protect internal organs and provide sites for muscle attachment. The ribs, cranial bones, and scapula are all examples of flat bones. Irregular bones are not shaped like any of the three aforementioned bones and therefore form their own category. The vertebrae and facial bones are categorized as irregular bones.

Location rather than shape classifies other types of bones, such as sesamoid and sutural bones. Sesamoid bones bear pressure as the result of being buried in tendons. The kneecap, or patella, is the best-known example of a sesamoid bone. Sutural bones are tiny bones located between the joints, or sutures, of the cranial bones.

The adult skeleton consists of 206 bones. A baby is born with 270 bones, many of which fuse together during adolescence and adulthood. The bones of males and females differ in that male bones tend to be larger and heavier than female bones.

The skeletal system can be divided into the axial skeleton and the appendicular skeleton. The axial skeleton is composed of the bones that surround the midline or axis of the body, forming the head and trunk. These bones include the **skull** bones, auditory ossicles, hyoid bone, vertebral column, sternum, and ribs.

The skull can be subdivided into eight cranial bones and fourteen facial bones. The cranial bones include the frontal bone, two parietal bones, two temporal bones, occipital bone, sphenoid bone, and ethmoid bone. The facial bones include two lacrimal bones, two nasal bones, two inferior nasal conchae, vomer, two zygomatic bones, two maxillae, two palatine bones, and mandible. Within the middle ear are three auditory ossicles: the maleus, incus, and stapes. These tiny bones transmit vibrations from the eardrum to the inner ear. The hyoid bone is located in the superior part of the neck and attaches the muscles of the tongue.



Overview of the skeletal system. ILLUSTRATION CREATED BY ARGOSY

The vertebral column typically consists of twenty-six vertebrae that protect the spinal cord and provide attachment sites for ribs and back muscles. The seven most superior vertebrae are the cervical vertebrae. The first vertebra is called the atlas and enables the head to move forward and backward. The second vertebra, the axis, is unique in that it is the only vertebra that has a process called the dens or odontoid process. The axis enables the head to rotate from side to side. The vertebrae immediately inferior to the cervical vertebrae are the twelve thoracic vertebrae. These vertebrae are larger than the cervical vertebrae and, except for the eleventh and twelfth thoracic vertebrae, have facets that articulate with the ribs. (The point where two bones meet forms a joint and the bones are said to articulate with one another.) Just below the thoracic vertebrae are the five lumbar vertebrae. The lumbar vertebrae are the largest of the vertebrae because they support a tremendous amount of the body's weight. The five sacral vertebrae are actually fused together in adults to form the sacrum. Inferior to the lumbar vertebrae, the sacrum articulates with the pelvic girdle to form the pelvis. The four remaining bones of the vertebral column constitute the coccyx. These individual bones also become fused together in adults.

The sternum, also known as the breastbone, consists of three parts. The manubrium and the body are the superior and middle parts of the sternum that articulate with the ribs. Additionally, the manubrium articulates with the clavicles. The xiphoid process is the inferior part of the sternum that provides attachment for abdominal muscles.

There are twelve pairs of ribs that make up the rib cage. The first seven pairs are true ribs because they are attached directly to the sternum by cartilage. The next three pairs of ribs are false ribs because they are indirectly attached to the sternum by the cartilage of the seventh pair. The two remaining ribs are known as floating ribs because they do not connect to the sternum at all.

The appendicular skeleton is comprised of two pectoral girdles, two pelvic girdles, and the bones of the upper and lower extremities. Each pectoral girdle, or shoulder girdle, includes the clavicle and scapula responsible for attaching the upper extremities to the axial skeleton. The clavicle, or collarbone, is the anterior component of the shoulder that articulates with the scapula and manubrium of the sternum. The scapula, or shoulder blade, is positioned posterior to the clavicle and articulates with the humerus. The humerus constitutes the upper arm and articulates with the two bones of the forearm. The radius is the lateral bone and the ulna is the medial bone of the forearm. The distal end of the radius articulates with the carpals, the first row of bones in the hand. The proximal row of carpals located from lateral to medial includes the scaphoid, lunate, triquetrum, and pisiform. The distal row of carpals that articulates with the metacarpals are the trapezium, trapezoid, capitate, and hamate. The metacarpals are numbered one through five, beginning on the lateral palm of the hand extending medially. The fourteen bones of the fingers, named phalanges, articulate with the metacarpals. Each finger has a proximal, middle, and distal phalanx except for the thumb, which only has two phalanges.

Each pelvic girdle, or hipbone, in an adult is made of three fused bones. Also known as the coxal bones, the hipbones consist of the ilium, ischium, and pubis. The ilium articulates posteriorly with the sacrum. The ischium connects the ilium and pubis. The two pubis bones meet anteriorly to form the pubis symphysis. Together, the hipbones, sacrum, and coccyx constitute the pelvis. One major difference between the male and female skeleton is the bones of the pelvis. In the female, the pelvic bones form a wide, round opening called the pelvic inlet to accommodate for childbirth. The pelvic inlet of males is heart shaped and much narrower than in women. Additionally, the sacrum is wider and shorter in women than in men, allowing the forensic **identification** of the sex of the deceased

The bones of the lower extremities include the femur, patella, tibia, fibula, tarsals, metatarsals, and phalanges. The femur is the leg bone that articulates with the pelvic girdle. The distal end of the femur articulates with the foreleg to form the knee. Anterior to the knee lies the patella, or kneecap. Each foreleg consists of two bones: tibia and fibula. The tibia is the larger of the two bones and forms the shin. The fibula is the lateral bone in the foreleg. At the distal end of the forelegs are the proximal bones of the foot called the tarsals. The tarsals include the calcaneus, talus, navicular, cuboid, and three cuneiforms. The metatarsals form the sole of the foot and are labeled one through five beginning on the medial side of the foot. Each toe consists of three phalanges, the proximal, middle, and distal phalanx. The exception is the big toe, which contains only two phalanges.

SEE ALSO Asphyxiation (signs of); Bite analysis; Exhumation; Skull.

Skull

The skull is the ossified, bony structure that encloses and protects the brain, internal extensions of sensory organs, and some facial structures. The skull is usually considered to consist of a cranial section (the cranium) and a facial region.

When a person has been dead for a long time, much of the body may have decomposed. One body part that will remain intact is the skull. Thus, it can become an important part of a forensic examination designed to determine the **cause of death** and, especially when the teeth are intact, to determine the identity of the deceased.

The cranium is a large, rounded, dome-shaped region of the skull that is composed of paired left and right frontal bones, parietal bones, temporal bones, and an unpaired occipital bone that forms the posterior base of the skull.

The bones of the cranium are fused by sutures—joints that run jaggedly along the interface between the bones. At birth, the sutures are soft, broad, and cartilaginous. This flexibility allows the skull to grow as the child matures. The sutures eventually fuse and become rigid and ossified near the end of puberty or early in adulthood. The coronal suture unites the frontal bone with the parietal bones. In **anatomical nomenclature**, the primary coronal plane is the plane that runs through the length of the coronal suture. At right angles to the coronal suture, the metopic suture separates the frontal bones in the midline region. The area formed by the fusion of the four bones near the top of the skull is termed the anterior fontanel or bregmatic fontanel (also commonly known as the topmost "soft spot" in a baby's skull). As with the sutures, the fontanels are soft at birth to permit growth. The fontanels shrink and close during childhood and are usually fully closed and hardened by young adulthood. The changing suture pattern can be used forensically to help estimate of the age of the deceased.

The sagittal suture unites the two large domed-shaped parietal bones along the midline of the body. The suture is used as an anatomical landmark in anatomical nomenclature to establish what are termed sagittal planes of the body. The primary sagittal plane is the sagittal plane that runs through the length of the sagittal suture. Sagittal planes run anteriorly and posteriorly, are always at right angles to the coronal planes. The lambdoidal suture unites the left and right parietal bones with occipital bone. The area where the two parietals and the unpaired occipital bone meet is termed the posterior fontanel, lamdoidal fontanel, or lambda point (also commonly called the rear "soft spot" on a baby's skull). Like the anterior fontanel, the posterior fontanel closes and hardens with age, but is an important feature that allows growth of the skull during embryological and childhood development.

Along the sides of the cranium, the squamosal suture unites the temporal bone lying above (superior to) the ear and ear canal with the parietal bone. The anterior region of the temporal bones is united with the great wing of the sphenoid bone by continuation of the squamosal suture. The junction of the temporal, parietal, frontal and great wing of the sphenoid takes place at the sphenoid fontanel. The posterior border of the temporal bone on each side unites with the corresponding mastoid bone.

A mastoid fontanel lies at the posterior region of the side of the skull where the parietal, occipital, and mastoid bones unite. A mastoid process extends anteriorly toward the ear canal. A bony finger-like styloid process protrudes from the interior area to the external auditory opening (external auditory meatus).

The facial area of the skull is composed of the left and right zygomatic arches that extend from the lowest, most anterior margins of the temporal bone where the temporal bones articulate with the mandible (the temporomandibular joint) into the zygomatic bone itself. The zygomatic arches and zygomatic bones thicken to become prominent facial landmarks, forming the lower and side orbits of the eyes. The orbits are separated by a number of smaller bones in the nasal region including the ethmoid, lacrimal, and nasal bones. The maxilla and upper teeth form the most inferior region of the facial portion of the skull and are fused to the zygomatic bones.

The mandible is not considered a formal portion of the skull. In decayed bodies, the mandible becomes detached from the skull as the temporomandibular joint and supporting ligaments deteriorate.

A number of small openings allow nerves and blood vessels to penetrate the skull. These openings are termed foramen and are generally named for the bone they penetrate. For example, openings in the parietal bones are termed parietal foramen. A large foramen magnum at the rear and base of the skull allows the spinal cord to exit the skull into the vertebral column. Rounded, smooth, bony protuberances termed the occipital condyles lie on the anterior sides of the foramen magnum and help articulate the skull with the vertebral column.

The external occipital crest marks the posterior midline of the occipital bone. The crest runs from the foramen magnum upward (superiorly) to a bony knot-like external occipital protuberance.

Forensically, the skull can be used as the basis of a reconstruction, where layers of clay are applied to mimic the muscles and other tissue that formerly overlay the skull bones. When skillfully done, the resulting image offers an approximation of what the person may have looked like.

A less expensive and time-consuming method of reconstructing the facial appearance relies on photographing of the skull from different angles. The photographs can be cut out and mounted side-by-side to give a two-dimensional model that an artist can use to produce a drawing.

SEE ALSO Bite analysis; Exhumation; Skeletal system overview (morphology).

Smallpox

Knowledge of the behavior of disease-causing (pathogenic) bacteria and viruses is especially vital when a forensic investigation is concerned with the possibility of an infection that is a serious threat to health and is easily spread from person to person. A prime example is smallpox.

Smallpox is an infection caused by the **variola virus**, a member of the poxvirus family. The disease is highly infectious. Passage from person to person via contaminated aerosolized droplets (from sneezing, for example) and even by touching objects such as books and blankets that have been previously used by someone who has smallpox occurs easily, and so the spread of smallpox through a population can occur quickly. Like most viruses and other microorganisms, the variola virus can be transported from one location to another without difficulty.

When infected with the virus, there is a twelve to fourteen day symptom-free period, during which the virus is multiplying in the body. There is then a sudden onset of symptoms. The symptoms include fever and chills, muscle aches, and a flat, reddish-purple rash on the chest, abdomen, and back. These symptoms last about three days, after which the rash fades and the fever drops. A day or two later, the fever returns, along with a bumpy rash starting on the feet, hands, and face. This rash progresses from the feet along the legs, from the hands along the arms, and from the face down the neck, ultimately reaching and including the chest, abdomen, and back. The individual bumps, or papules, fill with clear fluid, and, over the course of ten to twelve days, became pus-filled. The pox eventually scabs over, and when the scab falls off it leaves behind a pock-mark or pit, which remains as a permanent scar on the skin of the victim.

Smallpox can be lethal, usually due to bacterial infection of the open skin lesions, pneumonia, or bone infections. A severe and quickly fatal form of smallpox is known as "sledgehammer smallpox." This form of smallpox is characterized by bleeding from the skin lesions, as well as from the mouth, nose, and other areas of the body.

Smallpox has been present for thousands of years. For example, studies of the mummy of Pharaoh Ramses V, who died in 1157 B.C., revealed symptoms of smallpox infection.

Large smallpox epidemics have occurred throughout recorded history. Attempts to protect against smallpox infection began centuries ago, even thought the microbiological nature of the disease was then unknown. In the tenth century, accounts from China and India describe how individuals who had even a mild case of smallpox could not be infected again. Fluid or pus from the skin lesions was scratched into the skin of those who had never had the illness, in an attempt to produce a mild reaction and its accompanying protective effect. Unfortunately, these efforts sometimes resulted in full-fledged smallpox, and helped spread the infection. Such crude vaccinations against smallpox were outlawed in Colonial America.

In 1798, Edward Jenner published his observation that milkmaids who contracted cowpox infection caused by vaccinia virus (a relative of variola) were immune to smallpox. He used infected material from the cowpox lesions to prepare an injection that helped protect the humans. Although Jenner's development of immunization was harshly criticized at first, the work paved the way to the development of **vaccines**.

Until the development of a smallpox vaccine, no treatment for smallpox was known, nor could anything shorten the course of the disease. Until its eradication, smallpox was diagnosed most clearly from the patients' symptoms. Electron microscopic studies could identify the variola virus in fluid isolated from disease papules, from infected urine,

Smallpox lesions on skin are shown in this photograph taken in 1973 in Bangladesh. Smallpox infection was eliminated from the world by 1980, so any further outbreaks would likely be the result of an intentional act. © REUTERS/CORBIS

or from the blood prior to the appearance of the papular rash.

In the 1960s, the World Health Organization (WHO) began a campaign to treat people infected with smallpox and vaccinate those who might be exposed to the infection. The WHO program was extremely successful, and the virus was declared eradicated worldwide in May of 1980. Stored stocks of the virus were maintained in two laboratories. One is housed at the **Centers for Disease Control and Prevention** in Atlanta, Georgia. The other smallpox stock is maintained in Russia.

These stocks were slated to be destroyed in the late 1990s, however, President Bill Clinton halted plans for destruction of the American stocks. Concern that another poxvirus could mutate (undergo genetic changes) and cause human infection has made preservation of the smallpox stock for vaccine development purposes important. As of 2005, the stocks remain undisturbed.

SEE ALSO Bioterrorism; Pathogens; Vaccines; Variola virus.

Ron Smith

AMERICAN
FORENSIC SPECIALIST

Since 1972, Ron Smith has worked in both the government and private sectors as a forensic specialist, consultant, and trainer. He is recognized as an authority on friction ridge **identification** and palm print analysis, and is a certified latent print examiner. Smith also is known for the hundreds of seminars he has conducted on **forensic science** topics throughout the world. In addition, he has served as an expert witness in numerous criminal cases and has lectured extensively on courtroom testimony techniques.

Smith began his career in forensic identification in 1972, when he was hired by the Federal Bureau of Investigation in Washington, D.C. He later held positions with the Alabama Bureau of Investigation and the Mississippi Crime Laboratory, where he worked as assistant director. In these positions Smith did extensive fieldwork and research on the topics of friction ridge identification and palm print analysis.

Because of this experience and knowledge, he has provided testimony in more than 500 criminal cases across the United States. He has also served as the primary courtroom testimony trainer for the Mississippi Law Enforcement Officers Training Academy and the primary expert witness trainer for the Mississippi Crime Laboratory.

For more than fifteen years, Smith has also taught hundreds of forensic workshops for organizations and universities throughout the United States and around the world. He has frequently spoken on the topics of courtroom testimony techniques, latent print examinations, forensic ridgeology, footwear impression comparison, and crime scene examinations. Smith has also been actively involved in the **International Association for Identification** (IAI). He serves on the board of directors and was awarded IAI's 2001 John A. Dondero Award for his contributions to the science of forensic identification.

After his retirement from the Mississippi Crime Laboratory in 2002, Smith opened his own forensic consulting and training company, Ron Smith and Associates, Inc. The company provides technical training and criminal investigation services to government agencies, private corporations, attorneys, and individuals. The company employs professional career forensic specialists located in different cities throughout the United States and Canada, in order to provide forensic services around the world.

SEE ALSO Careers in forensic science; Expert witnesses.

Snowball the cat

In 1994, Royal Canadian Mounted Police (RCMP) found a woman's body in a shallow grave in Prince Edward Island, Canada. She was identified as a 32-year-old woman named Shirley Duguay. The mother of five children, Duguay was separated from her common-law husband Douglas Beamish. Beamish had a criminal record and was on parole during the time of the murder. The primary suspect in the case was Beamish, however RCMP had no **evidence** to associate him with the crime.

Near the scene of the crime, RCMP found a leather jacket that was stained with **blood** that matched that of Duguay. Some of Beamish's friends told RCMP that they thought that Beamish owned such a coat, but they could not be certain. Forensic investigators studying the jacket found 27 white hairs on the inside lining. They initially thought that the hairs might belong to Beamish, but microscopic analysis showed that they were actually cat fur.

One of the investigators on the case remembered seeing a white cat named Snowball at the house of Beamish's parents. At the time of the murder Beamish was living with his parents. Proving that the white fur belonged to Snowball would provide evidence tying Beamish to the crime. While forensics investigators could tell that the hair belonged to a cat, their microscopic **hair analysis** was not accurate enough to assign ownership to a specific cat. Determining the identity of the individual animal that shed the hairs required genetic testing. However, the forensics investigators on the case had no precedent for **DNA** fingerprinting of cats.

An RCMP investigator contacted the Animal Genetics Group at the Laboratory of Genomic Diversity (LGD) in Frederick, Maryland. They agreed to attempt DNA fingerprinting of Snowball. RCMP took a sample of blood from Snowball and one of the hairs found on the jacket contained a root with enough DNA to perform an analysis. The primary geneticist in the case, Marilyn Menotti-Raymond, developed a method that looked for short tandem repeats (STR) in the cat's DNA. Both the DNA from the hair root and the DNA from Snowball's blood sample matched.

Investigators were concerned that because it is an island, Prince Edward Island is relatively geographically isolated. Therefore many of the cats on the island might be close relatives. If this were the case, the match between Snowball's blood sample and the hairs found on the jacket would be insignificant. To test whether this was a problem, RCMP collected cats from all parts of the island, including the area around the crime scene. They took blood samples from these cats and performed the **STR analysis** that Menotti-Raymond developed. The cats on the island showed a high degree of genetic variation, indicating that the STR match between Snowball and the hairs found on the jacket was significant.

Based on the genetic evidence linking Beamish to the jacket, he was convicted of second-degree murder and sentenced to prison for 15 years. The case set a legal precedent allowing DNA fingerprinting of animals to be admitted as evidence in **criminal trials**.

SEE ALSO DNA banks for endangered animals; DNA fingerprint; Hair analysis; PCR (polymerase chain reaction); Wildlife forensics.

Sobriety testing

Sobriety is defined as a physiological and mental state in which a person is unaffected by the presence of a chemical substance. The quintessential example of sobriety is the popular image of a return to an individual's normal behavior after the effects of excessive alcohol consumption have dissipated.

The possibility of alcohol or other intoxicants in a crime, accident, or death is uppermost on the mind of a forensic investigator. In 2002, for example, almost 17,500 motorists were killed in alcohol-related traffic accidents in the United States, according to statistics from the U.S. National Highway Traffic Safety Administration. While the involvement of alcohol in traffic fatalities has been declining in the United States since the 1980s, this fatality toll still represented 41% of all U.S. traffic fatalities.

Alcohol-fueled domestic disturbances can also result in injury and death. Crime Report statistics complied in the late 1980s by the State of New Jersey, and reports examining telephone calls to domestic hotlines indicate that at least 40–50% of domestic disturbances were correlated with abusive behavior linked to the use of alcohol. Sobriety testing is not just a factor in alcohol use. While the term sobriety is commonly linked with the consumption of alcohol, the misuse or overuse of prescription drugs and the use of **illicit drugs** also affect sobriety.

Thus, when responding to a report of a traffic accident (or even stopping a motorist for a suspected traffic infraction) or other incident, police officers can be confronted with need to establish the sobriety of an individual.

Aside from safety issues (operation of a motor vehicle while impaired), sobriety testing is another piece of forensic **evidence** in the investigation of a crime, accident, or death. Sobriety testing involves the recognition of key indicators of impairment, assessment of physical coordination, and the level of ethanol or drugs in the bloodstream.

This assessment begins as soon as the police officer or forensic investigator encounters the person. For example, police officers are trained to inhale when the driver of a vehicle rolls down the window. Use of alcohol, marijuana, and phencyclidine (PCP, also known popularly as angel dust) can be evident on a person's breath. This is also an opportunity for a brief visual inspection of the inside of the vehicle. Open or discarded bottles or cans of alcohol, aside from being illegal in many jurisdictions, can indicate over-consumption, and are grounds for conducting more rigorous sobriety testing.

Another immediate aspect of sobriety testing is the observance of physical appearance and behavior. A red-appearing face, especially the cheeks, can be caused by the overuse of alcohol, which can increase the flow of blood through the capillaries.

Behavioral changes depend on the nature of the intoxicant. Alcohol is a depressant, as are **barbiturates**, sleeping pills, and benzodiazepines. Impairment can be evident as slurred or thick speech, sluggish reactions, features of exhaustion such as yawning and drooping of the eyes, and disorientation with surroundings and events.

Some of the behaviors, such as speech difficulties and disorientation, can also be present when impairment is due to narcotics and inhalants (e.g., vapors produced by solvents like nail polish remover and gasoline or adhesives like airplane glue). Drugs like cocaine stimulate the activity of the central nervous system. The result can be euphoric behavior. This also occurs when narcotics and PCP are taken.

A key early sobriety test is examination of the pupils of the eyes. A police officer will typically make direct eye contact with a driver, even asking the driver to remove sunglasses if necessary. Bloodshot eyes and droopy eyelids can be indicative of alcohol overuse. The use of stimulants, hallucinogens, and inhalants can cause the pupils to be become larger than is normal for the light conditions (dilation). In contrast, narcotics such as codeine, heroin, and opium cause the pupils to become smaller (constriction). A blank or dazed stare can result from the use of PCP, hallucinogens, and inhalants.

If the early assessment of sobriety warrants further action, a police officer or forensic investigator can conduct more rigorous tests.

One standard sobriety test is the indirect measurement of the level of alcohol in the blood by measurement of the alcohol in the expired breath. A portable **Breathalyzer®** displays the level of alcohol as a number that indicates the grams of alcohol per 100 milliliters of blood. In many jurisdictions, this legal limit is 0.08. If the breathalyzer reading exceeds this value, it is evidence that the person may be impaired.

Other sobriety tests typically adhere to a standard field sobriety testing program. Use of established guidelines lessens the chances that the results of the tests will be questioned in court, even in the absence of a Breathalyzer® test, and allows the test results to be the basis of an arrest for driving while intoxicated (DWI) or driving under the influence (DUI).

Standardized Field Sobriety Tests (SFST) were developed in the 1970s by the U.S. National Highway Traffic Safety Administration. The validity of the testing methods and legality of the results was verified by repeated testing under controlled conditions. Without the power of this standardizing procedure, sobriety tests can be merely anecdotal and so less apt to stand legal scrutiny.

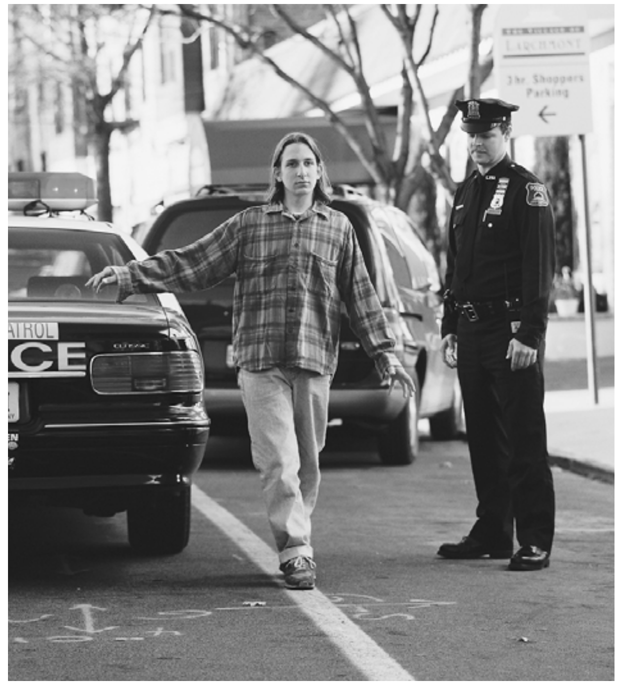
SFST involve scoring of the results of a number of requested actions. A determination of intoxication is made if a person fails to successfully perform a sufficient number of these actions: the walk-and-turn, one-leg-stand, and horizontal-gaze nystagmus (eye-movement) tests, which are detailed below. Failing a single test is not grounds for determining that a person is not sober.

The walking and leg-stand tests are assessments of balance, while the eye movement test assesses motor control of the eye muscles. All are tests of coordinated action of muscles and nerve activity. However, the legal admissibility of the first two tests can be challenged more successfully than the eye test. This is because the assessment of walking and standing abilities are more subjective. The eye muscle control that is the basis of the horizontal gaze test is involuntary, and so is able to be assessed more definitively.

Nystagmus is defined as an involuntary rapid and repetitive movement of the eyes. It can occur as a result of brain damage, **epilepsy**, or other pathological disorders. However, for the majority of people, the condition is indicative of impaired motor function. Normally, when concentration and the nervous system are unimpaired, movement is followed by a smooth and controlled change in gaze. However, a sign of impairment can be the loss of this coordinated activity.

Typically, a subject is asked to look straight ahead and, while keeping the head still, to focus on a horizontally moving object (a finger, pen, or pencil, for example). The object must be 12–15 inches from the subject's eyes, at a distance that the subject indicates is comfortable to focus.

People with an eye impairment or an artificial eye are excluded from the test. Evaluating a single eye and then doubling the score with the assumption that the other eye will behave in the same manner is improper technique. Some people do exhibit a difference in the reaction times of their eyes (a condition called lazy eye). In this case, each eye should be tested separately while the other eye is covered.



Police officer giving a sobriety test to a young man suspected of drunk driving; the suspect is walking a line painted on the street.
© HUTCHINGS STOCK PHOTOGRAPHY/CORBIS

A normal eye reaction in this test includes the smooth movement of the pupil from side to side while maintaining focus on the moving object. As well, the pupil should remain still when the object is brought to rest at the end of a leftward or rightward horizontal path. The object can also be moved up or down, to assess if the pupil tracks smoothly.

The side-to-side and up-and-down motions of the object are done a total of at least six times. A score of one is assessed if eye motion in an individual trial is jerky. A score of four or more is indicative of intoxication.

In the walk-and-turn assessment, a reasonably straight line is drawn on a flat surface. The subject is then instructed to place their left foot on the line and then to walk heel-to-toe along the length of the line, by placing the heel of one foot in contact with the toe of the planted foot. In this way the feet remain close together, and balance becomes critical in maintaining progression along the line. When reaching the end of the line, the subject must turn around while keeping one foot planted and repeat the walk in the other direction.

Indications of intoxication include loss of balance (swaying or falling), holding the arms out from the body to maintain balance, stopping and starting rather than walking with a smooth cadence, stepping off of the line, failure to listen to instructions, and starting to walk before being instructed to do so. These aspects of performance are evaluated, scored, and used to assess if coordination is impaired.

For people aged less than 65, who are not judged to be obese, and who do not have a neurological or other disorder that affects balance, another assessment of balance involves standing motionless on one leg. The raised leg must be positioned in front of the body at least six inches off the ground for a time that is determined by the assessor. Swaying, falling, hopping, use of arms for balance, and putting the elevated leg down prematurely are all indications of impairment.

SEE ALSO Automobile accidents; Breathalyzer®; First responders.

Sociopathic personality

In 1941, American physician Harvey Cleckley wrote a groundbreaking book in **forensic science** entitled *The Mask of Sanity.* Before that time, psychopathy had been loosely defined as insanity without delirium (psychotic features such as delusions and hallucinations), psychopathic inferiority, and moral insanity. Cleckley was the first to study this personality syndrome from a more scientific perspective. He generated a list of sixteen traits that clustered together to create an identifiable character sketch (a set of traits, behaviors and attitudes that define a particular way of moving in the world) of the sociopathic personality. The central characteristics in this cluster were: lack of empathy or anxiety, shallowness, self-centeredness, irresponsibility, and manipulativeness. These individuals, Cleckley found, were far more likely to commit crimes, to be more violent, to recidivate (to repeat their criminal behaviors), and less likely to respond to treatment efforts than were other criminal populations. He found the psychiatric community uniformly unwilling to work with this population or to address them in any way, and speculated that this might be due to the fact that they (psychopaths) often afford no outward signs of their **pathology**. In fact, a person with a **psychopathic personality** can be quite charismatic during early interactions. It was Cleckley's contention that it is difficult to fully appreciate the deviancy of the psychopath under treatment or confinement (prison or jail) circumstances; they need to be seen in their social environment, where they often operate as abusers, manipulators, scammers, or con artists.

In 1952, the term psychopath was replaced in the psychiatric literature by sociopathic personality. These terms became synonymous, as the concept of personality disorders evolved. With the advent of *DSM-II (Diagnostic and Statistical Manual of Mental Disorders*, *Second Edition)*, the uniformly accepted manual of psychodiagnosis) in 1968, the term personality disorder, antisocial type replaced sociopathic personality. In contemporary forensic psychiatric, psychological, and sociological literature, the terms psychopath, sociopath, criminal personality and ASPD/APD (antisocial personality disorder) are used commonly to describe the affected criminal population.

Antisocial personality disorder, common among convicted felons, is chiefly characterized by flagrant disregard for the rights of others, a refusal to conform to the rules and norms of society, and an inability to experience feelings of either anxiety or guilt. Other clinical symptoms are predatory behaviors, manipulativeness and deceitfulness, inability to plan for the future or to envision the potential consequences of their behaviors, consistent irresponsibility, irritability and aggressiveness, callous disregard for the safety and well-being of others, and an inability to experience feelings of guilt or remorse after doing material, emotional, or physical harm to others.

The central characteristics of the psychopath are described in somewhat more emotional or affective terms. They are highly self-centered, impulsive, irresponsible, manipulative, and remorseless; they do not experience guilt or regret. They tend to be pathological liars and they persistently violate social norms and rules. Their crimes tend to be described as "cold-blooded," as they are committed without obvious motivation (except to satisfy their own material needs, by robbery, for example). Psychopaths commonly exert power and control over others, and they do so through the use of superficial charm, manipulation, intimidation, and violence. They tend not to outgrow their behavior, do not benefit from treatment, and do not rehabilitate during periods of incarceration.

Sociopaths are typically described as conscience-less. They are extremely shallow, selfish, self-centered, boastful, antagonistic, and unable to bond with others or to form lasting romantic relationships. They also tend to be extreme risk-takers who are unable to refuse temptation of any sort. Sociopaths view other people as vehicles for their own gain, and they fail to recognize their own negative characteristics. Sociopaths are generally adept at rationalizing their behavior and asserting (and believing) that they are victims of the ill will of others, and that they are good people put in bad circumstances. Sociopaths often report difficult childhoods: single parent homes, extreme poverty, neighborhood or family violence, lack of parental supervision, early separation from family, or rearing in foster homes, state-run group homes, or institution-like settings.

There is no effective treatment for these personality disorders: incarceration is merely palliative. That is, an individual with sociopathy, psychopathy or ASPD may either not exhibit the offending behaviors while incarcerated, or may use them adaptively in order to function well in the prison setting, but will immediately (and admittedly) return to utilizing them upon release from prison.

SEE ALSO Bundy (serial murderer) case; Contact crimes; Profiling.

Harry Söderman

8/28/1902–1956
SWEDISH
CRIMINALIST

Harry Söderman was a Swedish criminalist whose career and research is unique in the history of forensic sciences. His name is associated with the greatest contributors to forensic sciences, such as the French criminalist **Edmond Locard** (1877–1966), the French anthropologist **Alphonse Bertillon** (1853–1914), the Austrian criminalist **Hans Gross**, and the Swiss criminalist R.A. Reiss.

At age 22, Söderman began a long journey to the Orient. He persuaded a Swedish bicycle manufacturer to lend him a bicycle to ride to Constantinople (now Istanbul in Turkey). In addition, he obtained extra support from the Swedish police magazine as a correspondent, and while he was visiting different countries, Söderman reported on their police systems and criminal activities. His travel did not stop in Turkey, and he spent many months in Asia, venturing into the interior of China. Söderman returned to Stockholm two years later, in 1924.

The encounter that probably changed his life and made his dreams possible occurred at a small mountain resort in northern Sweden not long after his return from Asia. Because of a bad blizzard that interrupted his hike, Söderman was required to stay for three days and three nights in a hut with three men that he had never met. During their long talks, one of the men revealed that he was an acquaintance of Edmond Locard, in Lyon, France. Söderman immediately said that he considered Locard the greatest living police scientist and expressed his desire to study under him. Some time later, young Söderman received a letter from Lyon stating that he was accepted as an intern in Locard's laboratory.

In 1926, Söderman left Sweden for Lyon, where he spent the next six years. He was able to absorb a great amount of knowledge and experience from Locard, while also obtaining his doctoral degree from the University of Lyon. His dissertation research was on the scientific study of the individual characteristics present on fired bullets that originate from the barrel of the firearm, as well as those left on cartridges from the firing pin. He was the first researcher to tackle the problem of firearms **identification** from a scientific perspective. Söderman invented the Hastoscope, which is an improved **comparison microscope**. The Hastoscope holds two bullets that can turn on their axles in order to accelerate the identification process by comparison of their striations. The origin of the word Hastoscope is a mystery, but the theory that it is a contraction of Ha(rry) S(öderman) + toscope has been offered. This theory also states that the word contains the word haste, as this microscope accelerated the observation process.

In 1932, Söderman returned to his native Stockholm and started a private forensic laboratory. His work was successful and he obtained a position at the University of Stockholm, where he taught scientific police techniques. In 1933, he left for two years to study American police systems in the United States under a fellowship, spending one full year in New York City. After being back in Sweden for about two years, he left again in 1937 for Dublin, Ireland. He spent one year reorganizing the Irish police force at the request of the Irish government. In 1939, he was asked by the Swedish government to become the head of the National Forensic Science Institute, the equivalent to the **FBI** laboratory in United States. Söderman was at the pinnacle of his career and he remained in this position until his retirement. He continued to be extremely active in international relations, and a few years later, he was one of the founders of **Interpol**.

During World War II (1939–1941), Söderman was asked by the Norwegian minister to train Norwegian police officers in anticipation of the end of the war. Söderman created **training** camps in Sweden, and as a result about 17,000 men were trained between 1943 and 1945. In 1953, Söderman resigned from his position as head of the National Forensic Science Institute to devote himself completely to international activities. The same year, he moved to the

United States, where he worked as a consultant for police organizations from around the world. He died at the age of 54.

Söderman wrote hundreds of articles and books. He was fluent in several languages, including Swedish, English, French, and German. As a columnist for many journals, he was widely read and known in the forensic science community. His most famous books are *Modern Criminal Investigation*, which he co-authored with American Police Deputy Chief John J. O'Connell and *Policeman's Lot*. It is estimated that more than 100,000 copies of *Modern Criminal Investigation* have been sold.

SEE ALSO Firearms; Criminalistics; Microscope, comparison.

Soils

Soil on a suspect's shoe or splattered inside a car fender can provide forensic scientists with information about the travels of suspects and crime victims.

Soil is the product of biological, chemical, and physical alteration of materials at Earth's surface. Soils form in horizons, or layers, that are approximately parallel to the surface, have distinct properties, and are denoted by uppercase letters. The uppermost O horizon consists of decaying organic matter. It is underlain by the A horizon, or topsoil, which consists of a mixture of mineral and organic material. Beneath the A horizon is the B horizon, which consists of slightly altered mineral material, and the C horizon, which consists of the unaltered but loose parent material from which the soil developed (for example, sand). If intact rock is present, it can comprise an R horizon. Desert soils rich in calcium carbonate can also contain Bk or K horizons (the K is used to avoid confusion with the C horizon) that range from light accumulations of calcium carbonate to so-called petrocalcic horizons that are limestone formed in place. The term soil is also used loosely to refer to virtually any unlithified material at Earth's surface regardless of whether it has undergone the soil forming process known as pedogensis. Examples of materials that do not fall under the strict definition of soil include sand in dunes or along beaches and mud deposited by a recent flood. Because soils form by a complicated process that is influenced by factors such as temperature, precipitation, the mineralogical and chemical composition of the parent material, and even the nature of particles that may be washed out of the air during rainstorms, soil from different locations can have different physical and chemical characteristics that are useful to forensic scientists.

Soil recovered from shoes, clothes, and automobiles can be analyzed in order to determine if a suspect was or was not in a particular location. This is done by carefully comparing the color, particle size and shape, mineralogical composition, and biological components of a soil sample obtained from a suspect to those of soil from a known location. Particle sizes and shapes can be compared using reflected light **microscopes**. The chemical and mineralogical composition of the soil can be compared using techniques such as x-ray diffraction, in which a pulverized soil sample is subjected to x rays that produce patterns indicative of the crystal structure of **minerals** in the soil. Soils that are, or once were, adjacent to water may also contain distinctive shell fragments. The presence of soil unique to a particular area can show that a suspect must have traveled to that area, just as the absence of soil can be used to disprove an alibi. In some situations, layers of soil or mud can be used to establish presence at a sequence of locations.

The fictional British detective Sherlock Holmes is generally credited with the first use of soils as forensic **evidence** in the late nineteenth century, and soils have been employed as real life forensic evidence since the early years of the twentieth century. Holmes possessed the ability to distinguish different soil types and, using that information, make inferences about the travels of suspects. Real-life German chemist **Georg Popp** used goose droppings, sandstone fragments, and three different kinds of dust on a suspect's shoes to link to the same materials found at a murder victim's home, the place where the body was found, and the place where the murder weapon was found. Just as importantly, Popp used the absence of distinctive quartz crystals to disprove the suspected murderer's alibi he was walking in a specific field near his home when the crime occurred.

In more recent times, soil analysis was used in an attempt to track down the killers of Italian prime minister Aldo Moro in 1978. Investigators matched sand found on Moro's body to that found on an 6.8 mile (11-km) long beach north of Rome, which helped to focus their investigation. Another high profile case involved United States drug enforcement agent Enrique Camerena Salazar and his pilot Alfredo Zavala Avelar, who were killed by Mexican federal police in 1985. Their bodies were reported to have been found at the scene of a shootout between police and known drug dealers, implicating the drug dealers as murderers. Close examination of soil samples taken from the bodies, which contained an unusual combination of mineral and volcanic **glass** particles, revealed that the bodies had originally been buried in a remote mountainous area far from the shootout. This, combined with other forensic evidence, eventually showed that the federal police had been involved in the kidnapping, torture, and murder of the two.

Soil analysis is not restricted to cases involving politics and international intrigue. Soil found with a body inside a plastic garbage bag in New Jersey was identified as material that had been dredged from Newark Bay and used as fill to create new land along the shore. This clue led investigators to the victim's wife and daughter, who had killed him and temporarily buried the body beneath their home, which was built on the fill. California authorities were confounded when soil found in a murder suspect's car partially, but not completely, matched the soil around an oil well where the victim's body had been dumped. Further research showed that gravel from a different location had been spread around the well, explaining why the soil from the car was not an exact match with the natural soil in the area.

Small fragments of chert, a sedimentary rock made of silica, in cow manure collected from the back of a truck were used to prove that a herd of cattle had been rustled in Missouri and taken to Montana. Although the cattle rustlers had altered the brands on the cattle in an attempt to cover their tracks, they did not realize that the manure contained evidence that could have come only from Missouri. Another example of agricultural soil forensics is the comparison of soil samples to determine whether valuable plants were removed from protected government land and sold for landscaping.

SEE ALSO Geology; GIS; Minerals.

Souvenirs from athletic events

With the advent of computer technology, counterfeiting of clothing and other goods has proliferated in the world's markets. Basic computer software and hardware can be used to copy, alter, and reproduce almost any item, and sports logos are particularly easy to duplicate. Computers also make it easier to produce and distribute illegally reproduced items. In 2000, the counterfeit market in the United States was estimated to be approximately $1 billion. The **FBI** estimates that between 50–90% of all celebrity and sports collectibles sold in the United States are fakes.

Although many companies producing and selling sports souvenirs have used sophisticated methods, such as holograms and refractive logos, to try to discourage counterfeiting and forgery, pirates have continually been able to circumvent the preventative measures. Beginning around 1996, some companies adopted authentication methods that rely on **DNA** as well as optical taggants (a substance or material added to a product to indicate its source of manufacture).

In 1997 the FBI initiated an undercover operation targeting counterfeiters of sports and celebrity memorabilia. Nicknamed Project Bullpen, the operation culminated in 2000 with the seizure of more than $10 million in illegal goods and the arrests of 25 people. The charges included conspiracy to defraud the United States and tax evasion. Penalties included up to five years of imprisonment and fines up to $250,000 per offense.

Typical memorabilia seized by Project Bullpen operatives included jerseys, shoes, bats and balls, helmets, hockey sticks and pucks, photographs, posters, and trading cards, all of which bear the signature of an athlete or celebrity. The most commonly forged autographs on seized memorabilia included Babe Ruth, Lou Gehrig, Ty Cobb, Sammy Sosa, Mark McGwire, and Tony Gwynn.

The report filed as a result of Project Bullpen claimed that, although there is an extremely large public market for sports memorabilia, almost all of the counterfeit autographs, especially those of deceased athletes, trace back to a small group of forgers. These counterfeiters are able to maintain a low profile by selling much of their merchandise over the internet.

A key player in the marketing chain for forgeries is the authenticator. Sometimes memorabilia are sold with mass produced certificates of authentication, but often people claiming to be experts in verifying autographs assign authenticity to the item. The certificate of authenticity allows sellers to claim that their items are authentic and gives them an excuse if the items are found out to be fraudulent.

In order to evade forgers, some athletes have signed agreements that give certain distributors exclusive rights to their signed memorabilia. For example, all souvenirs autographed by Michael Jordan are sold through the company Upper Deck. Mark McGwire has refused to sign his signature for money since 1990.

Some athletes and professional sports leagues are adopting more technical means to prevent forgeries. DNA markers and optical taggants have proven to be excellent tags for sports memorabilia and they have also been used to authenticate artwork, ID cards, and certificates. Because of their complexity, DNA tags and optical taggants can be used for tracking products during manufacture and shipping. They have also been used to authenticate valuable wines and pieces of artwork.

The DNA molecule is composed of a sequence of four different nucleotides: adenine (A), guanine (G), cytosine (C) and thymine (T). Because DNA is a double stranded molecule, the nucleotides are connected in pairs on opposite strands. Adenine always pairs with thymine and guanine always pairs with cytosine. Because the nucleotides are found in pairs, they are referred to as base pairs. Using biochemical techniques, scientists can engineer short strands of DNA, called oligomers, with any sequence of base pairs. This inherent variability of the sequence can be used as a code to verify the authenticity of objects. For example, there are 10.5 million possibilities for engineering an oligomer that is ten base pairs long. An oligomer that is twenty base pairs long has 1.1 trillion possible variations. If several different oligomers are combined, the possibility of reproducing the DNA code is extremely remote. In addition, masking DNA can be combined with the authenticating DNA to make reverse engineering of the oligomers nearly impossible. Finally, it is sufficiently easy to frequently change the base pair sequence used for authentication.

Once the specific oligomer or several oligomers have been synthesized, they are coated with a protein. This is similar to putting a hard shell around the DNA, protecting it from interacting with other chemicals such as alcohols and dyes. The coated DNA is incorporated into a special matrix, which is then added to ink. The DNA-laced ink can be applied to practically any surface. The ink into which the matrix is added can either be invisible or colored, depending on the intended use.

After DNA has been incorporated into ink and applied to an item, authentication can be performed in a laboratory. A small piece of the item that has ink markings is removed. This piece is digested and the DNA is chemically extracted. **PCR (polymerase chain reaction)** produces many copies of the DNA from the ink. This amplified DNA can then be sequenced to verify that it is the code associated with the item. The ink marks are expected to be permanent and therefore can be used for authentication into the future.

Some chemicals are optically active, which means that they react in the presence of light. These chemicals absorb a photon of light traveling at a particular wavelength and then reemit it at a different wavelength. This process is called excitation and emission. Usually there is a range of wavelengths, or a spectrum of light, that excites a chemical. Similarly, there is a range of wavelengths of light that will be emitted by the chemical. Combining different chemicals with different excitation and emission spectra can result in a mixture with a fairly complex emission spectrum. This emission spectrum is sometimes referred to as a spectral signature.

Companies seeking to authenticate their products have developed a variety of optically active chemicals. Scientists have developed methods to assemble these chemicals in a variety of different combinations so that they emit a unique spectral signature in the presence of the proper excitation wavelengths. These chemicals are referred to as optical taggants and they can be added to a matrix along with engineered oligomers of DNA. Just like the protein-coated DNA, optical taggants are stable molecules that can withstand exposure to alcohols, dyes, plastics, and threads.

Hand-held optical devices have been developed that can be programmed to emit the exact wavelengths of light necessary to excite the optical taggants. They can also be programmed to detect the emission spectra of the chemicals and emit beeps or lights when the correct spectrum is detected. These devices are battery powered and relatively inexpensive. They allow authenticators to scan objects for the presence of the correct spectral signature in the field and to apprehend counterfeiters when the optical taggants are not present.

Counterfeiting of souvenirs and apparel at Olympic games is an enormous market. At the 1996 Olympics in Atlanta, Georgia, it is estimated that as much as 40% of all merchandise sold was unlicensed. Following that enormous loss of revenue, the Australian Government passed the Sydney 2000 Games Indicia and Images Protection Act, which protects the Olympic word and the symbols associated with it from being copied illegally. In order to help uphold the Act, Sydney Organizing Committee for the Olympic Games (SOCOG) contracted with DNA Technologies, a subsidiary of CrossOff Incorporated in Halifax, Nova Scotia, to develop DNA and optical tags for the 2000 Sydney Olympics.

SOCOG decided to incorporate the DNA of an Australian Olympic athlete into the DNA tag as a means to increase public awareness of the counterfeiting detection strategy. DNA was extracted from cells swabbed from the inner cheek of the athlete. A portion of this DNA was then amplified using **PCR** and mixed with other sequences of DNA to mask the original sequence. Both the engineered DNA and a unique optical taggant were used to label nearly everything sold at the Olympics including pins, clothing and hats. More than 34 million labels and tags were produced by DNA Technologies and distributed to 40 official Olympic licensees.

Olympic counterfeit investigators were provided with optical scanners that emit a light in the presence of the optical taggant. They performed more than 3,400 inspections during the course of the Olympics. The inspections uncovered 507 trademark violations and more than three quarters of the violations occurred within the first three months of the inspections. Early seizures of unlicensed items included soccer balls and watches. The Olympic committee estimated that less than 0.5% of the revenue generated by merchandise sales at the Sydney Olympics was lost to counterfeiting.

Beginning in 2000, the National Football League contracted with DNA Technologies to tag football souvenirs. About 100 footballs used at the Super Bowl games were tagged each year. The NFL also used the DNA labeling technology to identify jerseys worn during the Super Bowl and Pro-Bowl games. In 2003, the National Hockey League began a program in which they sold hockey pucks that were used in games. DNA Technologies labeled all these pucks with the DNA and optical taggant-laced ink. The label associates the pucks with the specific game in which they were used and also shows whether or not the puck was used to score a goal.

A variety Major League Baseball souvenirs have been labeled with DNA and optical taggant markers. These include baseballs and bases from the 1999 World Series and the uniforms, baseballs, and bases used by the Detroit Tigers in the final game at Tiger Stadium. A number of historical baseballs have also been labeled with DNA tags. These include the baseballs hit by Mark McGwire for his 70th home run in 1998, Sammy Sosa for his 66th home run in 1998, Mickey Mantle for the 500th home run of his career and Hank Aaron for the 715th home run of his career. DNA Technologies authenticated the bat used by Babe Ruth to hit his first home run at Yankee Stadium in 1923 and a DNA and optical taggant label was applied to that bat. It later sold for almost $1.3 million at a Sotheby's auction. Shoeless Joe Jackson's "Black Betsy" bat was authenticated and labeled with DNA and an optical taggant. In 2001, it sold for $577,000 at auction.

Beginning in 1998, DNA Technologies teamed with Professional Sports Authenticator, a Newport Beach, California company. Called PSA/DNA, the collaboration has developed a method for professional athletes to guarantee the authenticity of their autographs by incorporating DNA and an optical taggant into the ink they use to sign their names. The DNA and optical taggant label is expected to remain detectible in the ink indefinitely. The company guarantees that the chance of duplication of the DNA sequence used in the ink is one in 33 trillion.

SEE ALSO DNA sequences, unique; Handwriting analysis.

Walter Specht

GERMAN
FORENSIC SCIENTIST

In 1937, at the University Institute for Legal Medicine and Scientific Criminalistics in Jena, Germany, Walter Specht introduced the use of **luminol** as a presumptive test for **blood** at crime scenes. This is forensically important, because perpetrators often wash away visible signs of blood at the scene, in an effort to remove all possible **evidence** of the crime.

A presumptive test for blood is used when forensic investigators have strong reason to suspect that blood is present but is not currently visible at the scene. A presumptive test will neither prove nor disprove, in and of itself, the presence of blood at a crime scene—it will merely indicate a likelihood, which should then be further investigated.

Forensic scientists use a spray containing luminol and hydrogen peroxide to detect trace blood at crime scenes. **Hemoglobin** in blood catalyzes the breakdown of hydrogen peroxide into oxygen, which can oxidize the luminol. It works well with both fresh and dry blood, and can be applied several years after the incident. The luminol solution is fine sprayed over the suspected area of a room or object in the room. When sprayed on an area containing blood, luminol produces a chemiluminescent reaction (a glow) instead of color. It is best viewed in total darkness, due to its relatively weak luminescence. The order of use for luminol at a crime scene is: (1) Spray walls first, to illuminate spatter patterns; (2) Spray ceiling next, to highlight cast off patterns; (3) Spray floors, in order to detect **shoeprints**, drag marks, etc., last. Luminol should only be applied once; additional application will only serve to dilute any blood present.

Luminol is considered highly sensitive: it can detect the presence of blood in a ratio of one part per million (1:1,000,000). In contrast to its high sensitivity, it has a relatively low rate of specificity: in addition to reacting to the presence of blood, it can also react to chemical oxidants such as chlorine bleach, certain types of chemical cleaners, and detergents. Crime scene investigators always follow up a positive presumptive indicator with more specific quantifying tests at the luminol-identified sites.

Among the many benefits of presumptive testing with luminol are its heme-specific sensitivity; its relative stability and lack of toxicity (important due to repeated exposures over time at multiple crime scenes); and its reliable yet inexpensive preparation. Of particular forensic significance is the fact that luminol rarely destroys other evidence (if properly prepared and used) and will not interfere with the future **DNA** testing of recovered crime scene blood. In addition, presumptive testing with luminol meets the Frye standard for general scientific and legal acceptance.

Because it works well with both fresh and dry blood, and can be applied several years after the incident, luminol is as useful in cold cases as it is in current **crime scene investigation**. Though originally designed for use in the German copper mining industry as a means of uncovering new sources of ore, Walter Specht's use of luminol in crime scene investigation settings made an enduring contribution to the field of **forensic science**.

SEE ALSO Blood spatter; Cast-off blood; Cast-off trails; Cold case; Crime scene cleaning.

Spectrograph

Forensic analysis of a wide and diversified range of samples seized at crime scenes, accidents, **fire debris**, explosions, and autopsies requires the use of several analytical methods and tools, such as gas chromatography/mass spectrometry (GC/MS), atomic absorption **spectroscopy** (AAS), inductively coupled plasma spectroscopy (ICP), infra-red spectroscopy (IRS), nuclear magnetic resonance (NMR) spectroscopy, and high performance liquid **chromatography** (HPLC). Spectrography and spectroscopy are basically synonyms, referring to "a picture of a spectrum." The terms spectroscopy and spectroscope are more commonly used because they are older and easier to pronounce than the denominations spectrography and spectrograph. Spectrography is also known as spectral imaging techniques.

Spectrographs or spectroscopes are optical instruments that measure wavelengths and energy levels, radiated from atomic bonds between elements in molecules, or from other light sources such as stars. Spectrographs and spectroscopes disperse light into wave patterns known as a spectral image. The first spectroscope was developed at the beginning of the nineteenth century and consisted of three metallic tubes containing lenses disposed with converging axes and a flint glass prism, which dispersed light originated from a light source or the radiant energy emitted by chemical compounds into a wave spectrum. The spectral image allowed the quantitative analysis of chemical elements, index of refraction, wavelengths, and mass as well as the composition of chemical molecules. Its first application was in astronomy (telescopes) and chemistry (analytical spectroscopy) to determine the composition of chemical elements present in nebulas, stars, and in unknown chemical compounds.

With the advent of photography, spectroscopes were renamed spectrographs because a camera was coupled to the device instead of a telescope, allowing the development of the resulting spectral image into a photographic picture. During the twentieth century, with the advances in physics and electronic technology, the photographic camera was substituted by a photomultiplier that permitted instantaneous spectrographic analyses. A variety of spectral imaging technologies are presently available that are supported by computer software. Examples of forensic applications for these technologies include: isolating trace residues on surfaces; identifying **fibers** and micro particles; detection and quantification of organic and inorganic contaminants in food, water, and air; identifying semivolatile and volatile (explosive) fuel residues; and analyzing paint fragments.

Infrared (IR) spectroscopy uses infrared light to identify substances, due to chemical bonds vibrating in different frequencies, absorbing different amounts of infrared wavelengths, and emitting specific quanta of radiation (e.g., energy at known wavelengths). The device registers the absorbed wavelengths and produces a graph that is compared to those of known substances, which are recorded in a computer database. Each peak in the spectrum represents a different chemical element with unique properties. Each chemical molecule gives a unique spectrum, known as a fingerprint region. Forensic experts may use this method to identify types of drugs in a sample or paint chips from a car. Forensic analysts can gather

physical evidence to support claims of sexual assault by testing samples of **blood** or urine from the victim with infrared spectroscopy. If Rohypnol or other "date-rape" drugs are found, investigators have not only physical **evidence** of the crime, but also information about what investigators should search for in the suspect's house.

Gas chromatography/mass spectroscopy is a combined method used in forensics to identify residual fuels, such as accelerants and chemical residues, in the debris of a fire scene in order to determine whether the fire was accidental or was caused intentionally. These methods are also used to verify the purity of chemical products and the presence of contaminants in cosmetics, hygiene products, and food products. High performance liquid chromatography is another forensic method for **identification** of food and cosmetic contaminants.

Mass spectrometry is used to measure the masses of chemical isotopes (e.g., molecular mass) and to detect impurities in materials. Beams of ionized gas molecules are accelerated in the mass spectrograph, passing through a combined electric and magnetic selector that deflects them, before entering into a vacuum chamber. The amount of deflection is given by the mass/charge ratio, with each molecule being fragmented into smaller particles. In the vacuum chamber, a magnetic field interferes with the beam trajectory creating a spectrum on a photographic plate. Each peak in the spectrum represents a specific mass/charge ratio of a charged fragment and the largest mass/charge ratio indicates the molecular ion used to determine the molecular mass.

Another application of spectrometry is in the forensic analysis of **questioned documents**. Imaging spectrometers equipped with spectral scanners permit the detection of slight differences in inks and paper surfaces, as well as the presence of erased or added lines in numbers or letters. These optical instruments scan the document point by point through absorption, reflection, and **fluorescence** of materials, forming a spectral image where existing adulterations become evident to the naked eye. Spectral imaging is a convenient forensic method because it does not destroy evidence during analysis.

Atomic absorption spectroscopy (AAS) allows the precise quantification of inorganic elements in paints, water, air, or **soils**. AAS can, for instance, determine environmental contamination of water by mercury or other heavy metals. However, when multiple inorganic elements need to be simultaneously analyzed in a sample, inductively coupled plasma (ICP) spectroscopy is the method utilized. The ICP method can detect multiple metals in a solid matrix, in welding fumes, or in water or paints. Another analytical method used in forensics is Raman spectroscopy, especially when the preservation of samples is important as with court exhibits. This method can identify drugs, chemicals, fibers, and paints through spectral microscopy.

Determining the postmortem interval (PMI) or the time elapsed since death is crucial for investigators of a **murder**, especially when the body was subjected to environmental influences such as water, soil, or insects. In these cases, postmortem metabolic changes can be assessed through high-resolution magnetic resonance spectroscopy (H-MRS). It also provides additional valuable information to other traditional forensic methods used to determine PMI. In one study, decomposing brain tissue was used in H-MRS to identify metabolites and gases that helped to determine the time elapsed since death. The brain metabolites showed expected decreased concentrations that correlated with the estimated PMI of known samples.

In spite of the great utility of analytical instruments in forensic investigations, it is important to keep in mind that nothing substitutes human scientific and technical competence along with the exchange of information when interpreting data, especially when lives are at stake in a criminal court. One example of this was given by a scientist in a 2004 report alerting that bullet matching based on chemical analysis has sometimes been biased by errors in analysts' interpretation of data. In the report, "Forensic Analysis: Weighting Bullet Lead Evidence," the limitations of lead content analysis as a tool for matching evidence and evidence validation were described. Chemical analysis through ICP spectroscopy detects minute amounts of trace elements in bullet fragments such as arsenic, antimony, copper, silver, cadmium, tin, and bismuth, which are present in less than 1% of bullet lead alloys. Although the resulting bullet characteristics are accurate, the way data is interpreted may be misleading. It was long assumed that if two bullets are chemically identical, they originated from the same smelting source or were manufactured at the same day at the same factory. **FBI** examiners even assumed in courts that they came from the same bullet box. The report featured evidence from forensic chemists that even in a single lead smelting pot, sometimes the composition varied from one batch of bullets to the next batch, whereas the composition of different pots matched, implying that bullets made from different pots, by different manufacturers, sometimes matched.

Another forensic analytical chemist at the Committee of the National Academies discovered that bullets made of lead from different sources can get mixed into the supply and manufacturing processes, which can lead to the same ammunition box containing bullets with different elemental compositions. The National Academies Committee concluded in their report that it is impossible to determine with absolute certainty that a bullet from a crime scene came from a specific box of bullets, or that two bullets were manufactured on the same day by the same manufacturer. In the face of these and other gathered data generated from spectrography and shown in the report, the committee has asked the FBI to revise its rules on the interpretation of results from bullet chemical analysis.

SEE ALSO Accelerant; Analytical instrumentation; Ballistic fingerprints; Ballistics; Chemical and biological detection technologies; Chromatography; Circumstantial evidence; Document forgery; Electromagnetic spectrum; Energy dispersive spectroscopy; Fire debris; Gas chromatograph-mass spectrometer; Ink analysis; Isotopic analysis; Micro-spectrophotometry; Paint analysis; Spectroscopy; Trace evidence.

Spectroscopy

Forensic analysis utilizes a variety of physical, chemical, and molecular techniques to detect and, in many cases, determine the quantity and composition of a specific compound. Some of these techniques are extremely sensitive and accurate. One such example is spectroscopy.

Spectroscopy is the measurement of the absorption, scattering, or emission of electromagnetic radiation by atoms or molecules. Absorption is the transfer of electromagnetic energy from a source to an atom or molecule. Scattering is the redirection of light as a result of its interaction with matter. Emission is the transition of electromagnetic energy from a one energy level to another energy level that results in the emission of a photon.

When atoms or molecules absorb electromagnetic energy, the incoming energy transfers the quantized atomic or molecular system to a higher energy level. Electrons are promoted to higher orbitals by ultraviolet or visible light; vibrations are excited by infrared light (thermal energy). Atomic emission spectroscopy (AES) is designed to measure the amount of light emitted by excited atoms. Atomic absorption spectroscopy (AAS) is more sensitive, because it measures the amount of light absorbed by ground state atoms. Atomic absorption tests are more sensitive because there are more ground state electrons than excited electrons in a sample. UV-VIS absorption spectroscopy is used to obtain qualitative information from the electronic absorption spectrum, or to measure the concentration of an analyte molecule in solution. Molecular **fluorescence** spectroscopy is a technique for obtaining qualitative information from the electronic fluorescence spectrum, or for measuring the concentration of a chemical compound undergoing analysis, also known as an analyte, in solution.

Infrared spectroscopy has been widely used in the study of surfaces. The most frequently used portion of the infrared spectrum is the region where molecular vibrational frequencies occur. This technique was first applied around the turn of the twentieth century in an attempt to distinguish water of crystallization from water of constitution in solids.

Ultraviolet spectroscopy takes advantage of the selective absorbance of ultraviolet radiation by various substances. The technique is especially useful in investigating biologically active substances such as compounds in body **fluids**, and drugs and narcotics either in the living body (*in vivo*) or outside it (*in vitro*). Ultraviolet instruments have also been used to monitor air and water pollution, to analyze dyes, to study carcinogens, to identify food additives, to analyze petroleum fractions, and to analyze pesticide residues. All of these can be forensically relevant. Ultraviolet photoelectron spectroscopy, a technique that is analogous to x-ray photoelectron spectroscopy, has been used to study valence electrons in gases.

Microwave spectroscopy, or molecular rotational resonance spectroscopy, addresses the microwave region of the **electromagnetic spectrum** and the absorption of energy by molecules as they undergo transitions between energy levels. From these spectra, it is possible to obtain information about molecular structure.

In nuclear magnetic resonance (NMR), resonant energy is transferred between a radio-frequency alternating magnetic field and a nucleus placed in a field sufficiently strong to separate the nuclear spin from the influence of atomic electrons. Transitions induced between substrates correspond to different quantized orientations of the nuclear spin relative to the direction of the magnetic field. Nuclear magnetic resonance spectroscopy has two subfields: broadline NMR and high resolution NMR. High resolution NMR has been used in inorganic and organic chemistry to measure subtle electronic effects, to determine structure, to study chemical reactions, and to follow the motion of molecules or groups of atoms within molecules.

Electron paramagnetic resonance is a spectroscopic technique similar to nuclear magnetic resonance except that microwave radiation is employed instead of radio frequencies. Electron paramagnetic resonance has been used extensively to study paramagnetic species present on various solid surfaces. These species may be metal ions, surface defects, or adsorbed molecules or ions with one or more unpaired electrons. This technique also provides a basis for determining the bonding characteristics and orientation of a surface complex. Because the technique can be used with low concentrations of active sites, it has proven valuable in studies of oxidation states.

Atoms or molecules that have been excited to high energy levels can decay to lower levels by emitting radiation. For atoms excited by light energy, the emission is referred to as atomic fluorescence; for atoms excited by higher energies, the emission is called atomic or optical emission. In the case of molecules, the emission is called fluorescence if the transition occurs between states of the same spin, and phosphorescence if the transition takes place between states of different spin.

In x-ray fluorescence, the term refers to the characteristic x rays emitted as a result of absorption of x rays of higher frequency. In electron fluorescence, the emission of electromagnetic radiation occurs as a consequence of the absorption of energy from radiation (either electromagnetic or particulate), provided the emission continues only as long as the stimulus producing it is maintained.

The effects governing x-ray photoelectron spectroscopy were first explained by Albert Einstein in 1905, who showed that the energy of an electron ejected in photoemission was equal to the difference between the photon and the binding energy of the electron in the target. In the 1950s, researchers began measuring binding energies of core electrons by x-ray photoemission. The discovery that these binding energies could vary as much as 6 eV, depending on the chemical state of the atom, led to rapid development of x-ray photoelectron spectroscopy, also known as electron spectroscopy for chemical analysis (ESCA). This technique has provided valuable information about chemical effects at surfaces. Unlike other spectroscopy techniques in which the absorption, emission, or scattering of radiation is interpreted as a function of energy, photoelectron spectroscopy measures the kinetic energy of the electrons(s) ejected by x-ray radiation.

Mössbauer spectroscopy was invented in the late 1950s by Rudolf Mössbauer, who discovered that when solids emit and absorb gamma rays, the nuclear energy levels can be separated to one part in 10^{14}, which is sufficient to reflect the weak interaction of the nucleus with surrounding electrons. The Mössbauer effect probes the binding, charge distribution and symmetry, and magnetic ordering around an atom in a solid matrix. An example of the Mössbauer effect involves the ^{57}Fe nuclei (the absorber) in a sample to be studied. From the ground state, the ^{57}Fe nuclei can be promoted to their first excited state by absorbing a 14.4-keV gamma-ray photon produced by a radioactive parent, in this case ^{57}Co. The excited ^{57}Fe nucleus then decays to the ground state via electron or gamma ray emission. Classically, one would expect the ^{57}Fe nuclei to undergo recoil when emitting or absorbing a gamma-ray photon (somewhat like what a person leaping from a boat to a dock observes when his boat recoils into the lake); but according to quantum mechanics, there is also a reasonable possibility that there will be no recoil (as if the boat were embedded in ice when the leap occurred).

When electromagnetic radiation passes through matter, most of the radiation continues along its original path, but a tiny amount is scattered in other directions. Light that is scattered without a change in energy is called Rayleigh scattering; light that is scattered in transparent solids with a transfer of energy to the solid is called Brillouin scattering. Light scattering accompanied by vibrations in molecules or in the optical region in solids is called Raman scattering.

In vibrational spectroscopy, also known as Raman spectroscopy, the light scattered from a gas, liquid, or solid is accompanied by a shift in wavelength from that of the incident radiation. The effect was discovered by the Indian physicist C. V. Raman in 1928. The Raman effect arises from the inelastic scattering of radiation in the visible region by molecules. Raman spectroscopy is similar to infrared spectroscopy in its ability to provide detailed information about molecular structures. Before the 1940s, Raman spectroscopy was the method of choice in molecular structure determinations, but since that time infrared measurements have largely supplemented it. Infrared absorption requires that a vibration change the dipole moment of a molecule, but Raman spectroscopy is associated with the change in polarizability that accompanies a vibration. As a consequence, Raman spectroscopy provides information about molecular vibrations that is particularly well suited to the structural analysis of covalently bonded molecules, and to a lesser extent, of ionic crystals. Raman spectroscopy is also particularly useful in studying the structure of polyatomic molecules. By comparing spectra of a large number of compounds, chemists have been able to identify characteristic frequencies of molecular groups, e.g., methyl, carbonyl, and hydroxyl groups.

SEE ALSO Analytical instrumentation; Fourier transform infrared spectrophotometer (FTIR).

Spores

Illness and death can occur from pathogenic (disease-causing) microbial infections. Thus knowledge of the ways infections spread and the myriad of symptoms that can develop are a vital part of **forensic science**. This is especially important when the infection is a serious threat to health and is easily spread from person to person. One important contributor to the spread of infection by certain bacteria (including the infamous cause of **anthrax**) is the spore.

A spore is a hard casing that contains the genetic material of those bacteria and other microorganisms that are able to form the structure. This physically and chemically resilient package protects the genetic material during periods when the environmental conditions are so harsh that the growing form of the microbe would be killed.

The effect of temperature on bacterial and spore survival provides a good example of the resilience of bacterial spores. Temperatures of 176–199°F (80°–90°C) typically kill bacteria that are growing and dividing within minutes. These high temperatures cause structural components of the bacteria to dissolve, and strands of genetic material to separate from one another. A group of bacteria known as thermophilic bacteria can survive these temperatures; but, temperatures of (248°F) 120°C kill even thermophiles. In contrast, spores can survive exposure to 248°F for several hours.

Spores of bacteria that subsequently could be revived into the growing form have been recovered from materials that are over a century old. Thus, spores offer an extraordinary form of protection to bacteria. Anthrax spores that could germinate into living bacteria were recovered on Gruinard Island, an island off the coast of Scotland, that was used for biological weapons testing by the British government during World War II.

Bacillus anthracis, the bacterium that causes anthrax, is a spore former. The spores are very light and tiny. As a result, they can be readily dispersed through the air and can be easily inhaled into the lungs. The resulting lung infection, which is called inhalation anthrax, is almost always fatal without prompt medical treatment.

Another prominent example of a bacterial spore former of concern is *Clostridium botulinum.* The bacterium and the spore are widespread in nature. For example, they are a common inhabitant of the soil. This bacterium can also survive in canned foods for extended time periods, even when the food has been heated or is acidic. When the food is eaten, the dormant bacteria begin to grow again and produce a variety of potent **toxins** that disrupt the nervous system, causing serious illness.

Other microorganisms of human concern that form spores include protozoa (e.g., *Microsporidia*) and fungi (e.g., *Actinomycetes*).

The multi-step process of forming a spore is known as sporulation. The process begins when a bacterium senses that the environmental conditions are becoming life threatening. Bacteria are equipped with a whole battery of sensing proteins and other compounds that monitor environmental conditions, such as temperature, pH of the surrounding fluid, water content, and availability of food. After monitoring the environment for a period of time, the deteriorating conditions trigger the microbe to begin the change from a growing and dividing cell to a dormant spore.

The genetic material of the bacterium is duplicated. Then, the membrane coat that surrounds the inside of the bacterium pinches inward until the ends of the inward growing membrane meet. This isolates one of the copies of the genetic material from the remainder of the bacterium. This smaller cell is called a daughter cell. The remainder of the bacterium is called the mother cell.

In the next stage of spore formation, the membrane that surrounds the mother cell surrounds the daughter cell. This creates a daughter cell that is surrounded by two layers of membrane. Between these two membranes a thick layer of a rigid material forms. This layer is called peptidoglycan. Peptidoglycan is normally present in the bacterial cell wall, but not in nearly the same amount as is present in a spore. The thick peptidoglycan makes the double membrane layer very tough and hard to break apart. Finally, this tough membrane is coated on the outer

FBI and Army scientists began the process of opening an anthrax-laden letter sent to Vermont Democratic Senator Patrick Leahy in 2001, containing enough spores to kill thousands of people. © REUTERS/CORBIS

surface by proteins. The proteins are also resistant to breakage.

The remnants of the mother cell dissolve away leaving the spore. The spore is essentially in hibernation. There is very little chemical activity. Nevertheless, the spore is able to monitor the external environment and, when conditions are sensed as being more favorable, the conversion from the spore form to the growing organism begins.

SEE ALSO Anthrax; Bacterial biology; Pathogens.

Sports and drug testing SEE Performance-enhancing drugs

Sports testing

In 1967, the International Olympic Committee (IOC) and the International Cycling Union became the first sporting organizations in the world to ban the use of performance-enhancing drugs, sometimes also known as doping, in an effort to stop drug misuse during the 1968 Olympics. To be effective, the new measures had to be underpinned by a system of testing athletes and others closely involved in sports for banned substances. Forensic toxicologists carry out sports testing for a range of drugs, from steroids and beta-blockers, to growth hormones and diuretics. It is not clear how widespread the use of drugs in sports really is, but those who do cheat, including trainers, frequently use new substances in an attempt to evade the testers. It is up to the forensic toxicologist to keep a step ahead by developing new, sensitive, and, above all, reliable methods for sports testing.

The technology for sports testing was somewhat primitive prior to the early 1980s. Stimulants, like **amphetamines**, could be detected through reliable tests, but other substances in common use, like anabolic steroids, could not. However, this changed with the introduction of gas chromatography/mass spectrometry (GC/MS) systems, which can accurately analyze most **organic compounds** of the type used in sports doping. Unfortunately, some athletes bent on cheating used GC/MS to their own ends, testing their urine to see how long it took the drugs to leave their system. This enabled athletes to know when to stop taking the drugs before a game or competition where they were likely to be tested. This led to sporting organizations extending testing into the training period, so an athlete could be tested, without warning, at any time. Unfortunately, this too created problems, as some athletes trained in distant locations and could not always be contacted easily to have a test performed.

In the early days of sports testing, organizations did not always appreciate the importance of the **chain of custody** of a sample. Security from tampering and contamination could not necessarily be guaranteed. This led to several successful appeals against "false positives" where an athlete had tested positive for a drug he or she had not in fact taken. Today, many of these logistic problems have been reduced or even eliminated. Athletes competing at high levels are aware of the necessity of testing and are prepared for it, even if they do not all accept it. The **toxicology** laboratories operate more professionally and with a higher degree of scientific accuracy and reliability.

Anabolic steroids are one of the most well known drugs used in sports, both at elite and recreational levels. Related to the male hormone testosterone, anabolic steroids cause muscle growth, increased strength, and sharper reflexes, which is why such drugs have been abused in the context of most Olympic sports as well as team sports. Steroids allow the user to train more often at higher intensity without the risk of injury. However, steroids can damage the user, causing hair loss, impotence, acne, liver damage, heart muscle damage, and aggressive behavior (sometimes known as "steroid rage"). Steroids can readily be detected by GC/MS.

In 2005 the United States Congress tackled the issue of anabolic steroid use in professional baseball when it subpoenaed a panel of former and current all-stars, including former St. Louis Cardinal Mark McGwire—who once held the record for the most home runs hit during a single season—to provide testimony about the frequency of steroid use in the game. The House Committee concluded that officials in charge of baseball have not adequately policed the issue, which resulted in enhanced testing policies, along with increased suspensions and penalties for players who test positive for performance-enhancing drugs. As of April 2005, additional hearings were pending regarding use in other sports, including the National Football League (NFL).

One controversial anabolic steroid is nandralone, which several athletes across the globe have been accused of using. However, some debate exists over testing for the steroid nandrolone. In the body, it is broken down into a substance called 19-norandrosterone (NA) and measurement of levels of this in urine samples is the basis of drug tests. The IOC considers levels of above 2 nanograms/milliliter for men and 5 nanograms/milliliter for women as **evidence** of nandrolone misuse. The number of individuals testing positive for nandrolone appears to have increased in recent years, as the sensitivity of the detection technology has increased. Some athletes claimed false positive results with the new technology. A review found no problem with the testing procedure, but also found a number of reasons why it is at least theoretically possible to test positive for nandrolone without actually taking the banned substance.

The nandrolone test cannot determine the actual source of NA in the urine. Besides coming from knowingly ingested or injected nandrolone, NA can also be produced by the body itself. Self-produced NA levels are not usually above the IOC's limits. There is also some limited evidence that physiological factors, such as vigorous exercise and the stress of injury, might push NA levels into the positive range. Findings against this include a study of 370 male competitors at the 1996 Winter Olympics in Nagano, Japan, which found that none had a concentration of NA above 0.4 nanograms per milliliter.

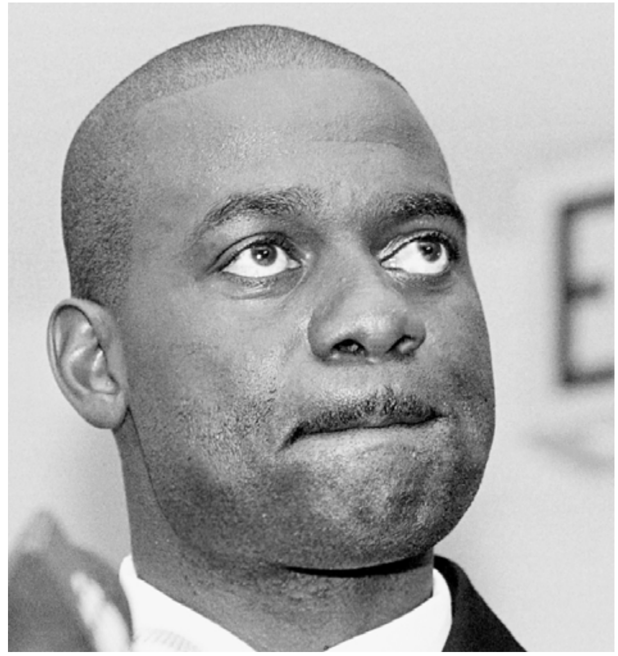
Some herbal and nutritional supplements also contain anabolic steroids, including nandrolone. The labels on such products may be incomplete or incorrect, or the products themselves might be contaminated. It's possible that some athletes are ingesting nandrolone unknowingly with sports supplements (especially if they take more than one supplement at a time). Current rules state that such ignorance is no defense against a drug charge. Testing methods need to be developed so they can properly distinguish the source of NA in urine, another challenge for the forensic toxicologist.

Most of the other drugs in common use are detected by GC/MS. Stimulants like amphetamines increase reaction time and decrease fatigue. They have been used in American football and cycling, but are perhaps less popular than in previous years because they are so readily detected by GC/MS. Beta-blockers are used to reduce trembling and anxiety in sports such as snooker and archery; however, they also have medical uses such as blood pressure control. Diuretics increase the flow of urine and may be abused in sports where weight control is an issue. They have also been used illicitly to help flush other drugs out of the system.

Human growth hormone seems to be increasing in popularity and has similar effects to anabolic steroids. It increases muscle strength and is thought not to have the same side effects as steroids. Growth hormone was historically in short supply, as it had to be extracted from human pituitary glands. It can now be made in a purer form by genetic engineering and it is this recombinant form that many athletes use, despite its expense. A related substance is insulin-like growth factor (IGF-1). Interest in this substance is sure to increase in the wake of **gene** therapy experiments that show how mice injected with the gene for IGF-1 have up to 30% greater muscle strength and muscle mass than ordinary mice. The animals also have better performance in resistance training.

Genetic engineering has also produced a hormone called recombinant erthyropoietin (EPO), which helps the body to produce more red blood cells and increases endurance in sports like running and cycling. The problem with testing for substances like growth hormone, IGF-1, and EPO is that they so closely resemble the natural versions of these molecules produced by the human body, and the need exists for more sophisticated tests. For instance, a separation technique called isoelectric focusing has shown the differences between natural and recombinant EPO, but more research is needed before it can be generally accepted. Such tests are also quite expensive.

Before the recombinant version became available, it was not unknown for athletes to utilize "blood doping," a process in which the athlete would transfuse himself with his own blood (drawn earlier and then stored for later use) or blood donated by another individual. This process increases the number of red blood cells, allowing the athlete's blood to carry more oxygen to the muscles and theoretically increasing performance levels on the day of the competition. This practice (particularly when the athlete's own blood is used) is difficult to detect in the laboratory. Yet recently forensic tests have been used to expose athletes when the blood is donated from someone else. In April 2005 professional cyclist and Olympic gold medal winner Tyler Hamilton was suspended from racing for two years after blood tests indicated the presence of blood doping via transfusion with donated blood. As of May 2005, Hamilton maintained his innocence and asserted his intent to appeal his suspension.



Canadian sprinter Ben Johnson ponders a question at a news conference where he announced the formation of a foundation to teach youth about the evils of drug abuse in sports. Johnson was stripped of his gold medal and 100-meter record after testing positive for steroids at the 1988 Seoul Olympics.

Currently, most sports testing is done on urine rather than blood samples. It is easy to perform a random test on a urine sample and such samples are simple to store and process. The way in which drugs are excreted into urine is also well understood, so results from the test can be related to the athlete's drug-taking behavior. More accurate results, however, could perhaps be obtained from taking blood tests. A urine test gives a quick and easy screen, which can indicate the presence of a drug. The urine test, if necessary, can be followed up by confirmatory blood tests. Replacing urine tests with finger-prick blood tests may give more accurate results, especially for newer substances such as EPO, but athletes may see it as unnecessarily invasive. There is also the risk of exposing laboratory staff to infection from blood-borne disease, albeit this risk may be small. More expertise is also needed for the storage and handling of blood samples.

Many of these same issues arise in another emerging field of forensic toxicology—workplace testing. Increasingly, employers will not tolerate their workforce being under the influence of alcohol or drugs and want to carry out random screening to ensure their requirements are being met. Blood testing could be interpreted as an infringement on the employee's liberty as the purpose is non-medical—as it is in sports testing.

A challenge for forensic toxicology is the use of body **fluids** as a medium for accurate drug testing without being unnecessarily invasive. When it comes to sports testing, there may be even bigger questions to address in the future. For example, what if athletes undergo gene therapy to increase their dose of IGF-1 and so increase their strength and endurance? How will it be possible to determine the presence of new genetic material in the genome? The new ethical questions posed by the issue of fairness in sport can only lead to the development of forensic toxicology as a science.

SEE ALSO Gas chromatograph-mass spectrometer; Toxicology.

Standardization of regulations

Forensic work is performed in laboratories worldwide for criminal casework and development of **DNA** databases. Laboratories often have their own particular methods and protocols for performing their analyses, which may present problems when it comes to the final evaluation of the data by a third party, especially when matters of guilt or innocence are at stake. Laboratories must demonstrate that the results they have obtained are reliable and justifiable in court. For this reason, standardized methods and techniques have been generated by governing forensic bodies in order to provide a common means by which forensic laboratories can work. In addition, particular DNA loci (the locations of selected genes on a **chromosome**) have been chosen that represent the basis for the creation of standard DNA databases. Standardized methods and DNA profile databases have revolutionized the manner in which crimes are solved.

Standards and guidelines are extremely beneficial to forensic laboratories as demonstration of conformity establishes a high level of quality assurance and competence within the laboratory. This is especially important when forensic **evidence** is presented in a court of law where it is subjected to the utmost scrutiny and skepticism. Furthermore, because of the nature of the investigations, most forensic DNA work is processed under strict confidentiality. Utilization of a defined standard protocol minimizes both the need to review confidential records and the potential non-inclusion of evidence where methods have been questioned.

Guidelines and standardized methods utilized by forensic labs are created by several different governing bodies in the forensic industry. For example, the Federal Bureau of Investigation (**FBI**) in the United States, the **European Network of Forensic Science Institutes** (ENFSI), and the International Standards Organization (ISO) are a few of the groups that work to ensure validated methods are followed for forensic analyses. The quality assurance guidelines set forth in documentation provided by the aforementioned groups are composed of a variety of specific requirements.

All forensic laboratories must maintain a documented system in which they demonstrate their level of quality of all components of a standard program. These components include much more than guidelines for scientific data evaluation. Specific guidelines are provided on the organization and management of the lab; **training** level and method of training staff; facilities; control of evidence, including complete documentation of the **chain of custody**; the methods, analysis, and validation process; equipment maintenance; review process; proficiency testing; corrective action; and audits.

Standards for DNA testing are constantly being monitored and reviewed. Within each of the organizations and governing bodies, there is a segment of people or expert working group, who meet specifically to ensure that the level of the standards and guidelines are high in all forensic laboratories. These groups include the Scientific Working Group on DNA Analysis Methods (SWGDAM) of the FBI and the DNA Profile Monitoring Expert Group (DNA MEG) of **Interpol**.

Three major DNA databases exist worldwide, each of which hold and catalogue DNA profiles. Each profile consists of the DNA sequence of a particular set of standard loci. The profiles contained in the databases are based on STRs, or short tandem repeats of DNA sequences that are obtained using **PCR (polymerase chain reaction)** to amplify the specific regions of DNA. Although these loci exist in the same place on the chromosome of all humans, the DNA sequence of the region is highly variable, such that when several are combined together, there is an extremely high probability that a particular combination can only be associated with a single person. These databases are maintained by Interpol (ISSOL), the FBI (**CODIS**), and ENFSI and contain several common loci. The FBI's CODIS database contains the most loci, at 13 per profile.

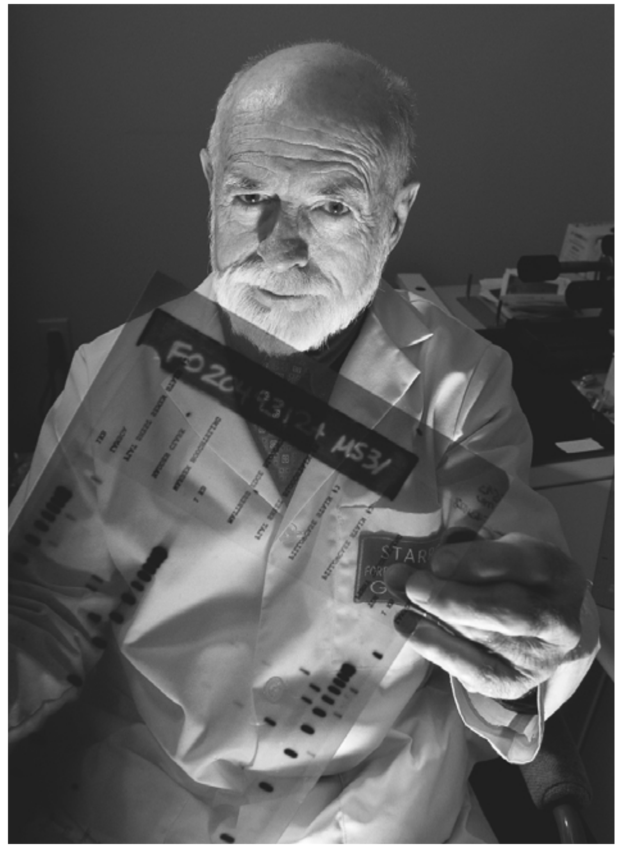
CODIS, ISSOL, and ENFSI databases have greatly increased the ability to solve violent crime on a worldwide level. Because they share loci, it is possible to link offenders to existing samples not only within a single country, but internationally. Two aspects exist to each database, one contains DNA profiles collected from evidence found at crime scenes and the second contains DNA profiles of convicted offenders. Initially, most countries only collected samples from convicted sex offenders or perpetrators of other violent crimes. However, as even small offenders tend toward a pattern of crime, the value of retaining profiles of all convicted offenders has been recognized. Thus, investigators can now compare DNA samples obtained at crime scenes and potentially obtain a match from the offender database.

SEE ALSO CODIS: Combined DNA Index System; DNA; DNA profiling; European Network of Forensic Science Institutes; STR (short tandem repeat) analysis.

James E. Starrs

1930–
AMERICAN
FORENSIC SCIENTIST

James E. Starrs has made significant contributions to the field of **forensic science** as a writer, professor, and investigator. He has taught law and forensic science at George Washington University for more than forty years, and has written many articles and books on his forensic work, including a leading textbook on scientific **evidence**. Starrs is perhaps best known for the numerous scientific investigations he has conducted, on such famous cases as the Boston Strangler, Alfred Packer, Senator Huey Long, CIA agent Frank Olson, Jesse James, and Meriwether Lewis.



Forensic scientist James E. Starrs examines a gel x ray of DNA sequences at a George Washington University laboratory. © RICHARD T. NOWITZ/CORBIS

Starrs, even as a young man, had a keen interest in criminal law, reading many of the Sherlock Holmes mysteries. He earned an undergraduate degree at St. John's University, and a graduate degree at New York University, where he held a Ford Foundation Fellowship. In 1964, Starrs became a faculty member at George Washington University in Washington, D.C. There he has taught both law and forensic sciences, specializing in criminal law and procedure, forensic **pathology**, fingerprinting, document examination, and polygraph use.

In conjunction with his academic career, Starrs has led a number of scientific investigations of famous historic cases. In the Alfred Packer case, he exhumed the bodies of Packer's five traveling companions to determine if Packer was guilty of cannibalism. In the Boston Strangler case, Starrs exhumed the body of the Strangler's last victim to determine if her injuries correlated with Albert DeSalvo's confession. Starrs also worked on identifying the remains of Jesse James, determining the **cause of death** of CIA agent Frank Olson and explorer Meriwether Lewis, and determining the true assassin of Senator Huey Long.

Starrs has also contributed to the literature related to forensic sciences. Together with Andre Moenssens and Fred Inbau, he wrote *Scientific Evidence in Criminal Cases*, a leading textbook on scientific evidence. And in 2005, Starrs and co-author Katherine Ramsland published *A Voice for the Dead: A Forensic Pursuit of the Truth in the Grave*. The book details Starrs' work in body **exhumation**. In addition to the many articles Starrs contributed to **professional publications**, he also edited the *Scientific Sleuthing Review* for more than twenty-five years. In 1996, Starrs became a distinguished fellow of the **American Academy of Forensic Sciences**.

SEE ALSO Careers in forensic science; Exhumation.

Jean Servais Stas

8/21/1813–12/13/1891
BELGIAN
ANALYTICAL CHEMIST

Jean Servais Stas was born in Louvain (Leuven), Belgium. There he studied for a medical career and received his medical degree. After a short time as a physician, Stas turned to analytical chemistry.

In 1837, reportedly after much trouble, Stas gained admission to French chemist Jean Baptiste Dumas' laboratory at the Ecole Polytechnique in Paris in order to continue research on phloridzin (a flavonoid compound found naturally in some foods), which he had begun earlier in an attic in his father's house.

In 1840, Stas left Paris when he was appointed the chair of chemistry at the Ecole Royale Militaire in Brussels. He became a professor and worked assiduously on determining atomic weights (i.e., relative atomic masses), including the atomic weights of oxygen and carbon, with more accuracy than had been previously accomplished. Stas produced the first modern table of atomic weights, using oxygen as a standard (set at number 16). Stas' practice of using the number 16 for oxygen on the periodic table as a reference point would continue well into the twentieth century, when chemists returned to basing atomic masses on carbon-12. In 1920, the English chemist Francis Aston (1877–1945) discovered, by means of the mass **spectrograph**, that all atomic masses (isotopes taken into account) are very nearly integral multiples of the same number, a number now taken to be 1/12 the mass of carbon-12, for which Aston received in 1922 the Nobel Prize in chemistry.

Stas also aimed to prove the hypothesis of English physicist William Prout (1785–1850), a hypothesis independently elaborated by the German Johann Ludwig Georg Meinecke, that all atoms were conglomerations of hydrogen atoms. Instead, Stas' results discredited Prout's hypothesis that all atomic weights are whole numbers, but provided the foundation for the work of Dimitri Mendelejew and others on the periodic system. Though Stas started with a predilection in favor of Prout's hypothesis, he was later led by the results he obtained and by his failure to find any evidence of dissociation in the elements to regard it as a pure illusion, and to look upon the unity of matter as merely an attractive speculation unsupported by proof.

Stas also worked in connection with the poisoning of Count Hippolyte de Bocarmé with nicotine in 1850, working out a method for the detection of the vegetable alkaloids, such as caffeine, quinine, morphine, strychnine, atropine, and opium. These poisons affect the central nervous system. Plant alkaloids leave no demonstrable traces in the human body, thus requiring relatively complicated methods of extraction before an analysis can be performed. Stas searched for three months for the agent, and eventually managed to isolate nicotine from the body tissues. Using ether as a solvent, which he then evaporated to isolate the drug, he found the potent drug that was, in fact, the murder weapon. The man's killer had extracted it from tobacco and force-fed it to the victim. With Stas's testimony, the killer was convicted.

Stas thus became the first person to develop a method to extract material containing plant alkaloids from the organic material of the human body, and for many years thereafter, with some modifications, this method was used as the standard. Other toxicologists then developed qualitative tests with the so-called Stas-Otto procedure to determine the presence of various alkaloids in the obtained extract. With his treatise "Forensic investigation on nicotine" Stas became a founder of modern **toxicology** and a pioneer in industrial pollution.

Stas' interests also included the humanities, and in 1851–52, together with Guillaume Claine, he gave a series of lectures at the Cercle artistique et littÕraire de Bruxelles on daguerreotype and its applications in art.

After more than a quarter of a century, but before he had served the thirty years necessary to secure a pension, Stas was obliged to resign in 1869 because of a malady that affected his speech. He then advised the Belgian government on military issues and was also appointed to a post in connection with the Mint. In 1872 he succeeded in preparing pure platinum and iridium, metals necessary to produce the standard measure. Stas was openly critical of the part played by religion in education. He spent the rest of his life in retirement in Brussels, where he died in 1891.

Jean Servais Stas' name is best known for his determination of the atomic weights of a number of the more important elements. His work in this field was marked by extreme care, and he adopted the most minute precautions to avoid error, with such success that the greatest variation of individual determinations for each element are reported to be from 0.005 to 0.01. Stas was one of the most skillful, chemical analysts of the nineteenth century and his measurements remained the standard of accuracy for over 50 years.

SEE ALSO Isotopic analysis; Medicine; Spectrograph; Toxicology.

State courts (rules of evidence)

The state court system in the United States is a complex one, governed by myriad rules and specified procedures. The United States Constitution confers most of the powers in the country to the states, assigning only quite specific and discrete powers to the federal government. The United States has dual judicial systems, those at the federal level, and those operating at the state level. Within each of those judicial systems there are also civil and criminal courts. Violations of federal law are prosecuted through the federal court system; this occurs only in a discrete number of areas. The vast majority of civil and criminal proceedings related to violations of the law occur at the state level.

Using the 1995 **murder** trial in which the former football star O. J. Simpson was the defendant as an example, Simpson was tried in a state criminal proceeding for the murders of his former wife and her friend. Simpson was also tried for the crime of murder at the state civil level. Although at first glance it appears that he was tried twice for the same crime, which would appear to invoke (or violate) the rule of double jeopardy (a person may not be tried twice for the same crime), because the trials occurred at two different jurisdictional levels, a state criminal trial and a state civil trial, this did not constitute double jeopardy. Simpson was not convicted in the state criminal trial, but was found liable and required to pay monetary damages at the state civil trial.

The reason that O. J. Simpson could be tried twice for the murders of Nicole Brown Simpson and Ronald Goldman is this: the criminal and civil court systems in the United States are completely separate. The two courts have different rules of procedure and separate forms and means of imposing penalties. If an individual is convicted as the result of a criminal trial, there is the possibility of being sentenced to prison; this is not the case in a civil trial. A civil conviction typically results in the assessment of financial damages, and may involve being mandated to perform certain actions, like public speaking about the nature of the crime—as in the case of convictions involving the use of alcohol or illegal substances—or being prohibited from behaving in certain ways, such as being prevented from having contact with the individual that the defendant was accused of battering, for example.

In addition to the rules of evidence, there are a considerable number of other rules governing the means and the methods by which trials are to be conducted at the level of the state court system, whether civil or criminal. There are rules about pleading, which create a framework for the manner in which the claim or charge of the plaintiff must be stated. Discovery, the right to assemble information gathered by either the defense or the prosecution, is constrained by specific rules as to how the evidence is obtained, who has the right to custody of the evidence, the manner in which it is delivered or presented, what constitutes acceptable discovery materials, etc. There is a rule regarding burden of proof; in a criminal trial, there must be proof of the defendant's guilt beyond a reasonable doubt. In a state civil trial law, the burden of proof is lowered and the plaintiff's case need only be proven by the preponderance of evidence. That means there must be more weight in favor of guilt than there is in favor of innocence, in order for a conviction of guilt to occur at the state civil level. In a state criminal trial, the defendant is accorded more rights and protections than at the state civil level. For example, a defendant in a state criminal trial cannot be forced to testify. In the case of O. J. Simpson, he invoked his constitutional right against self-incrimination (saying something oneself that could, to a reasonable observer indicate admission of guilt).

The rule of protection states that a defendant has certain specific legal rights and protections in the case of a trial. In a criminal trial, the defendant is entitled to more safeguards and procedural rights than at the state civil level, because the potential penalties for conviction are much more onerous (burdensome, costly, or oppressive).

Whether the trial is at the criminal or civil level, every party has the right to appeal a conviction. In the case of an acquittal at a criminal trial, there is virtually no right of appeal, as a person may not be tried twice for the same crime in the same court of law. In a civil trial, the party for whom the court finds against (the losing party) has the right to appeal.

Although each state views this rule somewhat differently, and exercises the right to set its own parameters and create its own definitions, most states have laws regarding the speed with which cases must be tried. In the case of a criminal trial, there are generally constraints that it must occur within a reasonable time frame after the occurrence of the crime and the indictment of the defendant.

SEE ALSO Evidence; Evidence, chain of custody; Interrogation; Lindbergh kidnapping and murder; Trials, international.

Statistical interpretation of evidence

Because the **identification** of forensic **evidence** is not always obvious, forensic scientists today do not simply identify evidence but must also interpret it statistically. Such evidence—that is, the ways and means by which disputed facts are proven true or false in a legal setting—comes in many forms. Evidence may be spoken or written by expert or ordinary witnesses, law enforcement officials, or other relevant persons; contained in physical objects obtained from crime scenes, victims, and suspects such as **glass** fragments, fingerprints, and firearm marks; and found in physical materials recovered from forensic examinations such as body **fluids**, paint, **DNA** samples, and drugs. There are many other types of evidence, nearly all of which contain variations (or uncertainties) when measured and compared between the observed or calculated value and the actual value. For example, there is little likelihood (actually as low as one chance in 10^{60}) that **fingerprint** characteristics from one person would match the fingerprints of another person, but there is a greater likelihood (about 34 percent) that if one person has **blood** type A+, then another person has the same blood type.

The statistical interpretation of evidence, often performed by forensic statisticians, involves the evaluation and comparison of evidence found during crime scene examinations and in forensic laboratories, and identified from reference samples of suspects. Such matching of characteristics between crime scene and suspect evidence relies on the theory of probability, the branch of mathematics that deals with determining quantitatively the frequency of occurrence of an event. For example, if a coin is flipped 100 times, it is theoretically expected to land as heads 50 times and tails 50 times. Within probability, various statistical models and techniques—such as Bayes' Theorem, deductive and inductive reasoning, graphical modeling, grouping, likelihood ratios, distributions, samplings, and significance tests—are used to help forensic scientists correctly evaluate and accurately interpret evidence that contain elements of uncertainty. For example, a suspect may be identified because a rare blood type (AB−) found at the crime scene matches the suspect's own blood type, which only about one percent of the U.S. population carries.

Although used in both the nineteenth and twentieth centuries, the application of statistics to interpret evidence became especially important during the 1980s when **DNA profiling** first became popular. During those subsequent years, there was doubt within the legal community as to the reliability of such methods and to the appropriateness of the (often) simplistic calculations involved. Eventually, the use of statistics for interpreting evidence brought a positive change in the way quantitative data was viewed from a legal standpoint. Presently, the legal community continues to ask the **forensic science** community for more and better statistics to interpret evidence in order to prove the innocence or guilt of suspected criminals.

Statistics, however, can hinder the solvability of crime when performed improperly. When subjective assessment is introduced—that is, biased evaluations or those based on personal opinion—inaccurate conclusions can be made when comparing evidence characteristics. Subjective qualifiers, such as *high chance* for guilt when used by the prosecution (for example), and as *low chance*, by the defense, can often lead to angry and unproductive legal debates as to whether to implicate or exonerate a suspect. As an example of biased statistical interpretation, if a suspect has a five percent chance of possessing a particular trait in order to be deemed innocent of a crime, then the prosecution could state that the suspect has a 95% chance of being guilty (often called the prosecutor's fallacy), while the defense would simply compute five percent of the population (say one million) to be innocent and declare there is a 1 in 50,000 chance of guilt. Therefore, objective assessment, or the unbiased interpretation of the evidence, is preferred because it requires the rational and sound application of statistics to accurately interpret the uncertainties of evidence.

Although the choice of the statistical method is a subjective one, once it is chosen, different forensic experts with identical data and the same statistical method will produce (theoretically) the same assessment and make the same interpretation of the evidence. Of course, there is still controversy about the assumptions underlying the choice of the method used and the interpretations made thereafter. Debate also exists as to how often statistics are misinterpreted or overvalued as evidence. Although the field of statistics seems to have the potential for uniformity, clarity, and impartiality, it is still in the embryonic stage of development within forensic science. Because of its immature nature there are still risks of misuse by forensic examiners, law enforcement officers, courtroom lawyers, judges, and juries. Incorrect statistical use of evidence still leads to problems such as unnecessary forensic tests, unwarranted appeals against court rulings, and even miscarriages of justice.

In order to make a correct assessment of all the variations within a particular case and to present the information in the most understandable way possible, forensic statisticians need a well-rounded knowledge of both the theory and the application of statistics to forensic evidence. Statisticians must be able to evaluate rationally both subjective opinions and objective analyses in order to check, criticize, and verify all the evidence. For the field of statistics to be successfully applied to the interpretation of evidence, it must be appropriately applied, unbiased in analyses and presentation, and intelligible to the people involved in all phases of the forensic investigation and legal proceedings.

SEE ALSO Forensic science; Quality control of forensic evidence; Uncertainty analysis in forensic science.

Steganography

Forensic **evidence** ranges from the readily evident (i.e., stab or gunshot wound) to the harder to detect (i.e., **trace evidence**) to the invisible or disguised. Whether apparent or not, all evidence is potentially valuable in tracing the course of events of an accident, illness, or crime, and in personal **identification**. Disguised or hidden evidence can be physical or, in the case of **computer forensics**, electronic. An example of the latter is steganography.

Steganography (from the Greek for "covered writing") is the secret transmission of a message. It is distinct from encryption, because the goal of encryption is to make a message difficult to read, while the goal of steganography is to make a message altogether invisible. A steganographic message may also be an encrypted as an extra barrier to interception, but need not be. Steganography has the advantage that even a talented code-cracker cannot decipher a message without knowing it is there.

Steganography has been used since ancient times; Greek historian Herodotus records how one plotter of a revolt communicated secretly with another by shaving a slave's head, writing on his scalp, letting his hair grow back, and sending the slave as an apparently unencumbered messenger. The number of ways a steganographic message might be sent is limited only by human ingenuity. A photograph of a large group of people, for example, might contain a Morse-code message in the expressions of the people in the photograph (e.g., smiling for dot, blank for dash) or in the directions they are looking (e.g., slightly to the left for dot, straight at the camera for dash). Writing in invisible ink or miniaturizing a message, as on microfilm, are also forms of steganography. Probably the commonest form of steganography involves the embedding of messages in apparently innocent texts, with the letters or words of the message indicated either by subtle graphic emphasis (e.g., heavier ink, lighter ink, a small defect) or by special positioning. For instance, reading the first word of every sentence in what appears to be an ordinary letter might yield a steganographic message.

Like most other forms of cryptography and **secret writing**, steganography has thrived in the digital era. Most digital documents contain useless or insignificant areas of data, or involve enough redundancy that some of their information can be altered without obvious effect. For instance, one might conceal a message bitstream inside a digital audio file by replacing the least-significant bit of every waveform sample (or every *n*th waveform sample) with a message bit; the only effect on the file, if played back as audio, would be a slight, and probably unnoticeable, decrease in the sound quality. Although steganographic messages can be hidden in any kind of digital files, image files, because they contain so much data to begin with, are usually used for digital steganography. Today a number of commercial or shareware programs exist for encoding text into steganographic images, called stego-images), and are used by millions of people worldwide who wish to evade surveillance.

Steganography is also used for *watermarking*, which is the hiding of information indicating ownership or origin inside a digital file. (Physical watermarking, the practice after which digital watermarking is named, is the impression of a subtle pattern on paper using water. A watermark is only visible when the paper is held up to a light.) Watermarking can be used by forensic investigators for digital authentication (i.e., to prove that certain party was indeed the source of a file) or to check whether a digital file was obtained in violation of copyright.

SEE ALSO Codes and ciphers; Computer forensics.

Stimulants SEE Amphetamines

Mark Stolorow

4/28/1946–
AMERICAN
FORENSIC SEROLOGIST

From about the last quarter of the twentieth century to the present, Mark D. Stolorow has provided extensive experience as both a forensic serologist and a forensic laboratory administrator. Because of these qualifications, Stolorow serves as an expert witness in numerous court cases involving **forensic science**. Earlier in his professional career, Stolorow was credited, along with **Brian Wraxall**, with developing the **multisystem method** for simultaneously testing isoenzyme systems in 1978. That same year, Stolorow and Wraxall were also recognized as being the first to develop methods for typing **blood serum** proteins. Today, Stolorow is the executive director of Orchid Cellmark, an internationally recognized leader in providing forensic **DNA** analytical services to law enforcement agencies, lawyers, detectives and investigators, companies, and individuals, and in developing new methods to use DNA testing.

Stolorow gained his bachelor's of science degree from the University of Michigan and his master's of science degree in forensic chemistry from the University of Pittsburgh. He also earned his master's of business administration degree in management from Eastern Michigan University. After graduation, Stolorow was employed as a **training** coordinator for the state forensic **serology** program in Illinois. Later, he was the research program administrator at the Bureau of Forensic Sciences for the Illinois State Police.

After working with the Illinois Police, Stolorow joined Cellmark Diagnostics—a subsidiary of Lifecodes Corporation—as a general manager. When Orchid Biosciences acquired Cellmark Diagnostics in December 2001, Stolorow became the executive director of Orchid Cellmark, located in Germantown, Maryland, the forensic strategic business unit. Stolorow has the responsibility of directing Orchid Cellmark's international network of forensic testing laboratories, which are based in England and the United States. Stolorow and his employees have worked with many of the major U.S. police departments in such cities as New York City, Chicago, and Houston. They have also helped many international law enforcement agencies, including Scotland Yard and the Metropolitan Police Service in London, England. Stolorow has helped to build Orchid Cellmark into the largest independent supplier of DNA analysis services to English police departments, the world's leading country in forensic DNA testing.

Along with fellow Orchid forensic scientists, Stolorow has played important roles in conducting DNA testing for such high-profile cases as the 1995 criminal investigation of O.J. Simpson for the murders of Nicole Brown Simpson and Ronald Goldman; the 1998 **murder** trial of Theodore Kaczynski (the Unabomber); the 1996 murder case of JonBenet Ramsey in Boulder, Colorado; the 2002 trial of David Westerfield, the murderer/kidnapper of Danielle van Dam of San Diego, California; and the 1982–1984 homicide investigation and serial murder trial of Gary Ridgway (Green River murderer) near Seattle, Washington. In fact, Stolorow presented the DNA **evidence** from the O.J. Simpson case to representatives of the Smithsonian Institute in Washington, D.C., because the case heralded the importance of DNA evidence in crime investigations and courtroom proceedings.

For the **identification** of the 9–11 victims at the World Trade Center in New York City, traditional DNA methods often failed because the crucial genetic materials had been severely degraded by compressed **building materials**, bacterial contamination, high temperatures, and water. Fortunately, Stolorow was able to coordinate the development of innovative technologies that were able to overcome these difficulties. This new forensic technology—called single nucleotide polymorphism (SNP) markers—helped to identify the damaged DNA material found at the disaster site. By using SNP technology, Stolorow and the Orchid scientists were able to identify many more victims that were previously unidentified. Because of their pioneering SNP work with large-scale forensic DNA analysis, Stolorow and his team of scientists are exploring further uses of SNP tests in other difficult medical and scientific cases.

In 2003, Stolorow launched the DNA Express Service, a premium forensic DNA testing service by Orchid Cellmark that is used to help local U.S. law enforcement agencies analyze the estimated 500,000 backlogged cases of DNA evidence from unsolved "no-suspect" and other criminal crimes. Stolorow and his team of forensic scientists deliver DNA results in five business days as compared to the standard four to five weeks for routine casework. In the future, Stolorow intends to make DNA Express Service a key resource for providing quick, but accurate, DNA analysis of criminal cases.

Stolorow is also involved in providing increased DNA testing services that became available when the new law Justice for All Act of 2004 was signed by President George W. Bush. The legislation is providing about $1 billion between 2004 and 2009 in order to eliminate the backlog of unanalyzed DNA evidence in police departments across the country and to expand the FBI's Combined DNA Index System (**CODIS**). Stolorow is guiding Orchid Cellmark as a key partner with law enforcement organizations by reducing the DNA backlog, increasing the use of forensic testing, and adding more criminal information to the federal

CODIS database. Stolorow has already coordinated Orchid Cellmark's work to implement Biotracks, a pilot program with the New York Police Department to solve burglaries by matching DNA crime samples to DNA databases of convicted criminals.

SEE ALSO American Academy of Forensic Sciences; DNA; DNA recognition instruments; DNA sequences, unique; Genetic code; Multisystem method; September 11, 2001, terrorist attacks (forensic investigations of); Simpson (O. J.) murder trial; Unabomber case and trial; September 11, 2001, terrorist attacks (forensic investigations of).

STR (short tandem repeat) analysis

Short tandem repeats (STR) are, as the name suggests, very short stretches of **DNA** that are repeated back to back in various locations throughout the human genome. Typically, the repeating sequence is just two, three, or four base pairs in length, and the number of copies found back to back is variable across a wide range. Unlike the DNA sequences in coding genes, there is no "correct" number of repeats for any specific STR in the genome; they are simply areas within the genome where variation is normal and healthy. For any specific STR, each person will have two copies, one that is inherited from their mother at conception, and the other that is inherited from their father.

STRs are helpful in forensic and paternity testing. Because there is a lot of natural variation for STRs, the chance of two people matching for the exact number of repeats on both inherited copies of the STR is fairly small. By combining analysis of many STRs across the genome, the probability of two people matching by random chance is extremely low.

For example, if the normal variation for certain STR (we will call it STR-A) is from seven to twenty copies, there will be fourteen different lengths that could be passed on from either parent. Since each person has two copies of STR-A, the total number of possible combinations would be 196 (14 x 14). If each of these different STR lengths had an equally probability (1/14), and every possible combination was equally likely, the chance of two people matching on the pattern of STR-A would be 1/196. Now, suppose that there are many other STRs available for study (eg., STR-B, STR-C, STR-D ... STR-Z) each with the same probabilities we chose for STR-A. The likelihood of matching by random chance alone across these many markers would be found by multiplying the probabilities of each one individually. For two markers, the probability of a random chance match drops to 1/38,416. Adding a third marker drops the probability to 1/7,529,536. The addition of a fourth marker decreases the likelihood to less than one in 14 billion.

The discovery of STRs has greatly advanced **forensic science** by drastically reducing the chances that a suspect will be wrongly identified on the basis of forensic testing.

SEE ALSO DNA fingerprint; DNA profiling; DNA sequences, unique.

Sublimation

Sublimation is the term that describes the change of state of a material from a frozen form to a gas or visa versa. In sublimation, there is no intermediate liquid phase.

A well-known example of sublimation occurs with dry ice, the frozen form of carbon dioxide. When exposed to air, dry ice changes directly to vapor, which is visible as a cloud immediately above the frozen CO_2. In the case of dry ice, the frozen CO_2 is energetically more stable as a gas at room temperature than as the frozen solid.

The gaseous tail that develops behind a comet as it approaches the sun is another example of sublimation. Frost and snowflakes are products of a reverse path of sublimation, where water changes directly from the gaseous state to the solid state.

Sublimation has practical applications in **forensic science**. Forensic analysis of a crime or accident scene often relies on the examination of photographic **evidence** after the scene has been cleaned. A dye-sublimation printer enables digital pictures to be rendered in print form in a very realistic and detailed fashion, which helps investigators in their analysis.

The basis of a dye-sublimation printer is the vaporization of various colored dyes housed in the printer. The vaporized dyes penetrate the glossy surface of the photographic paper before returning to their solid form. The vapor-to-solid dye sublimation creates a gentle gradation at the edge of each pixel of color, rather than a sudden border between the dye and the paper (as is the case with inkjet type printers). The result is a more realistic image that yields more detail.

Dye sublimation is also used to create digital watermarks on documents. This enables a forensic examiner to differentiate an authentic document from a forgery.

Sublimation can be important in the recovery of compounds that are suspended or dissolved in a fluid or a solid like dry ice. The compounds can be recovered, at least in crude form, by allowing the suspending matrix to sublimate away. This method of recovery is usually gentle, which is advantageous in preserving the chemical structure or even activity of the target drug (i.e., cocaine) or enzyme. Many compounds will sublimate when heated. The effective temperature can be characteristic of the compound and can be measured in a forensic laboratory inexpensively, using a common hot plate.

SEE ALSO Analytical instrumentation; Exothermic reactions.

Suicide investigation

When the medical examiner (ME) is faced with an unexplained death, he or she has to determine whether the manner of death is natural, accidental, homicidal, or suicidal. The first involves disease, the other three manners involve some form of physical trauma. In a suicide, trauma is inflicted by the victim on himself. Gunshot wounds, jumping from a great height, hanging, and drug overdose are common causes of suicide. However, such deaths can also be caused by homicide or accident. In the case of a shooting, it can sometimes be obvious from the **autopsy** whether or not the death was likely to be a suicide. With a drug overdose, however, the autopsy findings are the same whatever the victim's intent, and the investigator must look carefully at the circumstances to arrive at the correct verdict. If the investigator comes to the wrong conclusion, a killer may either escape or be unjustly convicted. Suicide is always traumatic for those left behind. If an accident or homicide is wrongly ruled as a suicide, then the family of the deceased is caused unnecessary grief. In other words, suicide investigations must be undertaken with great care, because some cases are complicated.

Poisoning remains the most common method of suicide, especially among women. It is perceived as being less traumatic than other methods and with the widespread availability of alcohol and drugs, the means are easy to obtain. However, poisoning is also often accidental, especially if the victim is confused, which may happen if they have been drinking or ill, for example. Under these circumstances the victim may mistakenly take too many sleeping pills or painkillers. Poisoning could also be a homicidal act. Although **murder** by poisoning today is somewhat less common than in previous centuries, the pathologist should never rule out the possibility.

The suicidal use of corrosive agents such as acid or weed killer has decreased dramatically in recent years, perhaps because such chemicals are now less readily available than they used to be. Cyanide is a deadly poison that often features in books or films about murder and suicide. However, cyanide poisoning is not very common these days, especially as a tool of homicide. Cyanide turns to lethal hydrogen cyanide gas on contact with the acid of the stomach. Hydrogen cyanide prevents the body's cells from using oxygen; this gives the **blood** a characteristic pink color that will be evident to the pathologist on autopsy. The victim's face is often a brick-red hue after cyanide poisoning.

Aspirin and **barbiturates** are also less likely to be used as suicidal agents than previously. Doctors rarely prescribe barbiturates these days, but various other prescription and over-the-counter drugs can be equally lethal. There has been an increase in self-poisoning with antidepressants and acetaminophen. Moves to restrict the amount of some over-the-counter drugs purchased at one time have deterred some impulsive suicides. However, the person who is bent on suicide will merely collect up enough pills to commit the act.

It is not uncommon for a "cocktail" of drugs to be taken in suicide. The pathologist must take samples from blood, urine, and various body tissues and then has the difficult task of trying to work out what contribution each component of the cocktail made to the death. The presence of a suicide note at the scene of a poisoning (or other suicide) may be taken as an indication of suicide rather than an accident. However, the absence of a note does not mean the act was necessarily accidental. Some people simply do not leave a note, perhaps to protect the feelings of loved ones by trying to make the act look accidental. Moreover, forged notes may be used to help stage a homicide as a suicide. As ever, all the **evidence** must be carefully assessed to arrive at the truth.

Carbon monoxide poisoning accounts for many suicides, the classic method being to sit in a car with the engine running in a closed garage. Under such circumstances, it may take only a few minutes for a lethal level of carbon monoxide to build up in

The body of actress Marilyn Monroe is removed to the morgue on a stretcher by a police officer in 1962. Forensic scientists later ruled her death a suicide. © BETTMANN/CORBIS

the atmosphere. Carbon monoxide poisoning is relatively easy to diagnose on autopsy. Carbon monoxide gas interacts with **hemoglobin** in blood to produce a characteristic cherry red color. The skin and internal organs are all pink in color and analysis of the blood will show a high concentration of the gas. However, accidental carbon monoxide poisoning is also a possibility; many cases have occurred in dwellings with faulty gas appliances and heating systems.

Hangings are nearly always suicidal in adults and teenagers, though usually accidental among children. Commonly the **mechanism of death** in hanging is asphyxiation from compression of the carotid arteries and the airways due to the pressure of the ligature. However, if the body drops through a height on hanging, death may be from cardiac arrest from pressure on the vagus nerve in the neck. The **medical examiner** must distinguish between hanging and asphyxiation caused by other means such as manual strangulation and smothering. Neck marks are common, but may not be present if a soft material like a scarf or a sheet has been used. The marks run diagonally across the neck in a hanging, but are horizontal after manual strangulation. **Toxicology** testing for drugs or alcohol plays an important role in the investigation of a hanging. A suicidal victim may take drugs to get up courage to perform the act; a murder victim may be subdued or made unconscious in the case of a homicide. Homicidal hanging of a fully conscious able-bodied person is virtually impossible. Suicidal strangulation by a ligature is rare, but not impossible, and must be considered when a victim has been strangled. It takes 15 seconds or so to lose consciousness in strangulation, which allows the victim time to loop or knot a ligature around their neck. Another form of suicidal asphyxiation is smothering, where the victim places a plastic bag over the head, securing it in place with tape or a rope. In such cases, the face is often pale and does not exhibit the congestion or protruding tongue seen in strangulation.

When a body is found in water, the pathologist must consider the possibility of suicide, although most drownings, if this is the **cause of death**, are accidental. If the person is weighted down, perhaps by clutching stones or rocks or having them in their pockets, then this may indicate suicide.

Deciding whether a shooting was suicide, homicide, or an accident can be a major issue for the medical examiner. In the case of a suicide, the gunshot wound, or wounds, must be found in a site on the body consistent with the range of the deceased's arm. These wound sites often depend on the type of weapon that is used. Long-barreled weapons such as rifles and short-barreled weapons, like handguns, can both be used to inflict injuries inside the mouth, under the chin, on the front of the neck, and the center of the forehead, all of which will readily inflict a fatal wound to the brain. The classic discharge to the temple is found only with a handgun and the wound will be on the same side of the head as the dominant hand of the victim. A left-handed person cannot readily shoot himself in the right temple.

People rarely shoot themselves in the eye or abdomen. It is also virtually impossible to shoot yourself in the back. Women rarely shoot themselves, either intentionally or by accident. Multiple gunshot wounds are nearly always the result of homicide, although they are not unknown in suicide.

In a suicidal shooting, the weapon must be found at the scene. It may, however, be at some distance from the body because the recoil of the weapon on shooting can fling it away from the victim. If no weapon is found, homicide is the most likely verdict unless someone has been interfering with the scene of the crime and removed the gun. However, investigators must always be alert to the possibility of the staging of a homicide to look like a suicide by placing the gun by the side of the body. In short, deciding the manner of death in a shooting can be difficult, and it is important to consider all the evidence relating to the investigation.

Some railways deaths are suicides. People may lie on the track with their neck across a rail, which results in decapitation. Jumping in front of a moving train is a relatively common form of suicide. The injuries caused depend upon the exact events and are usually extensive. However, some victims do survive jumping in front of a train. It is important to distinguish between homicide and suicide in railway injuries, because it is not unknown for people to be pushed in front of moving trains. Similarly, a homicide may be staged as a suicide by placing a body on a railway track. In such cases, the pathologist may see evidence of injuries that may have been inflicted before the impact of the train on the body.

These are some of the most common methods of suicide, but suicide needs to be considered as a possible manner of death in many cases referred to the medical examiner. Often it is not possible to distinguish between accident and suicide on the evidence given, in which case an open verdict may reasonably be given.

SEE ALSO Death, cause of; Death, mechanism of.

Superglue® fuming

Superglue® fuming, also known as cyanoacrylate fuming, is one of the processes used to chemically enhance fingerprints on smooth or nonporous surfaces. When an object is subjected to superglue fuming, fingerprints that are present on its nonporous parts will appear in white. Further dying is possible, increasing the contrast with the background. This technique is one of the most used **fingerprint** enhancement techniques and has a paramount role in forensic sciences. It allows the observation of fingerprints that would not otherwise be detected. It was first used in 1978 by the Criminal Identification Division of the Japanese National Police Agency.

Superglues are monomeric liquids of cyanoacrylate esters. They are also known as high-strength or rapid glues. When vaporized, the cyanoacrylate ester vapors will selectively polymerize on the secretions left by fingerprints on nonporous surfaces. The resulting hard, white polycyanoacrylate coating covers the fingerprint pattern. This provides the forensic scientist with a first enhancement of the contrast of the fingerprint to the surface. If this enhancement is not enough, it is then possible, after allowing the fingerprint to dry for a moment, to apply different dyes selectively on the polymerized glue. Some of these dyes are also fluorescent (light-emitting) at given wavelengths, which greatly improves the contrast to the background.

In order to process an object for fingerprints with Superglue® fuming, the object is placed in a small chamber. The humidity inside the chamber is important, and a relative humidity of 80% is recommended; air that is too dry provides poor results. The Superglue® is placed on a hot plate and heated to about 212°F (100°C). The surfaces of the object are monitored, and the process is stopped as soon as the fingerprints appear with enough contrast. Many crime laboratories use a homemade unit, comprised of a recycled fish tank, a beaker with water, a small fan to produce humidity, and a modified soldering iron to vaporize the Superglue®. Over time, some companies have developed units specially designed for this process that allow for more accurate control of the humidity, temperature of vaporization, and vapor circulation. Different portable systems have also been developed for field work, and some police agencies have built big chambers to accommodate vehicles.

SEE ALSO Alternate light source analysis; Fingerprint; Fluorescence.

Superior SEE Anatomical nomenclature

Supreme court rulings SEE U.S. Supreme Court (rulings on forensic evidence)

Systematics

In its broadest sense, systematics is where nomenclature and taxonomy intersect. Nomenclature is the assignment of accurate names to taxa. A single group is called a taxon; multiple groups are called taxa; the study of taxa is called taxonomy. Taxonomy refers to the scientific method of classifying and organizing living organisms into specific groups according to their phylogenetic relationships. Phylogeny is the study of the evolutionary relationships occurring among living organisms. Classification is the process of putting organisms together into categories based on their relationships to one another.

Carolus Linnaeus (1701–1778), a Swedish scientist and explorer, is considered the originator of the concept of systematics. He created enormous classifications of plants and animals, and published them as *Species Plantarum* (1753) and *Systema Naturae* (tenth edition published in 1758). In the nineteenth century (1800s), those reference volumes were used as the starting point for the modern systems of botanical and zoological nomenclature. One of the reasons that Linnaeus's work was so widely adopted was his use of simple and logical terminology. Another was his hierarchical framework for grouping organisms. (That is, a system in which organisms, such as plants or animals, are grouped in progressive order, from lowest to highest. This was generally done from least complex to most complex.) And finally his use of binomial nomenclature, in which two-word names, consisting of a generic name and a descriptor, were created in combinations which were unique to a specific species. His naming system was based on observed physical similarities and differences between organisms; he called these "characters."

Systematics has developed into the science both of the diversity of living organisms and of their interrelationships. As conceptualized today, the biological science of phylogenetic systematics seeks to develop novel theories and means for classification that transcend the concepts of taxonomy, and consider not only the similarity of characteristics but also evolutionary processes that result in changes in the original **gene** pool. The English naturalist Charles Darwin (1809–1882) was the first scientist to state that systematic hierarchy should reflect similarities and differences in evolutionary history. In the 1950s, a German scientist named Willi Henning suggested the system that has come to be known as phylogenetic systematics; he reasoned that classification of organisms should closely reflect the evolutionary history of specific genetic lines.

On a molecular level and relative to **forensic science**, every organism has a genome that includes all of the biological materials necessary to replicate itself. The genome's information is encoded in the nucleotide sequence of **DNA** and RNA molecules and is subdivided into units called genes. The Human Genome Project, begun in 1990, was designed to identify each gene in human DNA (estimated to be between 20,000 and 25,000), to classify the sequences of chemical base pairs that make up human DNA (about 3 billion), and to store all of this information in a database. From a forensic science standpoint, the more specifically one can classify living organisms, and the more discretely it is possible to map an individual's DNA, the more accurately it will be possible to match a perpetrator to a crime victim or a crime scene.

SEE ALSO DNA databanks; DNA sequences, unique; Reference sample.

T

Tabun

Tabun (or "GA") is one of a group of synthetic chemicals that were developed in Germany during the 1930s and 1940s. (Tabun was developed in 1936.) The original intent of these compounds, including tabun, was to control insects. These pesticides were similar to organophosphates (pesticides that contain phosphorus and act as nerve poisons on most animals) in their action on the nervous system. However, tabun and the other human-made nerve agents proved to be much more potent than the organophosphates, and so quickly became attractive as chemical weapons.

Tabun is one of the G-type nerve agents, along with sarin and soman. They are all clear, colorless, and tasteless. As a result, tabun mixes readily with water, and so can be used as a water-poisoning agent. Food can also be contaminated. The fluid form of tabun can also be absorbed through the skin.

When in water, tabun loses its potency relatively quickly, compared to airborne vapors, which can remain potent for a few days. The vapors can even bind to clothing, where they will subsequently be released for 30 minutes or so. People close to the contaminated person can themselves be affected by the vapor. Tabun vapors tend to be denser than air and so settle into low-lying depressions or valleys. People in such regions are especially susceptible.

Like the other members of the G series, tabun is a nerve agent. Specifically, it inhibits an enzyme called cholinesterase. This enzyme breaks apart a compound that acts as a communication bridge between adjacent nerve cells. Normally, the transient formation and destruction of the bridge allows a control over the transmission of nerve impulses. But, the permanent presence of the bridging compound means that nerves "fire" constantly, which causes muscles to tire and eventually stop functioning. In the case of the lungs, this can be fatal.

Symptoms of tabun poisoning, which can begin within minutes of exposure, include runny nose, watery and painful eyes, drooling, excessive sweating, rapid breathing, heart beat abnormalities, and, in severe cases, convulsions, paralysis, and even fatal respiratory failure.

Treatment for the inhalation of tabun consists of three timed injections of a nerve agent antidote such as atropine. Since this may or may not be successful, prevention remains the most prudent strategy. Protective clothing including a gas mask is a wise precaution for forensic investigators who are in an environment where the deployment of tabun is suspected.

SEE ALSO Chemical warfare; Sarin gas.

Tape analysis

One useful tool in the arsenal of a forensic investigator are tapes of telephone conversations and other recordings. These analyses can help determine the identity of the caller and, from background noises, can provide clues as to the location of the call.

Tape analysis of a voice can produce what is known as a voiceprint. Like a fingerprint, a voiceprint can be a unique identifier. A voiceprint relies on anatomical features of the speaker. The dimensions of the vocal cavities including the throat, nose, and mouth, and the length and diameter of the vocal cords are influential acoustic factors in producing a voice whose characteristics are unique to the individual. The chance that more than one person will display the exact voice pattern is very remote.

As well, the interplay of the lips, teeth, tongue, soft palate, and jaw muscles produces intelligible speech, and can also introduce aspects of speech such as a lisp that can help in **identification**. Analysis of the timing and the pitch of the voice can also unearth distinctive intonations.

Tapes can be analyzed to produce a spectrographic pattern of the speech. The aforementioned aspects contribute to this pattern. Attempts to deliberately disguise speech such as whispering, raising or lowering the pitch of the voice, and speaking with an accent, are easily recognized. A suspect may be asked to read a sentence or words in a voice similar to the deliberately altered voice, so as to produce a comparable voice pattern of the two messages. Even the electronic alteration of a voice can be dealt with, since the natural wave form pattern will still be discernable spectrographically, even if the voice is unintelligible to the ear.

Tape analysis is a commonly used facet of law enforcement investigations. Some cases are more famous than others, however. For example, tape analysis of speeches purported to be from the Saudi-born terrorist Osama bin Laden have been carried out to help determine the authenticity of the speaker. Analysis compared the computer-generated wave patterns of the taped voice with other tapes known to be the voice of bin Laden. In particular, common words such as “America” are compared from the different tapes to see if the voice wave patterns are similar or distinct from each other.

While the quality of the recording tape and the acoustics of the room the recording was made in can detract from the analysis, tape analyses of various recordings purported to be from bin Laden as recently as 2004 have concluded that he is the speaker.

SEE ALSO Linguistics, forensic stylistics; Telephone recording system; Voice alteration, electronic; Voice analysis.

Taphonomy

Taphonomy, from the Greek, *taphos*, meaning tomb or grave, and *nomy*, meaning classification, is a field of paleontology, paleo-anthropology, and bioarcheology that studies human and animal remains in relation to the post-mortem (after death) transformations that occur in burial sites. In a broader sense, taphonomy is the study of the processes that leads to fossilization, as well as the stages of transformation of remains through the action of environmental factors. The knowledge gathered by this field is important to **forensic science** as a tool for the analysis of human remains at old crime scenes, mass graves, and mass disaster areas.

Osteology (or the study of bones), geochemistry, and **entomology** (the study of insects) are important aspects of taphonomy, as skeletons and skeletal fragments may yield information on the living conditions, availability of food, presence of infections, wear and tear of specific joints due to repetitive effort, size of muscles, and post-mortem events. Therefore, a scenario of living organism versus environmental characteristics may be inferred from such analysis as well as which forces and agents have acted over the remains after death. When the organism dies and is buried or covered by sedimentary layers of soil, such as clay, sand, volcanic ash, or ice, the taphonomic process of post-mortem transformations begins, which can lead to different types of mummification, **decomposition**, or skeletonization. If the conditions are right, skeletal fossilization will eventually occur. Bones can also be modified by animal scavenging, or be carried by rivers and scattered on riverbanks far from the original site of death before fossilization occurs.

Taphonomy studies three different stages of post-mortem transformation: necrology, biostratinomy, and diagenesis. Necrology refers to the factors present around the **time of death** or directly associated with the **cause of death**. Necrologic studies could include examination of bones or bodies for **skull** fractures, marks of fangs or claws in bones, signs of malnutrition, abscesses, infections, lesions by blunt instruments, bullets, or incineration, among other clues to the cause and events surrounding death. Biostratinomy identifies the changes that occurred after death such as decomposition and changes due to environmental forces acting in burial sites (tombs, graveyards, mass graves), or in places where remains were left or found, such as river or lake bottoms, sedimentary **soils**, or woods. Several events from this stage may leave their marks on the remains, such as animal scavenging, enzymatic and bacterial activity, insect activity, and transportation by water or landslides. Eventually, some bone fragments or entire skeletons may be buried under conditions that favor diagenesis, the process of lithification (compaction) of the sediments that envelop the remains, ultimately resulting in fossilized bones. Fossilization may occur in terrestrial (earth) and maritime (water) environments, and give clues to researchers about the environmental, geological, topographical, and climatic changes that occurred on Earth throughout the process of fossilization. The study of submarine layers of fossilized marine animals and crustaceans, for instance, allows the description of radical climate changes that occurred in different geological eras.

Forensic taphonomy focuses on the perimortem (at the time of death) and intermediate postmortem (days to weeks after death) biological and biochemical transformations in order to determine the cause of death, estimate the approximate time of death, and to identify humans remains including the sex, age, race, and, whenever possible, the individual's identity. The understanding of how different environments interfere with the biological and biochemical changes in human remains, affecting the process of decomposition, is crucial for the forensic interpretation of mass graves, mass disasters, war crimes, and cold cases of **murder**.

SEE ALSO Animal evidence; Anthropology; Body Farm; Death, cause of; Decomposition; Entomology; Exhumation; Geology; Medical examiner; Mummies; Osteology and skeletal radiology; Pathology; Skeletal analysis; War forensics.

Taser

A Taser is a type of gun. It is similar in appearance to a conventional gun, having a handle, squeezable trigger, and a blunt barrel. Instead of firing bullets, however, a Taser incapacitates someone for a short time by the use of electricity. Tasers are most often used by security forces, including police, to quell disturbances without causing injury to the people involved.

The Taser gun is one of three types of weapons that are known collectively as stun guns. The other two devices are known as the hand held stun gun and the liquid stun gun. As their name implies, these weapons are designed to be a non-lethal defense, rather than an offensive weapon capable of causing deadly injury.

Stun guns like the Taser operate by disrupting the electrical flow of signals through nerve cells. This electrical flow drives the ability of the muscles to respond to commands from the brain, and allows information that the body receives from the outside world (i.e., touch, taste, smell) to be communicated to the brain. The disruption of the nerve cells is achieved by the generation of an electrical charge by the Taser that has a high voltage and low amperage. Put another way, the electrical charge has a great deal of pressure, but is not intense. The pressure of the charge allows the charge to penetrate into the body, even through several layers of clothing. In order for it to be effective, the person must be close, even in direct contact, with the electrodes of the Taser. Because the electrical charge is not intense, the brief surge of electricity is not powerful enough to physically damage the person's body.

However, the electricity is powerful enough to temporarily disable the nervous system. This occurs when the added charge mixes with the electrical impulses flowing through the nerve cells. The added electricity overwhelms the meaningful signals, making it impossible for the brain to interpret the signals from the nerve cells. Confusion, difficulty in balance, and muscle paralysis results.

Only about one-quarter of a second is required to incapacitate someone. Once the electrical swamping of the nerve impulses has ceased—within a few seconds to a minute—recovery is complete with no adverse effects. Tests have shown that even heart pacemakers are not affected by Tasers.

The electrical signal from a Taser can be generated as a single burst, or in rapid pulses. If the pulses are similar to the frequency of the natural pulses that occur within the nerve cells, then the muscles are stimulated to contract and relax. However, there is no coordination behind the work, since the connections between the muscles and the brain have been disrupted. The muscles will become depleted of energy and tire. Even when the normal electrical rhythm is restored, the muscles often remain too tired to respond for a short period.

Because a Taser acts on muscles, and as there are muscles all over the body, a Taser applied almost anywhere over the body can cause total immobilization.

Stun guns, including the Taser, consist of a transformer, oscillator, capacitor, and electrodes. The transformer generates the voltage, typically between 20,000 and 150,000 volts. The oscillator introduces the pulsations in the electrical charge. The charge is built up in the capacitor, which releases the charge to the electrodes. It is the electrodes that send the charge into the body, when the electricity bridges the gap between the oppositely charged electrodes.

In a Taser, the electrodes are not fixed in position. Instead, they are positioned on the ends of two long pieces of conducting wire. When a trigger is pulled, a release of compressed gas expels the electrodes out from the gun. In addition, the electrodes have barbs on them, so that they can stick to clothing. This design of the Taser allows a charge to be transferred to someone who is 15 to 20 feet away. Hand-to-hand contact, in this instance, is not necessary. The disadvantage of this design is that only one shot is possible before the electrodes have to rewind, and a new compressed gas cartridge loaded into the gun. Some models of Taser have the attached electrodes, so that if the flying electrodes miss the target, the shooter can move in and try to touch the subject with the stationary electrodes to deliver the stunning dose of electricity.

SEE ALSO Electrical injury and death; Neurotransmitters.

Tattoo identification

A tattoo is a design imprinted onto the skin that can sometimes be a useful mark of **identification** of a non-skeletalized body or a suspect using a false identity. It is believed that tattooing was first practiced in Egypt around 2000 B.C., and its use has spread around the world. Today a wide cross section of the population bears tattoos, from fashion models to known criminals and gang members. The designs are as varied as the people who wear them; names of loved ones are popular, as are symbols denoting membership of a group. Tattoos may be done just for fun, or they may have a more sinister connotation; for instance, prisoners have sometimes been tattooed with numbers, especially in concentration camps. Some elderly people may bear tattoos relating to experience in the Holocaust.

When a pathologist carries out an **autopsy**, he or she will look for and record tattoos in the same way as for any other **body marks** that could be identifying, like scars or birthmarks. The location and nature of the tattoo are the identifying features. A tattoo is made by inserting dyes or inks into piercings created by a needle. One approach to identifying the body is to extract a tiny amount of the dye and subject it to laboratory analysis. The pigments can be identified by techniques such as atomic absorption **spectroscopy** or **thin layer chromatography** and may be traceable back to a specific tattoo artist. Black pigments may contain carbon, reds mercuric chloride, and greens potassium dichromate.

Tattoos are valuable identification marks because they tend to be permanent. They can be removed, but they do not fade, and they persist even if the outer layer of skin has perished. The color may, however, change with exposure to the sun. Typically, blue pigment may turn black or purple.

When it comes to identifying a corpse, family members may be aware of the existence of a tattoo and this can be used as a distinguishing mark even if the body itself has been dismembered or otherwise mutilated. In one famous case, dating back from 1935, two fishermen caught a shark off the coast of Sydney, Australia, and took it to a local aquarium where the animal proceeded to disgorge a human arm. The limb appeared to have been severed by a knife, seeming to rule out a shark attack as the **cause of death**. It looked, rather, as if the corpse had been dismembered and disposed of at sea. The arm also bore a distinctive tattoo of two boxers squaring up for a fight. This led to the identification of the victim as James Smith, an ex-boxer with a criminal past. His wife recognized the tattoo, and **fingerprint evidence** confirmed the identity. Suspects were arrested, but the defense argued that an arm alone was insufficient evidence to convict, even if it did carry a tattoo and fingerprints. The case became known as the Shark Arm Murder.

Statistics show that people with anti-social personality disorder are often involved in crime, and they are also more likely to bear a tattoo than the rest of the population. The reason for this is unknown, but the tattoo can be a useful way of identifying these people. Indeed, this may be why criminals on parole sometimes can be identified through their tattoos if they run into more trouble. Often an ex-convict will have a tattoo bearing his name, his street name, or the name of a loved one. If he carries a gun, he may reveal this through a tattoo of the weapon. Wearing a tattoo may be a part of gang and criminal culture. For some people, the tattoo is an important part of belonging and of intimidating others. Certain gangs have distinctive tattoos. In California, the CALGANG database stores data on gang tattoos. This is a useful resource for the investigator who finds a tattoo on a corpse suspected of being the victim of a gangland killing or similar incident.

In Florida, a database has recently been created which includes around 372,000 tattoo records. All of these have been found on examination of criminals

Although usually obtained for cultural reasons, tattoos serve as identifying features for the body. © HENRY DILTZ/CORBIS

serving sentences in the state's prisons. Any investigator discovering a tattoo on a suspect or body can now utilize this database to try to find an identifying match. On its own, a tattoo may be insufficient evidence of identity, but it can be crucial when placed in the context of the whole investigation.

SEE ALSO Identification; Profiling.

Karen T. Taylor

1952–
AMERICAN
FORENSIC ARTIST

During the last two decades of the twentieth century, Karen T. Taylor worked as a forensic artist for at the Texas Department of Public Safety (DPS). In that position, she reconstructed facial features of the dead and drew composite sketches of criminals. As one of only thirty certified professional forensic artists at that time, Taylor became internationally renowned for her facial reconstruction skills. Her work helped capture numerous criminals within the United States.

Taylor, born and raised in Texas, developed an early aptitude for sketching faces. She attended the University of Texas's School of Fine Arts and the Chelsea School of Fine Art in London. While in England, she worked as a portrait sculptor for Madame Tussaud's Wax Museum. Returning to Texas, Taylor found a job as an illustrator for the DPS; when detectives discovered her talent for drawing realistic facial sketches, she transitioned into the role of full-time forensic artist.

While working for the DPS, Taylor developed successful interviewing skills and produced incredibly accurate and detailed sketches. These sketches led to the arrests of many suspects accused of rape and **murder**. In order to develop her facial reconstruction skills, Taylor studied the techniques of Betty Pat Gatliff, an Oklahoma forensic sculptor considered a pioneer in the field. Taylor later used these facial reconstruction abilities to help identify missing persons and work on documentaries, studies, and other projects.

Throughout her career, Taylor served as a forensic art instructor at the **FBI** Academy and other international universities, medical schools, and law enforcement academies. She is also the author of *Forensic Art and Illustration*, which is considered an important text in the field of forensic art. Her artwork has been featured on numerous television programs, including *America's Most Wanted.* In addition, a character on the popular television drama *CSI:* was based on Taylor and her work.

In 1999, Taylor retired from the Texas Department of Public Safety. She continues to work as a forensic artist, but also works on fine art commissions from her studio in Austin. In 2002 she became the first woman to win the John A. Dondero Award from the **International Association for Identification**.

SEE ALSO Composite drawing; Identification; Television shows.

Technology and forensic science

Forensic science is a rapidly growing discipline and the tools available to forensic researchers are also evolving quickly. Painstaking protocols for

DNA collection, extraction, quantification, amplification, detection, and analysis have now been replaced by commercially available kits, high-throughput instrumentation, and computer algorithms. With these technologies, forensic scientists have the tools in hand to fortify databases and solve even the most complicated crimes.

There are several steps involved in the process of DNA analysis. These are collection, extraction, quantification, amplification, detection, and analysis. Each step can be accomplished by different methods and can encounter complications. In order to accurately determine a profile from a DNA sample and ensure it is admissible in a court of law, the process must be documented and the protocols followed appropriately.

Sample collection is the first step of **processing** a forensic sample for DNA analysis. Because contamination can instantly ruin a sample, the investigator at the scene must make cautious efforts not to touch any part of the sample. For example, a **blood** spot found on an article of clothing at the scene of a crime is easily contaminated with the investigator's DNA if it is picked up by a non-gloved hand. Therefore, forensic investigators and police at crime scenes wear gloves and immediately deposit samples in sealed bags or containers. Scene of crime samples can be in myriad of forms: hair found at the scene, an article of clothing, a piece of chewing gum, or the end of a cigarette, for example. All of these are collected, placed in sterile containers, and brought to the forensic laboratory for investigation.

Samples collected for reference databases are more straightforward than scene-of-crime samples. Reference samples are collected from the offender once he or she is arrested or found guilty. Whether or not a sample can be taken before the alleged perpetrator is convicted in court depends on the country and even the state in which the crime was committed. The most common means of **reference sample** collection is by buccal swab. This method involves using a sterile swab to wipe the inside of the subject's mouth. DNA is later isolated from the cheek cells attached to the swab. Other methods include drawing blood from the individual and storing it on an FTA® card. These are thick pieces of specialized, sterile paper on which a drop of blood can be absorbed and the DNA can be isolated later. Regardless of the method of collection, all samples are taken to the laboratory for further processing.

When a forensic investigator obtains a sample from which DNA must be analyzed, DNA must first be extracted from the sample. This is the case with either a scene-of-crime sample or a reference database sample. In the case of the latter, DNA extraction is much easier. Commercially available protocols exist for isolating DNA from buccal swabs or FTA® cards. Similarly, many companies now offer kits for the extraction of more complex scene of crime samples. Specialized protocols are available to isolate DNA from trace samples such as cigarette butts or blue jeans. DNA extraction kits are based on one of several different methods. The most basic means is an extraction using phenol-chloroform or alcohol precipitation. These methods are the most common in homemade methods. Kits are also available that use ion exchange resins or silica-based columns to isolate and purify the DNA. One of the newest techniques for DNA isolation involves the use of magnetic beads and specialized buffers. By adjusting the ionic charge of the environment surrounding the sample, DNA will stick to the magnetic beads and can be exposed to a series of buffers to remove contaminants.

A variety of manufacturers are now producing automated machines to aid in the extraction of DNA from forensic samples. Automated systems are available for all different types of chemistries, columns, and magnetic-bead-based extractions described above. There are many benefits to automated DNA extraction; it involves less hands-on time by technicians and thus, has a lower likelihood of contamination or human error with the protocol. Also, automated systems can be very simple and do not require that the laboratory staff be highly trained and specialized. Finally, the use of automated extraction allows for the processing of many more samples a day than manual methods, which can be quite time consuming.

Once the DNA is extracted and quantified, it must be amplified by **PCR (polymerase chain reaction)**. The **PCR** method involves three steps: denaturing, annealing, and extension, which are performed in an instrument called a thermalcycler. In more detail, DNA is placed in a reaction tube containing buffers, primers, nucleotides and an enzyme known as Taq polymerase. During the denaturing step, the mixture is subjected to high temperatures so that the double strands of DNA separate. Next, the temperature is lowered to one that allows for annealing of the specific primers to their sequence counterparts on the DNA of the sample. Finally, the temperature in the thermalcycler changes to the optimal temperature for the enzyme Taq polymerase, which extends the regions of DNA between the primers by adding the nucleotides, thus making a copy. The same reaction repeats over many cycles of these three steps resulting in an exponential amplification of the regions between the primers.

The forensic researcher chooses primers for specific sequences of the genome that show regions around the **gene** sequences that are common amongst individuals. The result of the PCR reaction is then copies of the sequences that differ in the regions between the primers. Several different companies now offer kits that contain all the necessary reagents to amplify STR profiles. Specific kits are even available to amplify only male DNA. The kits also include standards, or specific fragments of DNA of known size to determine the length of each gene sequence. This is important, as the length of the gene sequence is what differs among individuals. The number of repeats in the sequence determines its length. Accumulation of the various repeat regions provides a profile that is specific to a particular person.

In the detection step, the forensic researcher visualizes the DNA. The sequences of the amplified DNA are visualized on a gel that allows for the determination of the number of repeats in the sequence regions. The fluorescent dyes included in some kits help to visualize the sequences. Contemporary forensic scientists tend to use nucleic acid analyzers and automated sequencers for detection of DNA sequences. These automated methods remove the potential subjectivity of the analysis if performed by manual means. The DNA sequences are then entered into a computer and software is used to calculate and store the sequences. Then, sequences of the reference sample or scene-of-crime sample are compared via software programs to other gene sequence profiles in the database. Forensic scientists look for matches to assist them with their investigation.

Automation is commonplace in today's forensic laboratory for the amplification, detection, and analysis steps, as well. Most laboratories performing DNA analysis are equipped with a variety of instruments including extraction systems, thermalcyclers, nucleic acid analyzers, and gene analysis software. What was once was a complex manual process taking days can be accomplished with instruments in only a few hours. Automated methods must be validated, similar to manual methods, to ensure they meet the standards and guidelines set forth by the governing bodies in forensic science, such as **Interpol** or the Federal Bureau of Investigation.

Following collection, the processes of DNA extraction, quantification, amplification, detection, and analysis can be performed with almost no intervention of the forensic scientist. Automation has revolutionized the forensic laboratory to almost a high-tech factory. With the aid of automated systems, forensic scientists are not only processing their current case samples, but also chipping away at the large backlog of reference samples. DNA databases are building up at a rapid pace, which will ensure that investigators have the best chance of finding a match and solving a crime.

SEE ALSO DNA; DNA databanks; DNA fingerprint; DNA isolation methods; DNA profiling; Electrophoresis; European Network of Forensic Science Institutes; Interpol; Nucleic Acid Analyzer (HANAA); PCR (polymerase chain reaction); STR (short tandem repeat) analysis; Trace evidence.

Ludwig Karl Teichmann

1823–1895
POLISH
ANATOMIST

Ludwig Karl Teichmann was a Polish anatomist and physician who made an enduring contribution to **forensic science** with his discovery of the Teichmann test for **hemoglobin**. Also called the Teichmann crystal, this is a test that is used on dried stains to determine whether or not **blood** is present. Dr. Teichmann made his forensic discovery in 1853. His microcrystalline test remains in use today as a means of identifying whether or not dried stains at a crime scene, on clothing or other fabric, or elsewhere at the site of a forensic investigation contain (human) blood.

Teichmann attended medical school in Gottingen, Germany. After completion of his studies, he remained at the university as an anatomy professor. In 1853, Teichmann published a scientific paper in which he described the crystallization of several **organic compounds** contained in human blood. Within his research paper, he explained a process by which microscopic crystals of hemin could be prepared. Hemin is a substance made up of reddish brown, microscopic, prismatic crystals; it is formed from dried blood by the action of common salt and strong acetic acid (the substance in vinegar that gives it a distinctive odor and pungent taste).

Blood begins to dry after 3–5 minutes of exposure to air, and drips or spatters (blood that is not in large quantities, like pooled blood) typically form crusts quite quickly. Dried blood can readily be confused with other substances, both organic and inorganic, at a crime scene. That is why, when a black, brown, brownish-black, or very dark red substance is found at a crime scene, it is necessary to determine whether or not it is actually blood. The Teichmann test is a presumptive test for blood; it is used strictly to screen for the presence or absence of blood. A positive result from a crystalline test is an indication to go ahead and use other tests to confirm.

SEE ALSO Blood spatter; Bloodstain evidence; Cast-off blood; Crime scene investigation; Criminalistics.

Telephone caller identification (caller ID)

Electronic and digital information that is generated in the normal course of electronic communication can be valuable in the forensic tracing of the course of events in an accident or crime, and in the **identification** of a victim or assailant.

Caller identification, or caller ID, permits the receiver of a call to identify the caller's location. Available since the early 1990s, it has enhanced the sense of privacy enjoyed by people in their homes, and has also greatly reduced the number of prank calls, as well as calls made with threatening or criminal intent.

In the late 1980s and 1990s, telephone companies made such technology available. A caller ID box, or a caller ID unit built into a phone, simply reads the computerized information for the incoming call, assuming it is coming from a listed number. Calls from an unlisted number register as "Unknown Caller" or "Private Caller." Available on internal private branch exchange (PBX) telephone systems during the 1980s, caller ID gained use by businesses offering toll-free numbers in 1988. By 2005, over 50% of homes nationwide had caller ID.

SEE ALSO Dial tone decoder.

Telephone recording system

Electronic and digital information is a part of everyday communication. Recording or recovery of this information can be vital in the forensic investigation of an accident or crime, and in the **identification** of a victim or assailant. Telephone conversations can be easily recorded and can provide a wealth of information to a forensic scientist.

A telephone recording system can be as simple as a handheld phone receiver with an analogue (non-computerized, non-digital) recorder. In such a situation, the act of recording is hard to hide. On the other hand, some telephone recording systems are so seamless that the individual being recorded would not know he or she was being recorded someone unless informed them. For this reason, some states require that the person being recorded be informed of this fact, and many states require that the recorder emit a regular beep or other sound to serve as a reminder of the ongoing recording.

Consumers today are able to buy telephone recording systems that hook into the telephone line just as an answering machine would. Such systems, which retail from under $100, make it possible to begin recording as soon as the receiver is lifted. Twelve states require two-party notification, meaning that both participants in a recorded conversation must be informed of the fact that they are being recorded.

Digital systems are capable of saving a recorded call in a digital audio format, as a .wav file, making it possible for a user to e-mail a recording of a conversation.

SEE ALSO Tape analysis; Telephone tap detector.

Telephone tap detector

Telephone conversations can be monitored and recorded. Law enforcement personnel may even, with court permission, tap a phone to acquire information that can potentially be useful in a prosecution. But technology can also thwart this effort. When a telephone tap is suspected, an individual can acquire technology to detect the monitoring device.

A telephone tap detector aids communication security by providing electronic recognition of attempts to intercept a call through wiretapping or listening devices. Telephone tapping is, at least in certain particulars, an exact science, and tap detection technology must likewise be efficient to counteract those efforts. With telephone tapping no longer an extremely infrequent aspect of daily life, tap detectors have become a popular item among security-conscious consumers.

In tapping into a phone line, surveillance personnel use technology akin to that which an electrician might apply in attempting to siphon power from an electric line. However, whereas an electric wire attached to a circuit receives a regular supply of power, a telephone tap cannot maintain constant access to a telephone line, or it would be too easy to detect. Instead, the tap "seizes" the telephone line as a call is coming in.

The tap is most likely to engage between the first and third ring of an incoming call, and from that point onward, assuming all conditions are reasonably favorable for surveillance, the tap remains in effect for the duration of the call. A telephone tap detector recognizes this seizure of the phone line, and provides further verification once the call concludes. Depending on the number and timing of disconnection reactions after the receiver is reengaged, a good tap detector (consumer models sell for several hundred dollars) can determine whether wiretapping equipment is in the process of disengaging from the phone line.

SEE ALSO Telephone caller identification (caller ID).

Television shows

Since television's infancy, crime dramas, especially police procedurals, have been perennial favorites among viewers. Such shows typically focus on police detectives as they investigate the scene of a crime, gather clues, sift through suspects, and eventually bring the perpetrator to justice, either in court or at the end of a gun. At the center of many of these dramas are the mean streets of a big city, with its stew of suspects and complex motivations, as in the 1970s hit *The Streets of San Francisco.* Co-starring are the detectives themselves: strong, swift of foot, sure of shot, blessed with infallible instincts. The role that forensics is likely to play in these shows, though, is likely to be only a passing one. A detective orders a **ballistics** test run on a bullet removed from a murder victim. A subordinate finds a bit of fiber, a hair, or a suspicious cigarette butt, and the lead detective barks, "Run that down to trace!," the lab in the bowels of police headquarters where technicians examine **trace evidence** and read its story. In the past, though, those technicians rarely emerged from anonymity. Science was not considered as interesting to viewers as shootouts, car chases, or dramatic interrogations of suspects.

When science made an occasional appearance in past shows, it was generally in the figure of the **coroner**, whose bailiwick was where science and crime investigation intersected. From 1976 to 1983, for example, veteran actor Jack Klugman starred as the title character in 147 episodes of *Quincy, M.E.* (viewers never learned his first name). As chief **medical examiner**, Quincy served as the catalyst behind crime investigations, teasing clues out of bodies that less intrepid investigators would have overlooked. The show broke ground for its relatively high level of realism. Its forensic consultant had been a scientist in the Los Angeles Medical Examiners office, and his on-screen role as a technician enabled him to operate complex equipment rather than trying to teach actors to do it. One episode of the show, in which Quincy used bite marks to identify a killer, was credited with helping solve a rape case in the Midwest after a nurse, having watched the episode, photographed bite marks on a victim.

By the late 1990s and early 2000s, though, a change had taken place. Many television crime shows had replaced gruff, street-smart detectives with teams of polished forensic lab scientists—the result, according to some observers, of America's fascination with the televised O. J. Simpson murder trial, with its dramatic testimony about **DNA**, **blood spatter**, and other forensic **evidence**. Sweaty interrogation rooms and the litter of coffee cups in stakeout cars had given way to smartly appointed labs and the clutter of pipettes and gas chromatographs, and the neatly pressed lab coat had replaced the rumpled suit.

The flagship of this new crop of shows was the CBS hit *CSI: Crime Scene Investigation*, launched in 2000 under the direction of Jerry Bruckheimer and starring William Petersen as the brooding, scholarly Gil Grissom and Marg Helgenberger as his female counterpart, ex-stripper Catherine Willows. While the show explores the human drama of its cast of characters, always at the center is the forensic evidence, which infallibly guides police to the wrongdoers.

In an episode aired on February 17, 2005, for example, the team is called to a Las Vegas mansion where a casino mogul is lying dead, having fallen, jumped, or been pushed from a second-story balcony. The team takes careful note of the crime scene: no **tire tracks**, no **cast-off blood**, the head's position relative to the pool of **blood** suggesting that the body had been moved, a suspicious oil leak in the driveway, greasy palm prints on the balcony ledge, and the floor of the upstairs study. Examination of the body back at the lab finds no drugs in the blood but eventually turns up LSD in the victim's urine and, bizarrely, breast milk in his stomach. Attention focuses on the man's wife, whose bloody shoes were found in the trash. Comparison of the shape of the shoes with the pattern of blood on the ground near the victim's head suggests that the wife stood nearby and watched her husband die. Further, the investigators examine the hard drive on the home's electronic security system, which recorded the time when doors were opened, including the garage door. By recreating the timeline of events, the investigators determine that after arriving home, pulling into the garage, and finding her husband on the ground, the wife waited an hour before calling 911. Eventually, the team pieces together what happened: that the disturbed husband engaged in elaborate infantile fantasies (the palm prints were left by baby lotion) and that a woman he forced into the role of nursemaid administered the LSD, which caused him to hurl himself off the balcony. The wife, her eye on his estate, was happy to allow him to die.

CSI became so successful, often the highest rated show for the week, that it became a franchise with two spin-offs: the hip, sun-bronzed *CSI: Miami* and the darker and moodier *CSI: NY*. In 2003 CBS also premiered *NCIS* (Naval Criminal Investigative Service), in which lead investigator Jethro Gibbs, played by heartthrob Mark Harmon, relies heavily on the scientific expertise of his medical examiner, quirky Renaissance man "Ducky" Mallard, and Abby, an uninhibited, tattooed forensic specialist who dresses in Goth clothing. By then, the roster of shows with prominent forensic themes, including both dramas and documentaries, was growing almost exponentially. On cable television, the Court TV channel had four shows: *I, Detective; Body of Evidence; Extreme Evidence;* and the network's signature series, *Forensic Files*. The Learning Channel had *Medical Detectives*. The Discovery channel featured *The New Detectives: Case Studies in Forensic Science*, *The Prosecutors: In Pursuit of Justice*, *The FBI Files*, and *The Justice Files*, and on the Discovery Health channel was *Dr. G.: Medical Examiner*. On A&E (Arts and Entertainment) were *Cold Case Files*, *Investigative Reports*, and *American Justice*. NBC had *Law and Order: Special Victims Unit* and *Crossing Jordan*, the latter with a technician nicknamed "Bug" who was often called on to bring his knowledge of **entomology** to bear on murder cases. What all of these shows had in common, to a greater or lesser extent, was the prominent place they gave to such forensic themes as fiber analysis, blood samples, blood spatter, DNA analysis, fingerprinting, shoeprint **casting**, and handwriting analysis—all with the help of a panoply of high-tech gadgetry that became the envy of real forensic labs around the country.

In August 2002, Court TV capitalized on the popularity of these shows by airing a bundle of programs under the title "Forensics Week." Included were five new episodes of *Forensics Files*, during which viewers could "join the investigation" by logging on to the network's website and entering interactive, virtual forensics labs, including rooms devoted to **computer forensics** and linguistic forensics. Additionally, "Forensics Week" included two documentaries, one documenting an unsolved 1973 case that was reopened in 1995 and solved through new forensic techniques, the other documenting a three-year murder investigation solved with the help of FBI profilers and a handwriting expert. That week, too, Court TV's Mobile Investigation Unit (MIU), a traveling forensic lab, wrapped up a 20-city tour at the Children's Museum in Manhattan. The lab allowed visitors to take part in a "caper scene" and solve a crime using fingerprints, **handwriting analysis**, and fiber analysis.

Purists objected to technical and procedural flaws in such shows as *CSI*. They note, for example, the tendency of the shows to enhance drama by having investigators work in the dark, when in reality investigators set up floodlights to illuminate crime scenes. But science educators were delighted with the public's new fascination with forensics on television. Colleges and universities in the United States and around the world saw sharp increases in the number of students taking courses in such subjects as forensic **pathology**. In 2004 The College of New Jersey launched a 10-year, \$2.2 million effort to develop a **criminology** and **forensic science** program, fueled in large part by the popularity of forensic television. Singer Britney Spears was quoted as saying that she was growing tired of her status as a pop icon and, because of such shows as *CSI*, wanted to pursue a career in forensic science.

One of the most tangible effects of the interest in forensic television was its usefulness for educators in making science more accessible to students. In connection with the MIU's stop at the Children's Museum, Court TV announced the kickoff of its Forensics in the Classroom (FIC) program. Developed in partnership with the **American Academy of Forensic Sciences** and the National Science Teachers Association, FIC bridged the gap between scientific theory and applications in the real world by requiring students to gather data, think logically about the connections between data and explanations, analyze

Actors David Anders, George Eads, and Marg Helgenberger on an episode of *CSI: Crime Scene Investigation*. CBS/LANDOV

hypotheses, and communicate results, all goals of the science classroom. Teachers could download classroom units and lesson plans, complete with lab activities that take students step-by-step through the scientific investigation of a pretend crime. In *The Cafeteria Caper*, students use DNA, hair, and blood analysis and conduct an enzyme test to determine who was responsible for an act of school vandalism. *It's Magic* uses handwriting analysis, a pH test, and paper **chromatography** to solve a "dognapping" case. *The Car That Swims* uses footprint casting to expose a girl's false statements about a car found in a river. *Renters Beware* requires students to conduct a flame test, a Kastle-Meyer test, and **fingerprint** analysis to uncover a plot involving a money-hungry landlord with a mysterious chemistry lab.

SEE ALSO American Academy of Forensic Sciences; Bite analysis; Blood spatter; Careers in forensic science; Casting; Cast-off blood; Chromatography; Coroner; Crime scene investigation; Hair analysis; Handwriting analysis; Medical examiner; Simpson (O. J.) murder trial; Trace evidence.

Terrorism, biological SEE Bioterrorism

Test controls SEE Control samples

Thanatology

Thanatology is the science that studies the events surrounding death, as well as the social, legal, and psychological aspects of death. The term thanatology originates from the Greek *thanatos*, meaning death and *logos*, for study or discourse. Thanatologists may study the cause of deaths, legal implications of death such as the rights and destiny of the remains or requirements for **autopsy**, and social aspects surrounding death. Grief, customs surrounding burial and remembrance, and other social attitudes about death are frequent subjects of interest for thanatologists.

From the forensic point of view, causes of death may be due to natural causes, such as from lethal disease or advanced age), accidental causes, such as falls, plain crashes, fires, drowning, or **automobile accidents**, criminal actions, such as **murder**, neglect, malpractice, or other irresponsible acts by third parties, and finally, suicide. Thanatology also overlaps forensics when it focuses on the changes that occur in the body in the period near death and afterwards.

Some social issues explored by thanatologists, such as euthanasia (the merciful induction of death to stop suffering) and abortion (termination of a pregnancy) are subject to much ethical and legal controversy. These issues are legal in some countries, while considered a crime in other countries. In Brazil, for instance, although outright euthanasia is illegal, patients have the right to refuse medical treatment and artificial life supporting procedures, if they sign a legal statement in advance while of sound mind.

Rights over the corpse of the deceased is also determined by law in most developed countries, as well as burial, cremation, and embalming requirements. Clinical autopsies are generally required in cases of unexplained or violent death, suspicion of suicide, drug overdose, or when requested by the family of the deceased due to suspicion of medical error or when confirmation of certain diseases is sought.

The thanatology community is usually composed of a variety of health professionals including psychiatrists and other physicians such as forensic pathologists, advanced practice nurses, and veterinarians, along with sociologists and psychologists.

SEE ALSO Assassination; Autopsy; Body marks; Coroner; Death, cause of; Death, mechanism of; Decomposition; Drowning (signs of); Entomology; Ethical issues; Exhumation; Fluids; Medical examiner; Parasitology; Pathogens; Pathology; Saliva; Semen and sperm; Serology; Skeletal analysis; Time of death; Toxicology.

Thin layer chromatography

A central part of many forensic investigations is the analysis of materials that are recovered from the scene of the investigation. A mainstay technique used to separate and identify individual components in a mixture of compounds is **chromatography**.

One type of chromatography that is relevant in **forensic science** is thin layer chromatography (TLC). TLC is a type of liquid chromatography that can separate chemical compounds of differing structure based on the rate at which they move through a support under defined conditions.

TLC is useful in detecting chemicals of forensic concern, including chemical weapons, **explosives**, and **illicit drugs**. Advances in TLC technology, largely driven by the efforts to quell terrorism, have benefited forensic science. As one example, the Forensic Service Center of Lawrence Livermore National Laboratory has designed a computerized and portable TLC machine that can be taken to the field, and which has the ability to analyze 20 samples at a time. Analysis can be completed within 30 minutes. This allows an analysis that previously required a dedicated laboratory to be done at the scene.

The current TLC technology was introduced by Justus Kirchner in 1951. From its beginning, the technique was an inexpensive, reliable, fast, and easy to perform means of distinguishing different compounds from each other. The method was qualitative—it showed the presence of a compound but not how much of the compound was present. In the late 1960s, TLC was refined so that it could reliably measure the amounts of compounds. In other words, the technique became quantitative. Further refinement reduced the thickness of the support material and increased the amount of the separating material that could be packed into the support. In High Performance TLC (HPTLC) the resolution of chemically similar compounds is better than with conventional TLC, and less sample is required. HPTLC requires specialized analysis equipment, and so is still not as popular or widespread as conventional TLC.

In TLC a solution of the sample is added to a layer of support material (i.e., grains of silica or alumina) that has been spread out and dried on a sheet of material such as glass. The support is known as the plate. The sample is added as a spot at one end of the plate. The plate is then put into a sealed chamber that contains a shallow pool of chemicals (the solvent), which is just enough to wet the bottom of the plate. As the solvent moves up through the plate support layer by capillary action, the sample is dragged along. The different chemical constituents of the sample do not move at the same speed, however, and will become physically separated from one another. The positions of the various sample constituents and their chemical identities are determined by physical methods (i.e., ultraviolet light) or by the addition of other chemical sprays that react with the sample constituents.

SEE ALSO Analytical instrumentation; Toxicology.

Time of death

The determination of time of death is of crucial importance for forensic investigators, especially when they are gathering **evidence** that can support or deny the stated actions of suspects in a crime. The time elapsed from the moment of death until a corpse is discovered is also known as the postmortem interval, or PMI.

Both the time of death and the postmortem interval cannot be determined with 100% accuracy, particularly when a body is found in advanced state of **decomposition** or is recovered from fire, water, or ice. Therefore, time of death and PMI are given as estimates, and can vary from hours to days, or from months to years, depending on each particular case.

Evidence for estimating time of death includes **physical evidence** present in the corpse (postmortem changes, presence of insects, etc.), environmental evidence such as location where the body was found (indoors, outdoors, buried, burned, in water, etc.), and other evidence found at the crime scene (a stopped wrist watch due to a blow or impact, an answering machine record, a 911 call, phone calls received or made around the time of the assault, etc.), and finally, the historical evidence (habits and daily routine of the victim, relationships, existence of enemies, etc). The knowledge of the internal sequential changes a dead body undergoes in relation to the variations on the rate of their occurrence due to ambient temperature, humidity, and the presence of insects or other predators are all considered when estimating the time of death.

The classical method of estimating time of death is the rate method, which measures postmortem (after death) stages and the types of transformation a body undergoes such as cooling rates (algor mortis), stiffening (**rigor mortis**), initiation and duration, postmortem **lividity** (discoloration stains), degree of putrefaction, **adipocere** (body fat saponification), and maceration (tissue softening due to the presence of liquid). Not all these stages take place in a single cadaver. Adipocere, for instance, is not common in most male adult corpses. It occurs most often in women or obese adult individuals and children, requiring enough humidity or the presence of water to take place. The process of maceration occurs at known rates in fetuses that died in the womb. Stomach contents can reveal the stage of digestion of the last meal at the time of death. The time of onset and rates of each postmortem transformative event are also subjected to variations originated by existing chronic diseases, types of medication, and individual metabolic characteristics. These variables are known as endogenous factors. For example, if the deceased individual was taking **antibiotics** at the time of death, the internal process of bacterial-mediated putrefaction may be delayed beyond the normal observed rates, thus masking the real PMI.

Algor mortis, or the process of body cooling, is a useful parameter for PMI estimation during the first 24 hours after death, as the internal body temperature drops at known rates. However, these rates are valid only in cool or temperate climates because hot summer seasons or tropical temperatures slow down the loss of heat and, in some regions, can even raise postmortem temperatures due to rapid putrefaction through bacterial activity inside the digestive tract. Algor mortis rates are measured with a thermometer or through the use of a multiple-probe thermometer that measures the cooling rate of the brain, liver, and rectum. Other variables interfering with postmortem cooling rates include the size of the body, amount of subcutaneous (under the skin) adipose (fatty) tissue, existence of clothing and coverings, air currents and humidity, and the medium where the body remained after death (such as inside a closed car, under water, on ice or snow, or inside a metallic container).

Rigor mortis, or postmortem stiffening and contraction of all muscles, usually occurs three or more hours after death and can last for approximately 36–48 hours in temperate climates and about 9–12 hours in tropical temperatures. If a murderer moves a body before rigor mortis (RM), the new position will be "frozen" during RM, not the original one that would have characterized the pattern of the body falling at the crime scene. Therefore, the position a body shows during rigor mortis cannot be assumed as the position in which the victim was at the moment of death. The rigor mortis phase is not the best time for the pathologist to determine the **cause of death**, because several changes take place in the internal muscles, such as the heart and the ocular muscles, which can be misleading. For example, rigor mortis dilates the myocardial (heart) muscles, giving it the appearance of cardiac hypertrophy (enlarged heart). Contraction of the iris muscles also dilates the pupils during rigor mortis.

The factors that interfere with the onset and duration of rigor mortis are temperature, existing antemortem pathologies, age, body muscular mass, and the degree of muscular activity immediately before death. Higher temperatures shorten the time till the onset of rigor mortis and its time of duration. A strong fight or lengthy physical effort before death causes an earlier onset and shorter duration of rigor mortis. Children and older adults have also earlier rigor mortis than younger adults. Generalized infections, or long, debilitating diseases also produce earlier onsets and shorter periods of rigor mortis, whereas extensive antemortem bleeding or death due to asphyxia delays rigor mortis onset.

Livor mortis, or postmortem lividity, is characterized by the reddish/purple discoloration of the skin, sometimes with a pink border, in consequence of the lack of the arterial pressure that counteracts the gravitational force. Therefore, when blood circulation ceases, the blood is gradually deposited in the lower internal vessels and in the lower parts of the body, with the signs of livor mortis usually appearing within the first hour after death. However, in many cases it can appear 2–3 hours after death, and is usually fixed after about 12 hours. Livor mortis rates of appearance are delayed by severe anemia and starvation, but can be present before death in individuals slowly dying from circulatory insufficiency.

Postmortem decomposition or putrefaction consists of the destruction of soft tissues, usually starting internally through the action of microorganisms present in the stomach and bowel and in the nasal pharyngeal pathways. Open wounds also provide access to bacteria from the environment to the body. Obesity accelerates the putrefaction process, as well as infectious conditions, congestive cardiac failure, or when edema (swelling with fluid) is present. Conversely, extensive external bleeding during death or severe dehydration delays the putrefaction onset. As mentioned before, temperatures may accelerate or delay putrefaction onset and rates. Gases derived from the putrefaction process are used to estimate time of death, known as the Brouardel method. According to this approach, in the first postmortem 24 hours, abdominal gases are not flammable; between the second and the fourth day they are flammable; from the fifth day on, they are not flammable again. Putrefaction stains start to form on the abdominal skin around 24–36 hours after death in temperate climates and in 12–18 hours in tropical regions. These stains are green and gradually appear all over the body between the third and the fifth day after death. As the blood undergoes putrefaction, crystal blades are formed in fragmented or clustered patterns, crisscrossed and colorless. These crystals start forming after the third day and can remain in the blood up to 35 days. Determining time of death by observing blood crystals is known as the Westernhoffer-Rocha-Valverde method, and was first applied in forensic **medicine** by the Brazilian forensic pathologists Martinho da Rocha and Belmiro Valverde.

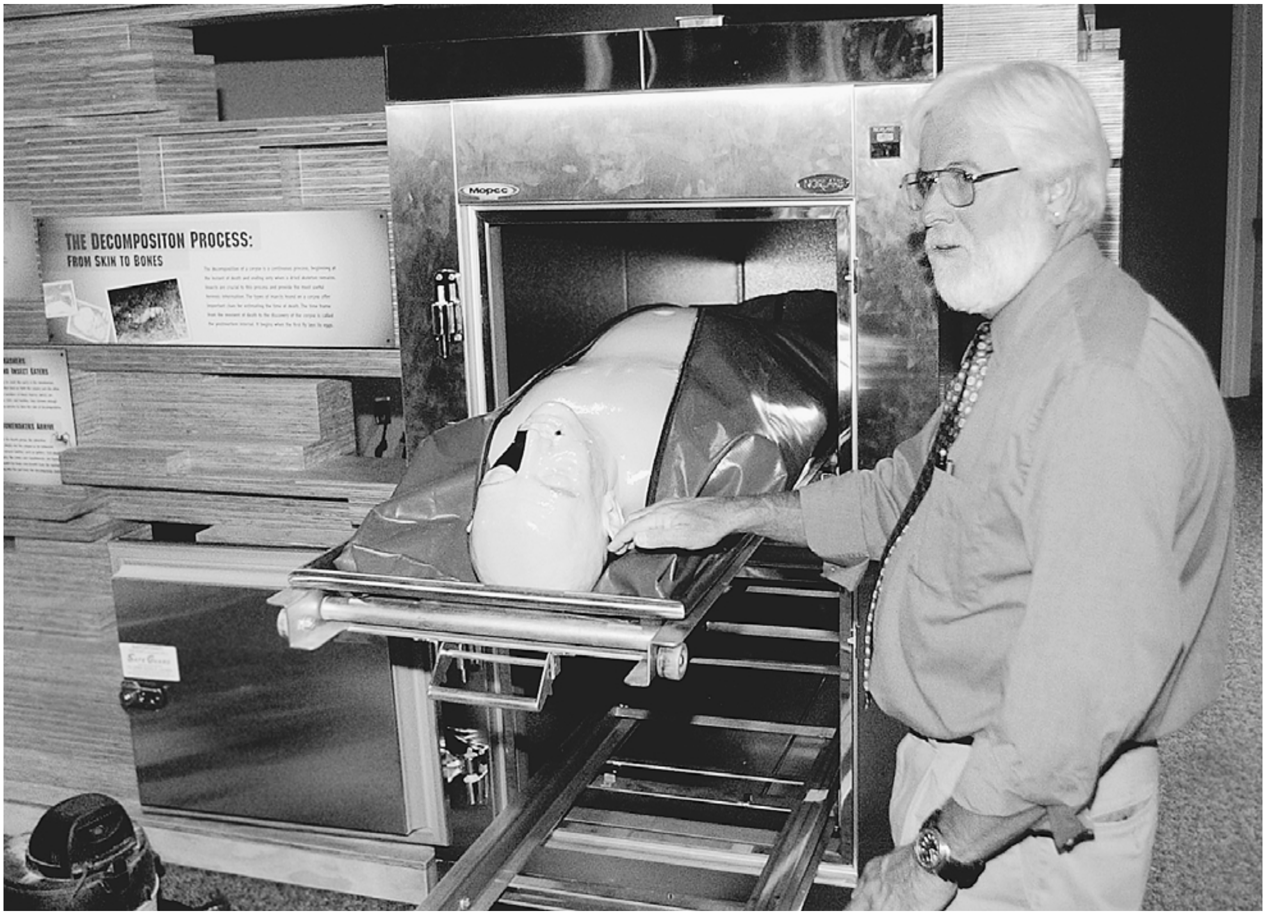
The first postmortem transformative event, known as autolysis, consists of spontaneous self-destruction of tissues by enzymes present in the cells without bacterial interference. One of the byproducts of autolysis is the building up of potassium ions concentrations known as vitreous humor potassium (VHP), and occurs during the first 20 postmortem hours. The quantitative analysis of the concentration rates of VHP is one of the methods for PMI estimation, which yields the best results when combined with other measurements.

Postmortem tissue survival rates constitute another PMI estimation method. Different types of tissues lose their vital properties in different moments of the postmortem interval. For instance **sperm** cells show mobility for about 36 hours after death. Muscles react to electrical or mechanical stimuli for a postmortem interval of six hours, and pupils can be dilated with atropine until four hours after death. Leukocytes, the white blood cells, die at the following PMI rates: 8% during the first 5 hours; 58% within 30 hours; and 95% within 70 hours.

Corpses exposed to outdoor environments attract insects with different behavioral habits and life cycles. Another modern technique utilized in time of death estimation involves forensic **entomology**. Forensic entomology utilizes insects on or surrounding the body, as well as their eggs and larvae, to estimate the amount of time a body has been dead and left in a certain environment. Entomology is useful as a forensic tool because the life cycles of insects are both well known and predictable. In addition, the succession of colonization of a corpse by insects occurs in temporally specific waves of different species.

Once a person or animal has died, insects that have access to the corpse colonize it very rapidly. The succession of inhabitants in terms of species and life cycle stage is clearly understood. This succession can then be used to determine several aspects of the crime. These include post-mortem interval, location of the murder, where the body was stored, and whether or not it had been moved.

The first insects to approach and colonize a dead body are usually species of blowfly (*Diptera: Calliphoridae*) or the flesh fly (*Sarcophagidae*). These holometabolous insects quickly deposit their eggs on an exposed corpse, and maggots, the larval form, are often found feeding on dead bodies. A forensic entomologist would be able, with the use of a microscope, to identify the stage of a blowfly larva. There are three larval stages, called instars, and by looking closely at the mandibles (mouthparts), genitalia, and spiracles (holes and tubes for gas exchange) the



Professor Lee Goff shows a dummy in a morgue crypt display for the Science Museum of Minnesota's exhibit: CSI: Crime Scene Insects. The types of insects and stages of their development on a body can help determine the time since death. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

entomologist can differentiate not only the species of the larvae, but also determine whether it is a first, second, or third instar.

The maggots then mature to the pupal form, which is often found deposited around the body. Forensic entomologists are cautious in scouring the region surrounding a corpse for the inactive pupae. However, if care is not taken by an investigator at a crime scene, the pupa can often be overlooked as it resembles rodent droppings. Once the insect has matured to an adult form, it emerges from the pupae. Empty pupal cases found in the vicinity of a body can also yield clues.

Beetles are generally the next insects to colonize a corpse. Carrion beetles of the order *Coleoptera* also undergo holometabolous development. Compared to the maggot larvae of flies, which are similar among species, the larval forms of beetle species are very different. In contrast to blowfly larvae, all beetle larvae also have legs, so the two orders of insect larvae are immediately differentiated by their appearance. Beetle larvae can be fat, slender, hairy, and a variety of colors from white to dark brown and black.

Forensic entomologists have been instrumental in solving homicide cases in recent years. Not only can they determine the approximate time of death from the succession of adult insects, larvae, and pupae found on the corpse, but they can also provide information such as if the body was moved. For example, if a body is found indoors, but colonized with insects typically found in a wooded outdoor location, the forensic entomologist would infer that the body had been moved.

In addition, bloodstains found at the scene of a crime can yield clues or confound police. Bloodstains could have been recently deposited, or possibly been there for a period of time from events unrelated to the crime under investigation. New and innovative techniques are now being used to establish time of death and age of bloodstains. These new techniques help forensic scientists and criminal investigators reconstruct more representative crime scenes and more precisely determine time of death.

When the suspected perpetrator of a crime is a relative or friend, crime scene analysis and reconstruction is much more complex. When the crime was committed in the relative or friend's home, it is difficult for investigators to separate evidence temporally since it is likely that the victim was in the environment previous to the crime. For example, if a woman murders her husband in their home, there may be small traces of blood in the house. However, this blood may have been present well before the crime and be totally independent of the events of the crime. Although forensic **DNA** analysis of the stain would easily identify to whom the blood belongs, this analysis would not provide any clues as to when the stain occurred. Similarly, a bit of blood found in an automobile could suggest a body was transported in a car. If the victim of the crime was a family member of the car's owner, how can it be determined if this blood came from a scratch before the crime was committed? Determination of the temporal events surrounding the deposition of a blood sample could prove crucial to solving a crime.

Often, characteristics of the blood protein **hemoglobin** such as color and solubility are used as an estimation of bloodstain age. These techniques have their drawbacks, however, as it is often necessary to determine the species from which the blood originated, and often the size of the stain affects the analysis. One new technique which shows potential for forensic analysis of bloodstain age utilizes RNA (ribonucleic acid) in the bloodstain. Although messenger RNA (mRNA) is easily degraded, researchers have found that highly abundant mRNA is detectable over six months following blood deposition. Furthermore, if **PCR** (ploymerase chain reaction, a DNA amplifying technique) is performed using species-specific primers, one can easily tell the species from which the blood originated.

The three different type of RNA—mRNA, transfer RNA (tRNA), and ribosomal RNA (rRNA)—are known to decay at different rates. Researchers have recently shown that using a ratio of mRNA of a highly abundant **gene** to that of rRNA, it is possible to determine the age of a bloodstain, because the degradation of the ribosomal RNA is much slower. Forensic scientists first isolate RNA from the bloodstain, then use real-time RT-PCR (reverse-transcriptase polymerase chain reaction) techniques to make DNA copies of the RNA. Real-time PCR provides an amplified DNA copy of the RNA, but still maintains a ratio of the amount of transcript in the reaction at the start of the reaction to that of the RNA at the end. By using primers specific to the RNAs of interest, only those are selectively amplified. Thus, it is possible to compare amounts of two different amplified DNAs that reflect the relative composition of those RNAs in the initial sample.

Although both RNA analysis and forensic entomology are relatively new techniques, they have great possibility for **crime scene investigation**. Forensic entomology has already proven useful in a variety of cases and, with more basic research, it is only a matter of time before RNA techniques prove equally as useful. As forensic techniques become more and more advanced, criminal investigations will be solved more rapidly and with even greater accuracy.

SEE ALSO Adipocere; Asphyxiation (signs of); Autopsy; Body marks; Crime scene reconstruction; Death, cause of; Death, mechanism of; Decomposition; DNA fingerprint; Drowning (signs of); Entomology; Hanging (signs of); Lividity; Mummies; Pathology; Rigor mortis; STR (short tandem repeat) analysis; Toxicological analysis.

Tire tracks

Tire tracks are the impressions left by tires on the surface onto which a vehicle drove. Not all tires and all surfaces will leave tire tracks. If the surface is soft or semi-soft, such as mud, dirt, or snow, the tire will leave an imprint under the weight of the vehicle. If the surface is hard, such as road pavement, the tire might still leave a trace, if dirt or dust was present. As with other traces such as fingerprints or **shoeprints**, tire tracks are extremely important in forensic investigations. They enable **identification** of the vehicle that left them. Tire tracks are usually found in road accident scenes or in the access and escape routes of other crime scenes.

Tires are made of semi-hard rubber and are characterized by class and individual characteristics. Class characteristics include size and general patterns. Individual characteristics include regular wear and tear as well as accidental cuts or holes. These characteristics may be reproduced in the tracks left by the tire, depending on the surface and the circumstances under which the track occurred.

When tire tracks are present at a crime scene or in the immediate vicinity, one must properly observe and record them. First, they need to be photographed

An aerial view shows skid marks leading from the end of the runway to a building where a corporate jet crashed after failing to take off from Teterboro Airport in Teterboro, New Jersey, on February 2, 2005. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

at a 90-degree angle. This allows for a permanent record of their class and individual characteristics. Then, the tracks are carefully measured. Not only it is important to note the width, but also the circumference of the tire, if the lengths permit it. In addition, if multiple tire tracks from the different wheels of the vehicle are present, it is important to make as many measurements as possible in order to determine the toe (the distance between the front of the tires and the rear of the tires on the same axle) and turning radius of the vehicle. Finally, if the tracks are present in relief, it is also possible to make a cast from it. Usually, plaster of Paris is used and, if the whole track cannot be cast, the most pertinent spot is cast.

Once the general size and pattern of the track is determined, it is possible to consult a database of tires to determine the brand and model of the tire that left the impression. In addition, there are also databases that list which tires are installed from the factory on which vehicles. Finally, with the dimensions of the vehicle, it is also possible to determine which vehicle could have left the tracks.

Recent advances in technology and research allow for the characterization of tire tracks by chemical analysis of the rubber. Based on **Locard's Exchange Principle**, if a tire leaves rubber residues on the surface, as is the case with skid marks, crime scene investigators can collect these traces and compare them with the tires from a suspected vehicle. The result of this analysis is not as powerful as having individual characteristics that will identify the exact tire, but it adds one more piece of information to the investigation.

SEE ALSO Accident reconstruction; Automobile accidents; Casting; Locard's exchange principle.

Toolmarks

A toolmark is defined as the impression left by the contact of a tool (or a similar object) onto a surface. When the tool or object contacts the surface with sufficient force to create an indentation, the pattern of the tool is permanently reproduced onto that surface. Toolmarks examination is an important discipline of **criminalistics**. Its goal is to establish a link between a toolmark and the tool that created it. Such links are crucial in forensic sciences, as tools are often used in criminal activities, particularly in burglaries, and can help to identify a criminal. For example, when a burglar uses a pry bar to force entry into a house, the marks left by the tool on the door frame are direct **evidence** of the presence of that tool for that particular use at the crime scene. If the tool is found with, or near, a suspect, it permits the establishment of a link between the suspect and the crime scene. Thus, the recognition and collection of toolmarks at the crime scene and their examination at the laboratory are paramount.

Toolmarks bear two kinds of characteristics: class and individual. The class characteristics of a toolmark include the type of impression, its general shape, and its general dimensions. Class characteristics typically allow the examiner to determine what type of tool created the impression and how the mark was created. Conversely, they do not permit for the **identification** of the exact tool that created the impression. This means that if only class characteristics are available on a toolmark, it will not be possible to distinguish which tool, among a series of similar tools, made the impression. Individual characteristics, also called accidental characteristics, are the striations and small particularities exhibited by the tool that are individual to one unique tool. They consist of small, commonly microscopic, indentations, ridges, and irregularities present on the tool itself. For example, the tip of a screwdriver is never perfectly flat, but shows small ridges along its edge. These are created by the history of the tool such as its use and misuse, its cleaning, and its maintenance. These characteristics are the only ones that permit a formal identification. If such characteristics are present in the toolmark, it is possible to identify the actual individual tool that created the impression, even among a series of identical tools.

There are two main types of toolmarks that can be distinguished: slipped and molded impressions. The slipped impression occurs as the tool drags or slides across the surface. The resulting toolmark is a series of striations running parallel to each other following the direction of the drag. For example, such impressions are created by slipping a key across the door of a vehicle, by cutting with a knife (not used in a sawing motion) through a given material, or by cutting an electrical wire using a pair of lineman's pliers. The molded impressions are the result of the contact of a tool onto a surface with no lateral motion (no drag nor slip). The resulting toolmarks are a three-dimensional mold of the part of the tool that contacted the surface. Examples of such impressions are the leverage of a door from its frame with a pry bar, or the serial number stamped onto a firearm's barrel. Some toolmarks are made of a combination of molded and slipped impressions.

Toolmark examination is a term that includes a wide variety of impressions that are not necessarily directly related to tools but that are created via the same fashion and are, therefore, examined with the same techniques. A clear example is the impression left by a firearm's barrel onto a bullet or by the firearm onto the cartridge. These are a specialized category of toolmarks. Other examples include the impressions left by human teeth or even the impressions left by shoes or tires. Very often, the toolmark examiner is the person responsible for examining and rendering expert opinions on such impression's identifications.

The examination of toolmarks is conducted in different phases. First, the toolmark is observed, measured, and described. Second, a photograph perpendicular to the toolmark, is taken. This provides a permanent record of the class and some individual characteristics of the toolmark. Then, if the support onto which the toolmark is located cannot be collected as evidence, a cast of the toolmark is made. This cast is usually made with polymeric dental paste. When a tool is discovered and its class characteristics match the ones exhibited by the toolmark, the comparison process is started. Usually, the tool is observed and photographed. Then, comparison toolmarks are made with the tool on a soft material so that extra marks are not created on the tool. A **comparison microscope** is used to perform the comparison process. The incriminated toolmark is placed on the left side of the microscope and the comparison mark on the right side. If a match exists between the individual characteristics, the common origin between the incriminated toolmark and the tool is established.

SEE ALSO Casting; Impression evidence; Microscope, comparison.

Toxicological analysis

An important facet of a forensic investigation can be the analytical examination of **fluids** such as **blood** and urine for the presence of compounds that are not normally present. These can include excessive levels of prescription drugs, **illicit drugs**, and toxic compounds. The latter can be naturally occurring inorganic or microbial **toxins** or can be synthetic in origin.

Toxicological analysis is concerned with over 150 different compounds, depending on the circumstances of the crime or accident, and the observations of the physical appearance of the victim or suspect. As just a few examples, these include stimulants (amphetamine, caffeine, cocaine), alkaloids and amines (dextromethorphan, ephedrine, quinine), narcotics and analgesics (codeine, morphine), hallucinogens (LSD, PCP), antidepressants, sedatives (**barbiturates**), tranquilizers, marijuana, and amyl nitrate.

Toxicological analysis is done in several different ways, depending on the target compound. Typically, the fluids that are of forensic interest are blood and urine. At a crime or accident scene, or even later, collection of the fluid is all that is necessary. The actual analysis is done in a dedicated laboratory using sophisticated equipment and trained personnel.

Collection for analysis needs to be done under controlled conditions using collection reservoirs especially designed for the purpose. For example, collection of a urine sample in a non-sterile container without a lid could result in contamination of the urine and would be grounds for subsequent legal inadmissibility of the results. Fortunately, protocols for sample collection and transport are relatively easy to observe.

Toxicological analysis is geared towards the detection of the presence of a compound (qualitative analysis) rather than determining the amount that is present (quantitative analysis). Other than alcohol, determining the actual amount of a compound is of little value. For many illicit drugs, there are really no beneficial levels. Thus, for example, merely demonstrating the presence of marijuana or cocaine is sufficient.

Often, a toxic or illicit compound is present in blood or urine along with other substances. To identify the target compound, it must be physically separated from the other compounds.

One tried and true method of physical separation is **chromatography**. In the various forms of chromatography, compounds are separated from one another based on their tendency to prefer either a solid material that is packed in the volume of the chromatography column (the stationary phase) or the fluid or gas that percolates through or over the stationary phase (the mobile phase).

There may be several compounds in a sample that show a preference for the stationary or mobile phases. By tailoring the chemistry of the stationary phase (commonly by judicious selection of the stationary phase material and the composition of the chemical side groups that protrude from the material or the thin coating of fluid that chemically clings to the solid) and the composition of the mobile fluid, different compounds will move through the column at different speeds.

Sample molecules can move through the matrix passively, under the force of gravity or via capillary action as liquid is drawn upwards into chromatographic paper, or can involve the use of a pump to drive the sample through the matrix at high pressure.

As the fluid emerges from the chromatographic column, it is collected in defined amounts. Thus, the separated compounds in the mobile phase will be collected in different reservoirs for their subsequent analysis.

The compounds that have been more tenaciously retained in the solid material in the column can then be chemically driven off of the material by the addition of fluid that differs in chemistry from that present initially. This step is known as elution. Elution can be tailored so that the compounds are released at different times.

In gas chromatography, the mobile phase is an inert gas such as helium, while in liquid chromatography this phase consists of a liquid. The latter form of chromatography ranges in sophistication from the dipping of one end of a strip chromatographic paper in liquid, with the separation of compounds occurring as the liquid moves upward through the paper via capillary action, to high-performance liquid chromatography (HPLC), in which compounds are powered through the matrix at high pressure.

Ion exchange chromatography is also useful in forensic **toxicology**. This relies on the net charge (the balance of positive charges and negative charges) of the target molecule. If a compound has an overall net negative charge, it will be retained more so by a positively charged material than by a negatively charged matrix. The opposite is true for a compound that has a positive net charge.

Chromatography can be combined with mass spectrometry to reveal very detailed information about the separated compounds. For example, the use of mass spectrometry can reveal the molecular weight of each separated compound. When two mass spectrometers are connected in series (tandem mass spectrometry), the arrangement of amino acid build blocks of the separated proteins can be determined, as can the types of fatty acids that comprise a lipid sample.

Other detection methods include the absorption of ultraviolet radiation by the sample molecules (evident by a change in absorbance on a plotted graph), the different refraction of light by different molecules (which can be quantified as a refractive index), and the reaction of certain sample chemical groups with light that results in the emission of light of a different wavelength (**fluorescence**).

A different, and very efficient and economical, way to separate various proteins in blood and urine is **electrophoresis**. The technique is based on the migration of charged molecules in a solution in response to an electric field. The differing rates at which proteins migrate depends on the strength of the electric field, the protein's net charge, the size and shape of the protein molecules, and on the properties of the support matrix through which the molecules move.

The support matrix is typically paper, cellulose acetate, starch gel, agarose (which is purified from various species of seaweed), or polyacrylamide gel. The latter two are used most commonly.

Agarose and polyacrylamide are prepared as molten suspensions, which are poured into a mold. As

Ukranian President Viktor Yushchenko photographed in March 2002, left, and December, 2004, right. Toxicological analysis found the mysterious illness that scarred Yushchenko's face was caused by dioxin poisoning. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

the suspension cools, a gel forms. Depending on the concentration of the agarose or polyacrylamide, the gel will contain spaces that vary in size. Thus, agarose and polyacrylamide gel electrophoresis provide ways of separating different protein species and even nucleic acid fragments based on their different sizes.

By the inclusion of the appropriate controls, nucleic acid electrophoresis can even reveal the sequence of nucleotide building blocks that make up deoxyribonucleic acid (**DNA**). Indeed, prior to the advent of computer technology and **gene** sequencers, the determination of DNA sequences was routinely done this way.

In electrophoresis, the separated compounds will typically form "bands" in the gel, which can be detected using special stains. As well, since under some electrophoretic conditions regions on the separated proteins can retain their ability to react with antibodies, the latter can bind to the protein. Then, tagging the bound **antibody** with a fluorescent probe allows a specific protein to be detected fluorescently.

More recently, the technique of capillary electrophoresis has proved useful in toxicologal analysis. Instead of a gel, compounds move through a tube of extremely small diameter (the capillary). The charge on the capillary wall retards the motion of the compounds to varying degrees.

Capillary electrophoresis is quite efficient; compounds that are very similar in character can be separated this way. As well, very small sample volumes are used and the separation is completed very quickly.

When the target compound is a protein, the molecule can be distinguished from other proteins by antibodies that have been formed in response. Generically, this approach is known as antibody capture. The binding of an antibody to its corresponding **antigen** can cause formation of a complex that becomes so large that it precipitates out of solution or suspension. Even more sophisticated applications of antibodies are available. For example, antibodies can be bound to magnetic particles. Once binding of the antibody-magnetic particle complex to a protein has occurred, the protein can be magnetically separated from other proteins in the mixture.

No matter what the nature of the toxicological analysis procedure, all are conducted using standard protocols and with the inclusion of the appropriate controls to ensure that the equipment is operating properly, that what is supposed to be detected is indeed being detected, and that extraneous or interfering compounds are excluded from detection.

These rigorous quality control procedures helps strengthen the validity and legal admissibility of the results of the toxicological analysis.

SEE ALSO Analytical instrumentation; Antibody; Biosensor technologies; Chromatography; Fourier transform infrared spectrophotometer (FTIR); Gas chromatograph-mass spectrometer; Pathogens; Spores; Thin layer chromatography.

Toxicology

Since **forensic science** is often concerned with determining the basis of death, investigations frequently are concerned with the influence and effects of **toxins**.

The science of toxicology is concerned with the adverse effects of chemicals on biological systems and includes the study of poisons, their detection, action, and counteractions. Toxicologists today generally use the techniques of analytical chemistry to detect and identify foreign chemicals in the body, with a particular emphasis on toxic or hazardous substances. Toxins can be simple metal ions or more complex, inorganic and organic chemicals, as well as compounds derived from bacteria or fungi and animal-produced substances such as venoms. Poisons can range in their effects from a low-level debilitation to a near instantaneous death. Many drugs used to counter diseases can also be poisons at higher concentrations.

One of the most significant historical figures in the development of the science of toxicology was the Swiss physician and alchemist, Paracelsus (1493–1541). He realized that there was a need for proper experimentation in the field of chemical therapeutics and distinguished between the therapeutic and toxic properties of substances, recognizing that they are indistinguishable except by dose. Paracelsus realized that it is not possible to categorize chemicals as either safe or toxic and laid the foundations for a key principle in toxicology known as the dose-response relationship.

There is a graded dose-response relationship in individuals and a quantal dose-response relationship in a population. The quantal "all or none" dose-response is used to determine the median lethal dose (LDm), which estimates what percentage of the population would be affected by a dose increase. Estimation of LDm involves the use of at least two different animal species and doses of the chemical under test are administered by at least two different routes. Initially, most of the test animals die within 14 days. Subacute exposure is then tested for a period of 90 days and long-term exposure testing takes a further 6 months to 2 years. Mathematical extrapolation is used to generalize results from animal testing to human risk incidence.

Another significant figure in toxicology was Spanish physician Matthieu Joseph Bonaventure Orfila (1787–1853) who contributed to the specialty known as forensic toxicology. He devised methods of detecting poisonous substances and therefore provided the means of proving when criminal poisoning had taken place. After Orfila, toxicology developed further to include the study of mechanisms of poison action.

Forensic toxicology involves the use of toxicological methods for legal purposes. There is a considerable overlap between forensic and clinical toxicology, **criminology**, forensic **psychology**, drug testing, environmental toxicology, **pathology**, pharmacology, sports medicine, and veterinary toxicology. The work of a forensic toxicologist generally falls into three main categories: **identification** of drugs such as heroin, cocaine, cannabis; detection of drugs and poisons in body **fluids**, tissues, and organs; and measuring of alcohol in **blood** or urine samples. Results of the laboratory procedures must then be interpreted and are often used as **evidence** in legal cases.

A forensic toxicologist is normally given preserved samples of body fluids, stomach contents, and organ parts along with a coroner's report containing information on symptoms and postmortem data. Specimens are generally divided into acidic and basic fractions for drug extraction from tissue or fluid. As an example, most of the barbiturate drugs are acid-soluble while most of the amphetamine drugs are base-soluble. After preliminary acid-base procedures, tissue or fluid samples are subjected to further laboratory tests consisting of screening tests and confirmation testing. Screening tests allow the processing of many specimens for a wide range of toxins in a short time and any positive indications from the screens are then verified with a confirmation test.

Various screening and confirmatory laboratory tests are used in **toxicological analysis**. There are three general types of screening tests. Firstly, physical aspects of a substance such as boiling point, melting point, density, and refractive index can be determined. Secondly, the substance can be crystallized, which can give a wealth of structural information. Thirdly, chemical spot testing can be done. Here, a substance is treated with a chemical reagent to produce crystals. Fourthly, thin layer or gas **chromatography** can be used to separate individual chemical components of a mixture.

Confirmatory tests generally involve mass spectrometry in combination with gas chromatography. Every toxin has a characteristic mass spectrum that identifies it absolutely.

Drug analysis in tissue samples can be very complicated and a substance under analysis must be subjected to rigorous tests with no margin for error. A range of screening tests employing color reactions exist for the detection of illegal drugs. Some commonly used color tests include the Marquis test for opium, Duqunois-Levine test for marijuana, Van Urk test for LSD, Scott test for cocaine, and the Dillie-Koppanyi test for **barbiturates**.

The challenges of modern science call on clinical and forensic toxicologists to expand their services. They are now encouraged to engage in research and development to meet a number of changing needs. Modern molecular biology has opened up a number of interesting possibilities for toxicologists. For example, genotyping for interpretation of potential toxic drug interactions and criminality testing is becoming a field of great interest. With the emergence of pharmacogenetics, genotyping may enhance rational drug therapy for better patient care, and may explain unexpected adverse or fatal drug reactions in postmortem analysis.

SEE ALSO Aflatoxin; Anthrax, investigation of the 2001 murders; Biological warfare, advanced diagnostics; Forensic science; Thin layer chromatography.

Toxicology, specialty areas

Broadly speaking, poisons are substances that cause harmful effects when they are introduced to living organisms. **Toxicology** is the systematic study of poisons. There are many different ways in which toxicology can be approached.

Interest in poisons, and their practical relevance to humans, goes back to antiquity. No doubt the earliest of humans recognized the effects of poisons in the form of animal venom or poisonous plants. Many poisons were included in the medical writings of ancient Egypt in the Ebers Papyrus (the oldest preserved medical document, written about 1552 B.C.), and by the time Greek **culture** had risen to prominence, the systematic study of poisons and their uses in everyday life had become fairly well developed. It was common practice throughout the ages for rulers and leaders to employ a cupbearer to taste their wine and food to avert threats of poisonings. Focus on toxicology has increased in recent years because of concerns for environmental pollutants and worries over toxic food additives. This resulted in the creation of the Environmental Protection Agency in 1970, and the Toxic Substances Control Act in 1976, which requires all uses of new chemicals be reported to the EPA prior to their use.

Forensic toxicology is a combination of analytical chemistry and general principles of toxicology. This is a branch of **medicine** that focuses on medical **evidence** of poisoning, and tries to establish the extent to which poisons were involved in human deaths. Forensic toxicology is in many ways a kind of detective work that assembles the subtle clues found in the tissues of the body during **autopsy**.

Clinical toxicology is the study of diseases and disease states caused by exposure to **toxins**. This differs from forensic toxicology in that it is most often a study of the living, rather than only the dead. It often involves a study of toxicokinetics, the study of how the levels of toxicants and their metabolites change over time, the time that it takes to eliminate toxicants after exposure, and ways in which the toxic effects of various poisons can be reduced in persons who have been exposed, or how elimination of the toxicant can be increased.

Descriptive toxicology is concerned directly with toxicity testing. In descriptive toxicology, the toxic properties of chemical agents are systematically studied for various endpoints using a variety of different organisms. At what point does a chemical agent cause death to 50% of the animals under study? To what extent are various agents irritating to the eyes? How frequent are birth defects in the offspring when mothers are exposed during pregnancy? Descriptive toxicology is an attempt to characterize the toxic potential of various agents in a wide array of systems.

Mechanistic toxicology is the study of the many mechanisms by which toxins exert their effects on living systems. This is the identification of the targets to which toxins may bind, the tracking of the toxin as it is absorbed and distributed throughout the body, and the process as it is metabolized and altered by the body. This includes study of the stepwise manner in which toxicants enter the system, find their targets, and make incremental changes on the natural system. Mechanistic toxicology also involves the study of how these agents are metabolized and excreted after exposure has occurred.

Regulatory toxicology is the translation of laboratory testing data into policies concerning the applications and uses of chemicals in society, and the limits of allowable exposure in various settings. The regulatory toxicologist compares the toxicity profile with other known toxicants and tries to establish standards for allowable limits that are consistent with other agents with similar effects. Regulatory toxicology is the primary basis for laws that limit exposures for people and for the environment.

Biochemical toxicology is the study of the interactions toxicants have within living systems. Many of the aspects of mechanistic toxicology are found in the study of biochemical toxicology. What are the portals of entry into the living system? How is the agent distributed and metabolized once it is taken in? How does toxicity vary by age, sex, diet, and during pregnancy? What are the sites of action of the toxicant? How is the toxicant eventually metabolized and eliminated?

It wasn't very long ago that lakes, rivers, and oceans were considered to be a nearly infinite in size; the atmosphere an infinitely large reservoir of air; and the ground a nearly endless reserve for solids. Consequently, wastes from manufacturing or daily living were dumped into the ocean, released through smokestacks into the air, or buried into landfills without concern for the long-term consequences. Rachel Carson's book *Silent Spring*, published in 1962, served as a powerful warning that continuing these practices would lead to a progressive erosion of many different ecosystems. The area of environmental toxicology arose to a high level of social concern for the study of the impact of toxic agents on the environment, and the fate of toxicants released into various ecosystems.

Pollutants in the air that can have sweeping consequences in human health and in various ecosystems have been long recognized as a problem in society. Environmental toxicology studies of the air can include the types and sources of airborne pollutants, acute and chronic health effects of various pollutants in the air, transport of particulate and gaseous pollutants in air, changes in the ozone layer resulting from natural and man-made pollutants, chemical and photochemical transformations and reactions, and monitoring of toxicant levels over time. Similarly, environmental toxicology studies of soil and water follow many of the same kinds of issues and problems seen with air pollutants.

Teratology is the study of the effect of toxicants on the developing embryo when the mother is exposed during pregnancy. Teratogens are agents that are capable of causing birth defects when exposure occurs during pregnancy. Embryonic and fetal growth and development begins at the time of conception, and continues on for a period of approximately 9 months. This is a time of remarkable growth, and a unique period of development of body tissues, organs, and structures.

For teratogens, the timing of exposure is a key consideration. The two-week period from conception until implantation into the uterus is generally regarded as an all-or-none period where toxins will either cause pregnancy failure altogether, or have no effect at all. As pregnancy proceeds from this point, many changes are taking place. The embryo starts off as a single cell, but very quickly grows and becomes highly organized, first with the development of specific tissues, followed by development of many different organs and body structures. Toxins that might not be very harmful in adults or children could disrupt these unique events during embryonic or fetal development. Because the various stages of development are carefully timed, it becomes essential to know the timing of exposures to various potential teratogens in assessing their safety. As in most other areas of toxicology, the amount of the toxicant reaching the target tissue is another important variable. As prescription drug exposures are fairly well defined both for dose and for timing, most of the reliable data on potential teratogens is associated with prescription drug use. **Illicit drugs**, and other environmental exposures are harder to track, and it is often difficult to establish the safety or risk associated with these kinds of agents. True teratogens generally leave a distinctive pattern of specific birth defects following exposure at a specified critical time during pregnancy. Exposures at times outside of the critical time period often have no toxic effects on the developing baby.

Genetic toxicology is the study of the effects of chemicals and other environmental agents that can cause mutations or cancer. Agents that cause cancer are called carcinogens, and those that cause genetic mutations are called mutagens. Agents that cause

chromosome breaks and rearrangements are called clastogens.

The Delaney Clause prohibits the use of any chemical intended for use in food in the United States that is found to induce cancer when ingested by humans or animals. Every new chemical that is proposed for use in foodstuffs therefore undergoes extensive testing to evaluate its carcinogenic potential, and all drugs and candidate drugs are subjected to similar scrutiny.

There are a number of approaches used to investigate the carcinogenic potential of chemicals. One method is to expose laboratory animals such as mice, rats, or dogs to a range of doses of a drug or chemical for the duration of their lives, and to compare their rates of cancer with control animals that are not exposed. A true carcinogen will generally show a significant difference in cancer rates between animals that are exposed compared with those that are not, and usually there is a higher rate of cancer in animals receiving higher doses compared with those receiving lower doses.

Other tests for cancer causing potential are focused on cells grown in culture. In these tests, the endpoint is usually not cancer, but some other physiological or biochemical change known to be associated with cancer such as breaks in **DNA**, chemical modifications of DNA, or a wide variety of other biochemical changes. Testing, such as the Ames test, may involve bacterial cells. Yeast, insect, rodent, and human cells may be utilized in different assays. These tests are relatively inexpensive compared to long-term animal exposure studies. Most often these tests are used to screen for carcinogens to avoid long-term whole animal studies, or are used to support the apparent safety of agents that test negative in long-term studies.

SEE ALSO Air and water purity; Animal evidence; Botulinum toxin; Death, cause of; FDA (United States Food and Drug Administration); Toxicological analysis; Toxins.

Toxins

Toxins are harmful compounds that are produced and released by a variety of microorganisms and other organisms. Toxins can be fast-acting and, because they are already pre-formed, do not require the growth of a microorganism in the host. The illness and death that result from exposure to a variety of toxins make their detection a central part of **forensic science**.

Toxins are the main disease-causing factor for a number of bacteria. Some examples include *Corynebacterium diphtheriae* (diptheria), *Vibrio cholerae* (cholera), *Bacillus anthracis* (**anthrax**), *Clostridium botulinum* (botulism), certain strains of ***Escherichia coli*** (hemolytic uremic syndrome), and *Staphylococcus aureus* (toxic shock syndrome).

Certain species of these bacteria are of particular concern in biological warfare and biological terrorism. As the events of 2001 in the United States demonstrated, powdered preparations of *Bacillus anthracis* **spores** were easily delivered to a target through the mail. The dispersal of the spores in the air and the inhalation of the spores can cause a form of anthrax that develops quickly and, without treatment, is almost always fatal. The bacteria in the genus *Clostridium* also form spores. Additionally, during the 1990s, a strain of *Staphylococcus aureus* emerged that is resistant to almost all known **antibiotics**.

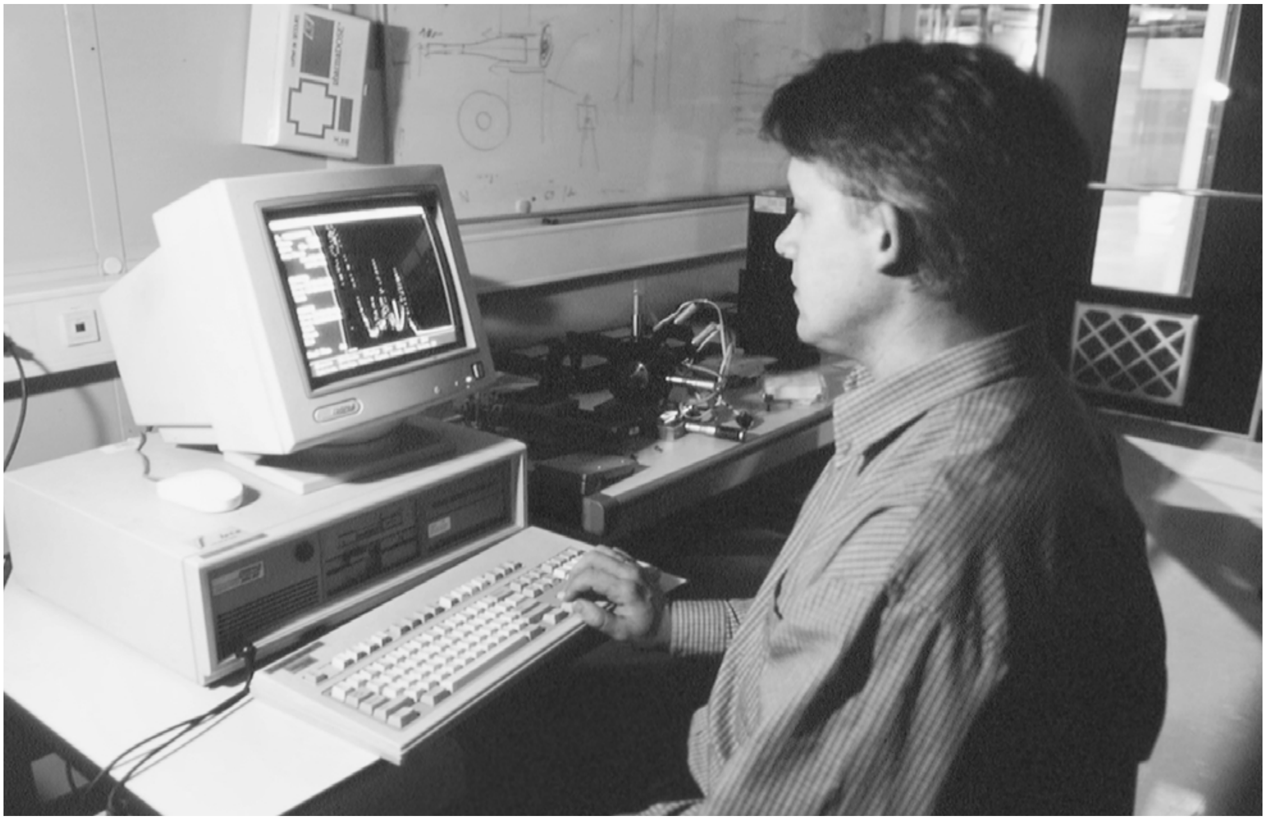
Bacterial toxins have a wide variety of activity. Some toxins damage the cell walls of host cells, either by dissolving the wall or by chemically punching holes through the wall. Examples of such toxins are the alpha toxin of *Clostridium perfringens*, hemolysin of *Escherichia coli*, and streptokinase of *Streptococcus pyogenes*. The damage to the host cells allows the bacteria to spread rapidly through the host. This can cause an overwhelming infection.

Other bacterial toxins kill host cells by stopping the manufacture of protein in host cells, or by degrading the proteins. Examples of protein blockers include exotoxin A of *Pseudomonas aeruginosa* and the Shiga toxins produced by both *Escherichia coli* and *Shigella dysenteriae*. Protein degrading toxins include those produced by *Bacillus anthracis* and *Clostridium botulinum*

Still other toxins stimulate an immune response of the host that is so strong that it can damage the host. The toxic shock syndrome associated with *Staphylococcus aureus* results from a host hyperimmune response to three of the bacterial proteins.

Other microorganisms also produce toxins. Marine microorganisms called dinoflagellates can produce toxins when they grow in species of shellfish. Eating the toxic shellfish can cause serious illness.

Some species of mold produce **aflatoxin**. *Aspergillus flavus* and *Aspergillus parasiticus* are aflatoxin-producing molds. The toxin is especially a concern when potatoes are contaminated. Ingestion of the contaminated potatoes can cause serious, even fatal illness.



In 1994, French researchers ran tests using two strands of Napoleon's hair to rule out possible intentional poisoning of the French ruler. Napoleon did have elevated levels of arsenic in his hair, but not enough to cause his death. © FREDERIC PITCHAL/CORBIS SYGMA

Ricin is a toxin that is produced by the castor bean. It is the third most deadly toxin that is known, after the toxins produced by *Clostridium botulinum* and *Clostridium tetani*. The symptoms of ricin toxin include nausea, muscle spasms, severe lung damage, and convulsions. These symptoms appear within hours, and, without treatment, death from pulmonary failure can result within three days. There is no vaccine or antidote for ricin toxin.

Some toxins that are capable of causing much harm are also a source of protection. Because of its potency, a toxin cannot be used protectively in its unaltered form. Toxins can be altered, however, so that they do not produce the undesirable effects, but still stimulate the **immune system** to produce antibodies to a critical part of the toxin molecule. The weakened version of a toxin is called a toxoid.

The anthrax vaccine that is currently licensed for use contains two toxoids in addition to other immune stimulating molecules. The immune response will produce antibodies to the two toxins of the anthrax bacterium.

SEE ALSO Aflatoxin; Biosensor technologies; Botulinum toxin; Food supply; Pathogens; Thin layer chromatography.

Trace evidence

The scene of a crime often yields a large amount of trace **evidence** that has come from contact between the perpetrator and his or her surroundings. The importance of collecting and analyzing trace evidence comes from Edmond **Locard's Exchange Principle**, which states that every contact leaves a trace. That is, criminals leave something of themselves, such as hair or clothes **fibers**, behind at the crime scene, and they also take something away with them from their contact with people and objects there. Often criminals are not aware of this, because traces of contact evidence are, by their very nature, difficult to detect with the naked eye. It is precisely this property that makes trace evidence so valuable to the forensic investigator. Try as he might, the perpetrator cannot clear away all forms of trace evidence from the crime scene.

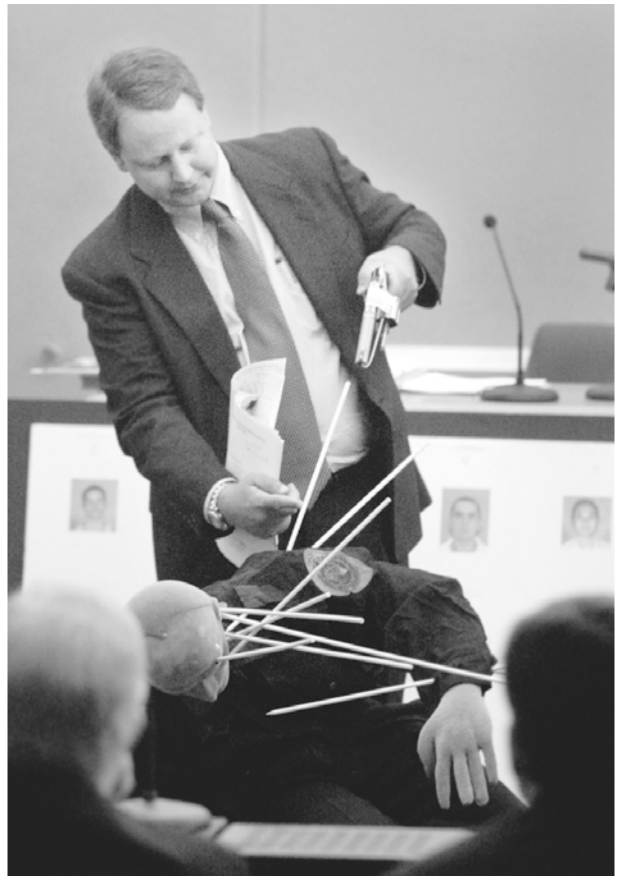
The most common forms of trace evidence are bloodstains, hair, textile fibers, paint, and **glass** fragments. The forensic scientist will be on the lookout for microscopic particles collected from the scene of the crime, to distinguish what is part of that environment and what is linked to the crime that took place there.

At the scene of a crime, the investigators will make an initial assessment that will tell them where to start looking for trace evidence. For instance, if a window has been broken, this might be a good source for textile fibers belonging to the perpetrator that might be matched in an examination of the clothing worn by a suspect. The investigator can probably work with a minute amount of trace evidence, given the power and sensitivity of modern analysis techniques. However, the investigator will be interested in how much material might be available for analysis. Rough surfaces will capture more trace evidence than smooth ones will, for example.

The persistence of the trace evidence is also an issue. Small particles persist longer than larger particles, as do those with irregular surfaces like broken glass or with rough surfaces like wool fibers. Trace evidence landing on a rough surface stays longer than that on a smooth surface. If a suspect's garments are worn between committing a crime and its investigation, there is a high chance that any trace evidence on the clothing may be lost.

However, material forming a smear on the surface through contact persists for longer than particle contact. This applies to **blood** or paint that might be found on a suspect's clothing. Washing may remove it, but otherwise it is more likely to be detected than particulate evidence, which can be brushed off.

Forensic scientists have a range of techniques for detecting invisible trace evidence. Much depends upon the contrast between the trace evidence and its background. Deeply dyed fibers are clearly easier to detect than pale ones, for example. One of the simplest methods of recovering trace evidence is to shake an item into a test container. This works for collecting glass and paint from garments. Some particulate trace evidence will not be dislodged by shaking but can be collected by brushing with a new toothbrush or paintbrush. Taping trace evidence can also be useful in the case of fibers and hairs. Strips of clear sticky tape are applied to surfaces like garments, car seats, and window ledges to pick up any trace evidence that might have been deposited there. Other methods of collection are vacuuming, swabbing, and hand picking.



In a 2001 murder trial in Texas, a senior trace evidence analyst for the Institute of Forensic Sciences shows the direction from which bullets hit a police officer. AP/WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

There are many different techniques in use for the comparison and characterization of trace evidence, depending on its nature. The physical and chemical properties of glass fragments can easily be measured and compared with **control samples**. Textile fibers are often found at the scene of a crime. Typically, these are tiny, broken, and fragmented fibers that are not usually visible to the naked eye. Tapings of these fibers are usually first examined under a low power microscope. Further analysis involves a number of techniques such as **thin layer chromatography** or infrared **spectroscopy**.

Paint is another important kind of trace evidence. It is particularly important in the case of hit and run accidents, where fragments of paint might have been transferred to a victim's clothes or to another vehicle. If a match can be made between paint chips and the missing flakes of paint using microscopy, then a suspect may be either eliminated or convicted.

Hairs collected from the scene of a crime can also be a significant source of trace evidence. The inner layer, known as the cortex, is where the pigment granules lie, and this determines the color of the hair. However, on its own this kind of evidence is not really individualizing. If the hair has fresh roots, however, it may be a source of blood grouping or **DNA profiling**, in which case it may well establish identity. Other sources of trace evidence that can prove significant include: oils and waxes, as found in car accidents; soil, which may be trodden in all types of crime; and invisible bloodstains, which can be visualized with **luminol**. Taking care of the trace evidence may be the key to the investigator helping secure the right result in a crime investigation.

SEE ALSO Crime scene investigation; Hair analysis; Paint analysis.

Training

As a rule, the training for a forensic scientist involves the attainment of at minimum, a bachelor's (four year college or university degree) in criminal justice, biology, chemistry or the physical sciences, **psychology** (or one of the behavioral or social sciences), or forensic technology. Many colleges and universities have begun to offer degrees in **forensic science**, with concentrations in areas such as **toxicology**, **pathology**, or **criminalistics**. Many forensic scientists choose to pursue a master's or doctoral degree in their specialty area. In the United States, there are currently no mandatory requirements for specific licensure in forensics. Most forensic scientists, however, choose to obtain professional certification or accreditation from one or more of the nationally recognized forensic specialty boards, such as the Forensic Toxicologist Certification Board, the Association of Forensic Document Examiners, the American Board of Medicolegal Death Investigators, the American Board of Forensic Odontology, the American Board of Forensic Document Examiners, the American Board of Forensic Anthropology, the American Board of Criminalistics, and the American Board of Forensic Sciences.

The activities of forensic scientists all stem from the concept of using science in its myriad forms to attempt to answer questions regarding the who, what, where, when, why, and how of crime—for all avenues of the law enforcement and legal justice systems. During the investigation of a crime, or at a crime scene, they may identify and collect samples, package and preserve **evidence**, photograph and measure, sketch, draw, and model, estimate timing, stage, and reconstruct events, and help to develop a literal and psychological picture of the crime and its perpetrator.

In laboratory settings, forensic scientists examine **blood**, fingerprints, fiber, clothing, **serum** and tissue, **saliva**, **semen**, and other substances that may contain **DNA** or other physiological identifiers in order to create a unique physiological profile. They assess weapons, drugs, paint, and other materials for their relationship to the criminal event. Forensic scientists examine decomposed or fragmented human remains and build models of their likenesses in order to facilitate **identification**; they gather and synthesize physical and behavioral evidence to create offender psychological profiles; they examine and identify **questioned documents**; they construct, conduct and analyze polygraph, galvanic skin response, and other physiological tests; they conduct forensic psychological and psychiatric assessments and evaluations for both criminal identification and culpability (fitness to stand trial, competency, criminal responsibility, assessments relating to the sentencing process, etc.). Part of the job of a forensic scientist is to document, analyze, interpret, and report findings and the measures used to achieve them, for the criminal justice and legal systems. Forensic scientists are often called to courtrooms as **expert witnesses**.

Forensic scientists may work in the field at crime scene investigations. They may also be employed in the private sector, state, federal, or military crime or toxicology labs, in law enforcement agencies, at hospitals and other emergency or trauma centers, in universities or training academies, at medical examiner's or coroner's offices, or at private forensic science consulting firms.

In addition to careers within the legal, criminal justice or law enforcement systems, a small sample of specialty areas within forensic science include: **forensic nursing** (may work in many areas of forensic science, from emergency wound and trauma care to coroner's offices, to **crime scene investigation**, to victim and offender counseling to consultation to expert witness work); forensic **psychiatry** and forensic psychology (can run the gamut from psychological **profiling** to psychodiagnostics to competency and culpability assessments and evaluations to psychological autopsies to expert witness testimony); criminalistics (the analysis, comparison, identification, and interpretation of **physical evidence**); crime scene investigation (all aspects of documenting, identifying, collecting, preserving and transporting evidence from the location of occurrence); document examination (all aspects of identification and authentication of handwritten, typed, printed, and electronic documents); forensic engineering (crash, blast, accident, and structural failure analysis); forensic anthropology (using physical anthropology techniques to locate, recover and identify human, and sometimes, animal remains, and to reconstruct models or likeness from decayed, decomposed or fragmented remains); forensic **entomology** (estimating **time of death**, or time since death, and studying corpse decay and **decomposition** via analysis of insect populations and insect larvae); forensic linguistics (studying the legal aspects of written and spoken communication, evaluating confessions and the results of **interrogation**, courtroom use of linguistics, etc.); forensic **photography** (use of **cameras** for recording all possible aspects of a crime scene, from all available angles, in order to create a minutely detailed pictorial documentation of the event); and forensic odontology (examination of the teeth of corpses for the purposes of identification; making casts and models of bite marks on victims and at crime scenes in order to identify the person who inflicted the bite).

No matter what the area of specialty, the objective of a forensic scientist is to apply the rules and methodology of science to the criminal justice and legal systems. Forensic scientists may do their jobs anywhere from actual crime scenes to laboratory settings, to hospitals, to medical examiner's offices, to computers, to consulting offices, to courtrooms and beyond. They may be employed by local, state, military, or federal law enforcement or criminal justice systems. They may be trained in criminal justice or in the physical, biological, social or behavioral sciences. They may come from other fields of undergraduate work and then pursue graduate training and specialization in forensics, or they may have academic training specifically in the forensic sciences. They may begin in law enforcement or criminal justice, and then pursue academic training in forensic science. The occupational world of the forensic professional is ever expanding, and will continue to keep pace with advances in science and technology.

SEE ALSO Archaeology; Autopsy; Casting; Crime scene investigation; Identification; Medical examiner; Photogrammetry.

Trajectory

The trajectory of a bullet is the path of flight it follows from being fired to reaching its target. In cases of shootings that claim a victim as their target, the forensic specialist will want to try to work out the trajectory of the bullet as part of the **crime scene reconstruction**. The science of investigating projectile motion is known as **ballistics** and involves equations that can be used to work out a trajectory.

Bullet trajectory of one of the assassin's bullets that killed U.S. president John F. Kennedy, included as an exhibit for the Warren Commission in 1964. © CORBIS

When the trigger of a gun is pulled, it sets off an explosion in the shell of the bullet. Chemical energy is converted into kinetic energy, and the bullet leaves the gun at a high velocity. At this point it is subject to the forces of gravity and air resistance, which make it travel in a roughly parabolic path. The range of the trajectory is the total distance the bullet travels in a horizontal direction, that is, the distance between the gun and its target.

When analyzing the trajectory of a bullet, ballistics investigators divide it up into three parts. First, there is the short journey the bullet makes from where the firing pin strikes it to the point where it leaves the gun. Then there is the journey it makes towards its target, which may last anything from a fraction of a second to several seconds. Finally, the bullet gives up its kinetic energy as it travels through its target. The bullet may end up lodged in a victim's body or, if it has sufficient kinetic energy, it may emerge on the other side, creating an exit wound as well as an entry wound. Sometimes a bullet will ricochet, that is, deviate from its trajectory because of an impact with an object. It can still hit someone but the shot would not have been aimed directly at the victim, which may be an important piece of **evidence**.

The main task of the ballistics specialist is to work out the range of a bullet's trajectory. When a bullet leaves a gun, it carries various gases with it that often form a tattoo-like pattern on the victim's skin. The extent and spread of this pattern is often revealing about the range between the perpetrator and the victim. The investigator will often try to reproduce the pattern by firing the weapon, if it is available, or a similar one at blank targets in a laboratory situation. Knowing the range can help establish where a perpetrator was standing and may either contradict or corroborate witness statements. The range can also help determine whether a fatal shooting was homicide or suicide.

SEE ALSO Ballistics; Bullet track; Gunshot residue.

Transfer evidence

Transfer **evidence** is defined as any evidential substance or particle such as **blood**, **fluids**, hairs, **fibers**, paint, and skin that is exchanged between an assailant and the victim or the scene of the crime. Such evidence can transfer either from the criminal to the victim or from the victim to the criminal. It can also be transferred into or out of the crime scene. This transfer often occurs when forcible contact occurs between persons, vehicles, or objects. For example, when **glass** fragments from one automobile are found on another vehicle, an exchange of transfer evidence has occurred. Different forms of transfer evidence can be small foreign materials such as food particles carried by the perpetrator to the crime scene and left behind, or identifying materials such as the victim's hairs or skin particles carried away from the scene on clothing. Other small particles of transfer evidence may lodge in the hair or under fingernails, or in some other way attach themselves to persons key to the criminal investigation.

An important forensic principle that involves transfer evidence is the **Locard's exchange principle**. Proposed in 1910 by Dr. **Edmond Locard**, the principle states that whenever there is contact between two objects (whether either are a living thing or not), there is a transfer of material between them. It is therefore the responsibility of forensic experts to find that transfer evidence, however difficult it may be to locate.

Transfer evidence often plays a critical role in hit-and-run accidents involving a pedestrian hit by a driver. When investigators locate the wrongdoer and his vehicle, it is common to find blood, pieces of clothing, and skin from the victim on the vehicle and pieces of paint or broken glass on the victim that has been transferred from the driver's vehicle.

The principal investigative value of transfer evidence is its ability to be traced. When it is found on a suspect it connects the suspect with the scene of the alleged crime or with the alleged victim. A suspect, who carries away fragments, small materials, or tissues that are clearly identifiable with the victim, can be definitely associated with a particular crime when such transfer evidence is found. Victims who scratch an assailant often lodge minute skin cells, clothing fibers, and other materials from the assailant's body and clothing under their fingernails. These materials can be retrieved by forensic investigators and used as evidence against the alleged criminal.

SEE ALSO Cast-off blood; Hair analysis; Locard's exchange principle; Paint analysis.

Tree ring analysis SEE Dendrochronology

Trials, civil (U.S. law)

Civil law is also referred to as procedural law; it is the system of legal jurisprudence providing the means and methods by which individuals may legally engage with one another in order to formally address disagreements, and enforce the right of the individual to ask for redress of wrongs (materially or by other means). Civil law provides an efficient, formal, systematic, and impartial means of dispute resolution in a public courtroom setting. The goal of a civil trial is to discern the truth of an event by employing and examining the best possible **evidence**. Civil procedures set forth the requirements for conducting a civil trial, and include laws of evidence to set guidelines for the presentation of witnesses, means of appropriate documentation, and presentation of items of evidence.

The highest Court in America, the United States Supreme Court, has judicial oversight in all matters pertaining to court proceedings, and it stipulates that all procedural rules in the legal system must be consistent with the tenets set forth in the U. S. Constitution, particularly as regards the due processes clauses specified in the Fifth and Fourteenth Amendments. Due process means that everyone in a civil action is entitled to have his/her story heard in an impartial manner.

The American judicial system is said to be an adversarial one, that is, a system in which the lawsuit occurs between the individuals engaged in the disagreement (or, more accurately, their attorneys). The attorneys are responsible for the case and evidentiary presentations, and the judge acts to guarantee the objectivity and fair outcome of the trial. In American civil trials, the judge is an active participant in the trial, examining the evidence and inquiring as to the factual presentations in the case.

Before the start of a jury trial, civil proceedings involve a number of pre-trial pleadings before a professional judge, who makes decisions as to the factual and evidentiary presentations in the case. This pretrial hearing period is then followed by the commencement of the jury trial. In the American civil trial system, juries are composed of lay people, not specially trained to act as officers of the court. As such, they need to have the facts of the case presented in a manner, and at a level of comprehension, that they can understand. They are available only for limited periods of time, as jury summonses pull individuals away from their normal daily business. As a result, trials are conducted in an intensive, focused fashion over the shortest possible period of time in which the evidence can be fairly presented and witnesses can offer their testimony (expert and otherwise). All evidence to be presented must be made available before the start of the trial; it is assembled and offered during the discovery phase of the proceedings. If new evidence is uncovered after the start of a trial, it may necessitate another hearing.

In civil law proceedings, the jury hears the evidence, convenes to make a decision based on presentation of fact, and offers a recommendation based on their conclusions to the judge. The judge makes all decisions regarding matters of law.

In order to be a party to a lawsuit (either plaintiff or defendant), the individual must have the capacity and legal standing to sue another person (or another group of individuals). Minor children and those judged to be mentally incompetent to participate in a lawsuit must be represented by a law guardian who can act on their behalf, and in their best interests.

Those who are directly affected by the outcome of a case are called the parties to an action, and they are generally the only ones bound by its outcome. However, there are situations in which a large group of individuals may be impacted by a specific controversy. In those cases, a class-action lawsuit may be the result. This is a situation in which a smaller number of individuals sue a corporation or a system in order to justify the right to legal relief of a much larger group. All parties to the class action are bound by the outcome. Recent examples of such class actions include an action in which a small group of individuals affected by the leakage of silicone breast implants represented the entire population of individuals who had experienced complications subsequent to silicone breast implants made by a specific manufacturer. All received financial damages as a result of the finding on behalf of the plaintiffs in the suit. In a much smaller example, a group of inmates in a maximum security penitentiary in the state of New Mexico filed a class action suit on behalf of all inmates in maximum and super maximum security facilities in the state regarding the conditions of their confinement, and their experienced limited access to mental health services. As a result of a negotiated agreement, all inmates received greater access to mental health services and improved living conditions, among other benefits.

Lawsuits often take several years for successful resolution. Because of this, the civil legal system provides for the imposition of provisional remedies in order to ensure that the outcome does not become superfluous by the time the case is decided in the courts. Provisional remedies constitute a sort of guarantee to the plaintiff that any obtained future judgment against the defendant will be meaningful. Provisional remedies are generally given if it is the opinion of the court that the plaintiff has a strong factual case, and is likely to garner a positive outcome. Some remedies ensure that the funds required to satisfy an eventual judgment, or to pay court costs, will remain available until the conclusion of the trial. In this case, the funds or real property involved may be "attached" by the court: an officer of the court will seize the funds or property in question and hold them until the conclusion of the case.

A lawsuit is generally divided into two phases, the pleading stage and the trial stage. At the pleading stage, the parties give notice of their claims, defenses, and proposed evidence. At the trial stage, their legal counsel presents their cases of fact before the jury. This is typically accomplished by the production and promulgation of material evidence, and the spoken (sometimes written or videotaped) testimony of witnesses and subject matter experts.

The pleading portion of the case involves the presentation of the formal written documents by which the parties make their claims. Pleadings specify the nature of the argument, they state each part's understanding of the facts of the case, they clarify the issues to be decided, and they provide a permanent record of the outcome and decisions in the case.

A civil jury trial is only mandated when there are disputes as to matters of fact. When cases can be adjudicated based strictly on matters of law, the party concerned can request permission to make a motion to the court to either dismiss the case or to request a summary judgment that can be issued immediately by a sitting judge.

Quite often, a pretrial conference or pretrial hearing is held in which the judge will either try to settle the case out of court, or try to narrow the focus of the issues to be presented at trial. As the civil trial process is so protracted in the United States, there is a great effort made to settle cases without having to go to trial. Generally, one party will make a motion, in an effort to resolve the dispute. When this occurs, both parties appear before a judge who receives all paperwork from each party specific to the motion. No witnesses are heard at motions, and the attorneys each present their specific arguments. In the matter of a request for a summary judgment, the judge is asked to decide whether there exists a matter of material dispute, or whether the preponderance of evidence is on one side of the case. If there is a material issue of dispute, the motion will be denied and the case will proceed eventually to trial. If the finding is the former, the judge can issue a final, legally binding, judgment.

During a civil trial, the attorneys for each party (plaintiff and defendant) make opening statements to the jury in which they specify what they believe to be the central issues of the case, and outline what they plan to prove in matters of fact during the course of the trial. The plaintiff's case is presented first: witnesses are called, questioned and cross-examined by the attorney for the defendant. When the plaintiff's case presentation has been concluded, the defense attorney will call and question his/her witnesses, who can then be cross-examined by the attorney for the plaintiff.

After all witnesses have given their testimony and been examined, and all evidence has been offered and explained, the attorneys for each side make closing arguments to the jury, in which they again present their interpretation of the case facts and the meaning of the evidence as it most positively impacts their client. The judge then instructs the jury on the applicable law. The jury retires to convene for private deliberation on the outcome of the factual case. When it reaches a verdict, the jury returns to the courtroom and the verdict is read in open court.

SEE ALSO Evidence; *Frye* standard; Trials, criminal (U.S. law); Trials, international.

Trials, criminal (U.S. law)

Criminal trials in the United States are governed by criminal law, defined as the body of law charged with the definition of criminal offenses, and the regulation of apprehension, charging, and trial of suspected individuals. Criminal law delineates penalties and specifies appropriate and applicable means and modes of treatment for convicted offenders.

Criminal law refers to offenses committed against the general public, even though the victim of the crime may be a single individual. It is distinguished from civil or tort law in that they (civil and tort law) refer to offenses constituting private injuries. Historically, criminal law has taken the approach that crime is morally, as well as legally, wrong. As a result, amends must be made and retribution for the offense must be exacted through the use of the criminal trial and penalty systems, in a proportion appropriate to the magnitude of the criminal act and the degree of culpability of the perpetrator. More modern views of criminal law have taken the perspective that it ought to serve as a deterrent to the commission of crime. As the tenets of the social and behavioral sciences have been progressively incorporated into the rubric of criminal justice, the concepts of rehabilitation of the criminal offender, and the need for protection of the public welfare have arisen. Among the goals of the criminal legal system are prevention, early intervention, and active deterrence from development and expression of criminal behaviors.

Although American criminal law was derived from English common law, it has some important differences. Primary among the differences is the principle that a person may not be tried for an offense unless it is specified in the statutory code of the state. In all American state systems, there is a rule that judicial proceedings must be fair and impartial, that the rights of the accused, as well as the accuser, must not be violated, and that society must be protected. Individuals have the right to be safe in their environments.

Criminal law is comprised of (1) definitions of the types of punishable offenses; (2) the standardized system for classifying crimes, by severity of general harm inflicted, as misdemeanors or felonies; (3) the specifications applied to the judgment of crime that indicate specific provisions or mitigations for criminal legislation, such as insanity, degree of mental illness (often utilized by the terminology of "guilty, but mentally ill"), necessity, and self-defense; and (4) guidelines for determining national jurisdiction over crimes with an international aspect, such as crimes committed on American soil by foreign nationals, crimes committed by Americans who are located in other countries, and crimes committed on aircraft or maritime vessels located in international waters.

The framework for the procedure and practice of criminal law is embedded in the principle of legality. First, it states that crimes can only be defined in the context of a law prohibiting a specific behavior. If there is no law against a particular act, its occurrence is not a crime. Second, criminal statutes must be rigorously adhered to; they must be construed fairly and consistently, with little or no ambiguity as to their interpretation. Third, and quite importantly, laws may not be applied retroactively; a person may not be tried according to a law enacted after the commission of the crime. Fourth, the language of the law, and the wording of criminal statutes, must be clear, direct, and unambiguous: individuals should be able to clearly understand the concept of violation of specific laws, as well as the potential penalties associated with the possible infraction. Lastly, a person may not generally be tried for the same offense twice (this is also referred to as double jeopardy). In the federal system of the United States, a person may be tried for the same crime in different judicial systems; that is, a person can be subject to both a criminal and a civil trial for a single offense. The principle of the statute of limitations provides the maximum amount of time that can elapse between the commission of a crime and the trial associated with it: generally speaking, the amount of time that may elapse between arrest and indictment and the commencement of the criminal trial can vary according to the seriousness of the offense. In the United States, there is no statute of limitations imposed on crimes considered to be the most heinous, including capital felonies (**felony** crimes punishable by death).

The principle of legal jurisdiction refers to the capacity of a court in a specific geographic region or, in the case of international crime, a country to take valid legal action. Many countries assert jurisdiction over the acts of their nationals even when they are in other countries, and refuse to turn over their citizens to law enforcement agencies in other countries in which their nationals are accused of the commission of a crime or crimes. American nationals who commit crimes in other countries may only be extradited if that is authorized or required by a valid treaty with the affected country.

In the United States, within-country jurisdiction is typically limited to criminal acts occurring in part, or in entirety, within the geographic boundaries of a single state. Historically, if a crime was committed that crossed territorial lines, such as a person in one state throwing an incendiary device across state lines and causing an explosion in a building on the other side of the state line, only the state with the explosion might be considered to have jurisdiction. In modern legal practice, many states have enacted statutes allowing them to extend their jurisdictional boundaries to encompass offenses in which the relevant conduct, or the relevant result, or any part of it, occurred in the specific state. Federal statutes give jurisdiction to United States courts in cases of forgery of ship's papers, bribery of an American official, acts of treason, enticing to commit desertion from the service of the United States military, crimes committed on vessels registered to the United States or on American aircraft flying over international airspace, and similar acts, whether or not those acts actually occurred within the geographic boundaries of the U.S.

There are two mandatory components of an act that lead to definition of a crime. It must be a voluntary action or voluntary omission of an action (legal term: *actus reus*); and it must be accompanied by a specific mental state, referred to as the guilty mind (legal term: ***mens rea***). There are four types of guilty mental state: acting negligently, recklessly, knowingly, or purposely.

The critical defining feature of the act is its volitional nature. A person may not be held criminally responsible for an act committed when they could not exert voluntary control of their behavior, for example, a crime occurring during a seizure or when the individual is in a state of altered unconsciousness not induced by ingestion of illegal substances. In order to be held criminally responsible for committing an act, the perpetrator must act in some way so as to cause its occurrence; it must be possible to establish a cause and effect relationship between the outcome of the act and the individual accused of perpetrating it. An individual may also be held criminally liable for failure to commit an action when he or she was legally responsible for doing so. For example, parents may be criminally prosecuted for failure to meet their obligation to provide food and water for their children.

There are some criminal offenses for which an individual can be charged without demonstrable evidence of a guilty mental state; one of these is statutory rape. An individual need not be aware that the child is below the age of legal consent in order to be prosecuted. Others fall into the category of public welfare offenses, involving such acts as those which endanger public health or safety.

United States criminal law makes a distinction between the concept of ignorance of the facts (in other words, a mistake) and ignorance of the law. In the former, a person is not held liable if he or she unwittingly commits an infraction such as inadvertently picking up the suitcase of another person from a luggage carousel at the airport when it is identical in appearance to his or her own. It is not theft if the baggage was taken without the intention to steal, but rather as a result of the person taking the item believing it to be his or her own personal property. Conversely, being unaware of the text of the law does not excuse a person from prosecution for violating it. It is a commonly held doctrine that criminal acts should be recognized as immoral, societally unacceptable, or harmful by any reasonable adult.

A forensic scientist identifies a .45 pistol during testimony in the trial of convicted sniper John Allen Muhammad, convicted of capital murder for his role in sniper attacks that killed 10 people and terrorized the Washington, DC area in 2002. © DAVE ELLIS/POOL/CORBIS

The issue of criminal responsibility has remained controversial in the American criminal system. Historically, a person was not charged with criminal responsibility if he or she either lacked substantial capacity to appreciate the criminality of his or her conduct or to be able to exercise volitional control over conforming his or her behavior to the extent required by law. The more modern interpretation of the principle looks more strictly at the ability to appreciate the distinction between right and wrong and leaves out the segment on ability to exert control over one's behavior.

The criminal system considers four degrees of participation in a crime. A principal in the first degree is one who commits a crime alone; a principal in the second degree is one who acts to aid the principal in the first degree and is present when the crime occurs; an accessory before the fact is one who instigates, counsels the perpetrator, or encourages the commission of the crime; and an accessory after the fact is a person who receives, conceals, or otherwise assists someone known to have committed a crime, in an effort to obstruct justice from being served. A conspiracy is when two or more individuals agree to act together in order to commit a crime.

Finally, there is the issue of effectiveness of punishment as a deterrent to the commission of future crimes. There is little evidence to suggest that this is an effective paradigm. If the most likely predictor of future behavior is past behavior, criminals who have already been convicted, or who have served prison terms, are more likely to commit future crimes than those who have never done so. Justice system statistics suggest that the degree of punishment is not a deterrent, in that lenient and stringent penalties appear to be equally effective (or ineffective) at preventing recidivism (repeat criminal behavior). Brief sentences are often considered particularly ineffective in that they remove the offender from providing for his or her family for long enough to lose employment but allow enough time to acclimate to being a convict and foster ostracizing from society upon release, yet they are not necessarily long enough to provide benefit from any sort of rehabilitation program. Long-term sentences are tantamount to institutionalization, and encourage complete indoctrination into the prison culture. Forensic psychiatric studies show that the most positive results occur when the principle of least restrictive means is employed; incarcerated individuals are given as much freedom for personal growth as possible within the confines of the penal system and are made to accept personal responsibility for their well-being by means of treatment, employment, education, job training, etc., in order to facilitate a productive transition back into society upon release.

SEE ALSO Criminal responsibility, historical concepts; *Mens rea*; Misdemeanor; Trials, civil (U.S law); Trials, international.

Trials, international

The European Union (EU) consists of a group of twenty-five (25) member and four (4) candidate countries that have established centralized ways of working together; central among these is international law enforcement. Europol is the international law enforcement organization for the European Union. It oversees international management of criminal intelligence, with stated goals of crime amelioration and prevention. Europol supports the underlying law enforcement agencies of each of the member states, and facilitates international cooperation.

The current member states of the European Union are Austria, Belgium, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, The Netherlands, and the United Kingdom. The candidate countries are Bulgaria, Croatia, Romania, and Turkey. Current research and statistics compiled by the International Criminal Police Organization (**Interpol**) suggest that crime among European Union nations has generally decreased during the past several years; this is thought to be due to both improvements in crime investigation methods brought about by advances in **forensic science** and to increasing international legal cooperation.

Exemplary of the increased spirit of international cooperation is an EU-funded program called CTOSE (cyber tools online search for **evidence**); this is an emerging best-practice model for the collection, analysis, storage, reporting, and presentation of electronic evidence. The EU members utilize state of the art forensic scientific methods, such as **DNA identification** and analysis; chemical, biological, biochemical, propellant, and explosive **trace evidence** analysis, and chemical component identification; and assaying, analysis, and identification of human bodily **fluids**, to solve and prosecute violent crimes. They also employ emerging information communication technologies (ICT) to solve and prosecute cybercrime, a burgeoning, and exceedingly expensive, concern worldwide.

An international concern in the prosecution of violent crime has been the lack of standardization of methods used for **DNA profiling**; this dilemma is being resolved by a project designed to standardize DNA profiling techniques in the EU (STADNAP). DNA profiling and analysis, because of its considerable expense, is not readily affordable for every nation in the EU. Consequently, the science of **ear print analysis** has been gaining a measure of popularity in international forensic science. In addition to the economic concerns, ear print analysis/identification is considered (relatively) incontrovertible in the justice system; it is virtually impossible to tamper with and equally difficult to accidentally introduce at a crime scene.

The European Union funds projects for the forensic scientific development and advancement of ear print analysis, called FEARID. The FEARID projects are considered another means of creating international standardization for the collection, analysis, interpretation, presentation, and legal system utilization of forensic scientific evidence. FEARID is setting the stage for a worldwide database for the collection and storage of individual ear print data.

Another international program spearheaded by the EU concerns explosive trace analysis (ETA). When a bomb explodes, residue remains in the form of unreacted explosive, propellants, accelerants, or other evidentiary materials. Minute amounts of trace materials can be collected, chemically isolated, and identified. These identified materials can be compared to those collected from suspects or known terrorist groups, and utilized as evidence in international trials.

In 2000, a new international currency was launched, called the euro. In anticipation, Europol expected a surge of counterfeit Euro coins and paper notes. An international decision was made to create a failsafe system consisting of distinctive watermarks, machine-readable properties, special fiber content resulting in identifiable (yet extremely difficult to reproduce) tactile qualities, and a foil hologram. The EU launched the Eurodetector project, targeted not only at uncovering counterfeiters, but also at providing an affordable system for authenticating and counting money.

Because humans have become progressively more mobile during the past century, it has become increasingly important for international police, criminal justice, and legal system authorities to become proficient at identifying even the most miniscule bits of evidence, whether they be paint, **glass**, solvents, or resins, soil, trace **minerals** from toxicological specimens, or bullet or weapon fragments. Until recently, there was little standardization among forensic chemical or biological laboratories; this made international (and sometimes interjurisdictional) comparisons virtually impossible. The EU created an expert working group of more than a dozen forensic science laboratories spanning Europe, the United States, and Australia for a project called Nite-Crime (Natural isotopes and trace elements in **criminalistics** and environmental forensics) designed to develop advanced mass spectroscopy-related chemical analysis techniques for identifying the components of extremely minute fragments in inert materials and unequivocally linking suspects to crime scenes.

Another international use for evolving mass **spectroscopy** techniques is in solving homicides in which the victim has been transported from one location to another. Forensic scientists sample traces of mineral debris on the victim's body or clothing, and compare them against samples removed from both sites in order to ascertain that the victim was at both locations. Mass spectroscopy procedures combining different methods of chemical elemental separation with **laser** ablation techniques requiring only scant samples are facilitated by the Nite-Crime project and have successfully provided proof of victim location and transportation between sites.

In 1999 the European Union committed to the creation of a cooperative network of national law enforcement authorities responsible for crime prevention. This laid the groundwork for the creation of the European Crime Prevention Network in 2001 and underscores the EU's commitment to a uniform and integrated approach to the investigation, solution, and prosecution of international crimes. Forensic scientific criminal investigations are at the cornerstone of Europol's intelligence efforts. With increasing terrorist threats, coupled with the very real concern of nuclear proliferation, a new market for international trafficking has been created—that of international transport of nuclear materials. This has, in turn, spawned a new field—international nuclear forensic science.

As information technologies continue to explode worldwide, the concept of international security, whether in individual homes, at the workplace, or online, has become progressively more difficult to effect. Because each nation varies in the level of sophistication of its information technology systems, there has been little international coherence; this is especially problematic as information technology (Internet) and cybercrime is propagated across the globe virtually instantaneously. Worldwide problems require worldwide solutions and the EU enacted a Council Framework Decision on "Attacks against information systems" in 2002, which was designed to promote global cooperation and thereby improve cross-border and cross-continent information security.

The Forensic Science Service, an affiliate of the ENFSI (**European Network of Forensic Science Institutes**), provides support to law enforcement and criminal justice systems worldwide. It is a UK-based organization providing services internationally, designed to partner with worldwide criminal justice systems in order to diminish criminal activity. In addition to its worldwide criminal investigation capabilities, FSS advises (and provides oversight for) global government agencies on best practice approaches to the construction and equipping of forensic science facilities; they also maintain FORS, a worldwide forensic science literature database. In addition, FSS provides on-site expert **training** in cutting edge equipment and emerging technologies for forensic laboratories. The FSS offers worldwide forensic expert/expert witness support to the criminal justice system; some examples drawn from international trial transcripts follow.

This example involves FSS's use of familial DNA searching, resulting in the world's first successful prosecution using this technique. Nineteen-year-old Craig Harman had spent the evening of March 20, 2003 drinking with a friend. On their way home, the pair decided to attempt to steal a car (a Renault Clio). Their attempt at hotwiring the vehicle was unsuccessful, so they each decided to take a brick from a neighboring garden and throw it at oncoming traffic (they were about to cross a footbridge over the M3 in Surrey, UK). As they crossed the bridge, Mr. Harman and his companion tossed their bricks at oncoming traffic. One brick broke through the windshield of a truck driven by Michael Little from Essex; the other nearly hit another car.

The brick struck Mr. Little on the chest, causing heart failure and death. Forensic scientific examination of the brick that caused Michael Little's death yielded a mixed DNA profile for the victim and another person. A full DNA profile was obtained from **blood** found on the nearby Renault Clio. A highly sensitive technique called DNA Low Copy Number was utilized; it revealed that the partial profile obtained from the brick matched the full DNA profile found on the Renault Clio, linking the two crimes. The full profile was run against the UK National DNA Database (NDNAD) without uncovering a match. The ethnic markers elicited form the DNA profile indicated that the suspect was a Caucasian male; crime scene details suggested a perpetrator less than 35 years of age. The nature of the crime indicated a likelihood that he was a local resident, so the Surrey Police force conducted an intelligence-led DNA screen of 350 individuals (volunteers) from the surrounding area; again, no match. A groundbreaking decision to use familial searching was made, in an effort to uncover a suspect by searching NDNAD for persons who most closely matched the unknown DNA profile. The search parameters were narrowed to Caucasian males below the age of 35 who lived in the geographic areas adjacent to the crime. This method yielded a list of 25 names; the closest profile matched 16 of 20 parameters, indicating that it belonged to a close biological relative of the perpetrator. This data provided a direct link to Craig Harman; he was interrogated and he supplied a DNA sample. When it was analyzed, the sample exactly matched the one from the brick at the crime scene. Craig Harman went to trial and was convicted of **manslaughter**.

In 1981, a fourteen-year-old girl was raped, beaten, and strangled after being attacked while en route from her home to band practice in Hampshire, UK. There was a massive investigation at the time of the incident, but no suspect was found. A single microscopic slide containing biological evidence collected from the victim by the FSS was intentionally saved, in hopes that DNA evidence processing techniques would eventually be perfected for use with very small samples. In 1999, the FSS perfected their use of DNA Low Copy Number (DNA LCN) technology. Using this method, they were able to obtain a full DNA profile of the perpetrator by using evidence obtained from the victim's clothing. They ran the profile against the NDNAD, and it came up with a "hit" in 2001, when it matched that of Tony Jasinsky. Forensic scientists then removed the 20-year-old slide from FSS archives and attempted to extract a DNA profile, endeavoring to develop a closer link to Jasinsky. They successfully obtained a full profile, which matched that from the victim's clothing, as well as one obtained directly from Jasinsky. When the **murder** was committed, Tony Jasinsky was employed at the local Army barracks as a cook. Tony Jasinsky went to trial, was convicted for Marion Crofts' beating, rape, and murder, and received a life sentence in May of 2002.

Antonio Imiela was sentenced to life in prison after being convicted of a series of rapes committed over a one-year period. This most critical evidence in the case came from DNA and **fibers**. In November of 2001, a 10-year-old female was abducted from outside a community center in Kent (UK). She was taken to a nearby wooded area, where she was assaulted and raped. A full DNA profile was obtained from the victim and the crime scene, but it failed to match anyone listed on the NDNAD. Eight months later, another attack occurred in an area geographically unrelated to the first; a 30-year-old woman was beaten and raped while out walking. Using the DNA Low Copy Number technique, a partial profile of the perpetrator was obtained; it matched the profile from the first rape. Three further rapes, each geographically distant from the last, occurred. In October of 2002, a 14-year-old girl was raped; she was able to give local authorities a sufficiently detailed description so as to enable them to create a composite picture of her assailant. The picture was widely circulated to the media. An anonymous caller contacted Crimestoppers, and directed the authorities to Imiela. Imiela gave a DNA sample to police detectives; two days later he kidnapped and sexually assaulted another 10-year-old girl. Imiela was arrested in December of 2002, as a result of DNA matching between samples obtained from the first crime scene and from the suspect.

FSS forensic scientists examined Imiela's clothing, and extracted a number of different brightly colored unusual fibers from it that hadn't come from the clothing itself. The fibers were sufficient in number so as to make the hypothesis that they might have come from the clothing of his victims via secondary transfer plausible (fibers from the clothing worn by the perpetrator being transferred to clothing that came into contact with the suspect's clothing; that is, the clothing of the victims). Over a period of several months, FSS forensic scientists were able to match these fibers, ranging from a single fiber in one case to numerous fibers of different types for the victim who had been in Imiela's car. In addition, a DNA profile matching the last 10-year-old victim was obtained from two hairs found in Imiela's car. Therefore, there was a transfer of fibers in one direction and DNA transfer the other way.

Ultimately, fiber evidence was recovered in all eight sexual assaults. Together with the DNA profile, there was sufficient forensic evidence to provide extremely strong material proof that Imiela was the assailant. He was ultimately convicted of seven rapes, one count of kidnapping, a sexual assault, and attempted rape of a 10-year-old girl. He was given seven life sentences.

SEE ALSO Accelerant; Artificial fibers; Cold case; Cold hit; Counterfeit currency, technology and the manufacture of; DNA databanks; Gas chromatograph-mass spectrometer; Inorganic compounds; Laser ablation-inductively coupled plasma mass spectrometry; Method of operation (M.O.).

Louis C. Tripoli

AMERICAN
PHYSICIAN

Louis C. Tripoli is both a physician and a forensic scientist. When not on active duty with the United States Navy (he was called up in August 2004 and deployed to duty in Iraq as a public health expert with the U.S. Marine 4th Civil Affairs Group), he is the Senior Vice President of Correctional Medical Services (CMS), the Chairman of the Correctional Medical Institute, an Adjunct Professor of Medicine at the Johns Hopkins University, Division of Infectious Diseases, and an Adjunct Professor at St. Louis University's School of Public Health. In addition to being Board Certified in internal medicine, he holds a certificate in forensic medicine from the American College of Forensic Examiners.

Tripoli is the Vice President of Medical Affairs and Chief Medical Officer for the Correctional Medicine Institute, a non-profit charitable educational organization dedicated to the advancement of medical care in correctional settings. He is committed to this premise, both as a forensic scientist and as a physician, because it is his contention that correctional healthcare is a growing specialty, dedicated to a population characterized by uniquely complex medical (and biopsychosocial) needs. As a forensic scientist, he understands that the majority of incarcerated individuals will eventually be released and returned to the community; by positively impacting inmate healthcare, it is also possible to improve public health and the health of the larger community.

Tripoli was born in Oklahoma and raised in Washington, Pennsylvania. The son of Charles and Rita Tripoli, he is one of twelve children, four of whom were adopted from other countries. Tripoli graduated from Harvard University and from medical school at the University of Pittsburgh.

His family has always strongly valued public service, and his father, a family medicine practitioner, has been a participant in numerous international medical missions. While in Iraq, Tripoli called upon his parents to come to Iraq to assist him in facilitating an international medical mission, in which he arranged for an infant with severe hemangiomas on her face (benign tumors of small blood vessels that can cause deformities and impinge on vital structures) to be brought to the USA for life-saving surgical intervention.

Tripoli was a contributing author to *Forensic Aspects of Chemical and Biological Terrorism*, published in 2004. This text is written particularly for professionals concerned with the interplay of forensics and public health and safety, particularly as they would be impacted by either the threat or the actuality of biochemical terrorism.

SEE ALSO Anthrax; Bacterial biology; Biological warfare, advanced diagnostics; Biological weapons, genetic identification; Chemical and biological detection technologies.

Truth serum

Part of a forensic investigation can involve interviewing or even interrogating someone to determine the course of events. An individual may not always be forthcoming with information. In such cases, one option can be to solicit information chemically.

Truth serum is a term given to a number of different sedative or hypnotic drugs that are used to induce a person to tell the truth. Truth serums are a misnomer. While they do cause a person to become uninhibited and talkative, they do not guarantee the veracity of the subject. Although inhibitions are generally reduced, persons under the influence of truth serums are still able to lie and even tend to fantasize. Courts have ruled that information obtained from narcoanalysis is inadmissible.

As well, the drugs are not truly serums. Nonetheless, once used, the term became ingrained.

In 1943 J. Stephen Horsley published a book in which he described a novel psychotherapeutic method, which he coined narcoanalysis. By chance, he observed that people who were under the influence of narcotics were uninhibited, talkative, and answered all questions that were asked of them. A **narcotic** is a drug that dulls the senses, relieves pain, and induces sleep. Persons who were under the influence of narcotics entered a hypnotic-like state and spoke freely about anxieties or painful memories. Once the drug effect had worn off, the person had no recollection of what he or she said. Narcoanalysis has since been used to assist in the diagnosis of several different psychiatric conditions.

Narcoanalysis is not used in the United States as an **interrogation** method. The Federal Bureau of Investigation (**FBI**) and other federal law enforcement agencies object to the use of truth drugs, preferring instead to use psychological methods to extract information from suspects or prisoners. The

United Nations considers the use of truth drugs to be physical abuse and, therefore, a form of torture.

The issue was revisited in 2002, when some authorities, including former Central Intelligence Agency and FBI chief William Webster, frustrated by the lack of forthcoming information from suspected al Qaeda and Taliban members held at the U.S. prison in Guantanamo Bay, Cuba, advocated administering narcoanalysis drugs to uncooperative captives. United States Secretary of Defense Donald Rumsfeld asserted that narcoanalysis was not used by United States military and intelligence personnel, but suggested that other countries have made use of the technique in the interrogation of suspected terrorists.

Two of the most commonly used truth serums are members of the barbiturate drug class. **Barbiturates** are sedatives and hypnotics that are created from barbituric acid. They are divided into classes according to the duration of sedation: ultrashort, short, intermediate, and long. Ultrashort-acting barbiturates are used as anesthetics whereas long-acting ones are used to treat convulsions (anticonvulsive). Barbiturates are controlled substances due to their high potential for abuse and for addictive behavior.

Sodium pentothal (pentothal sodium, thiopental, thiopentone) is an ultrashort-acting barbiturate, meaning that sedation only lasts for a few minutes. Sodium pentothal slows down the heart rate, lowers blood pressure, and slows down (depresses) the brain and spinal cord (central nervous system) activity. Sedation occurs in less than one minute after injection. It is used as a general anesthetic for procedures of short duration, for induction of anesthesia given before other anesthetic drugs, as a supplement to regional anesthesia (such as a spinal block), as an anticonvulsive, and for narcoanalysis.

Sodium amytal (amobarbital, amylobarbitone, Amytal) is an intermediate-acting barbiturate. Sedation occurs in one hour or longer and lasts for 10 to 12 hours. Sodium amytal depresses the central nervous system. It is used as a sedative, hypnotic, and anticonvulsive and for narcoanalysis. When sodium amytal is used for narcoanalysis it may be called an "Amytal interview."

Scopolamine (hyoscine) is an anticholinergic alkaloid drug that is obtained from certain plants. Anticholinergic drugs block the impulses that pass through certain nerves. Scopolamine affects the autonomic nervous system and is used as a sedative, to prevent motion sickness, to treat eye lens muscle paralysis (cycloplegic), and to dilate the pupil (mydriatic).

SEE ALSO Nervous system overview; Polygraphs; Psychotropic drugs.

Tularemia

One aspect of **forensic science** is concerned with the investigation of an illness, outbreak, or death that is thought to be caused by a microorganism. Some microbes are exceptionally more adept at initiating disease than others. A good example of this is the microbe responsible for tularemia.

Tularemia is a plague-like disease caused by the Gram-negative bacterium *Francisella tularensis*. The organism is transferred to man from animals (i.e., a zoonosis) such as rodents, voles, mice, squirrels, and rabbits. Reflecting the natural origin of the disease, tularemia is also known as rabbit fever. Indeed, the rabbit is the most common source of the disease. Transfer of the bacterium via contaminated water and vegetation is possible as well.

The disease can easily spread from the environmental source to humans (although direct person-to-person contact has not been documented). This contagiousness and the potential high death rate among those who contract the disease made the bacterium an attractive bioweapon. Both the Japanese and Western armies experimented with *Francisella tularensis* during World War II. Experiments during and after that war established the devastating effect that aerial dispersion of the bacteria could exact on a population.

Tularemia naturally occurs over much of North America and Europe. In the United States, the disease is predominant in south-central and western states such as Missouri, Arkansas, Oklahoma, South Dakota, and Montana. The disease almost always occurs in rural regions. The animal reservoirs of the bacterium become infected typically by a bite from a blood-feeding tick, fly, or mosquito.

Francisella tularensis does not form a spore. Nevertheless, it can survive for protracted periods of time in environments such as cold water, moist hay, soil, and decomposing carcasses.

The number of cases of tularemia in the world is not known, since accurate statistics have not been kept and illnesses attributable to the bacterium go unreported. In the United States, the number of cases used to be high. In the 1950s thousands of people were infected each year. This number has dropped considerably, to less than 200 each year. Those who are infected now tend to be those who are exposed to the organism in its rural habitat (e.g., hunters, trappers, farmers, and butchers).

Humans can acquire the infection through breaks in the skin and mucous membranes, by ingesting contaminated water, or by inhaling the organism. An obligatory step in the establishment of an infection is the invasion of host cells. A prime target of invasion is the immune cell known as a macrophage. Infections can initially become established in the lymph nodes, lungs, spleen, liver, and kidney. As these infections become more established, the microbe can spread to tissues throughout the body.

Symptoms of tularemia vary depending on the route of entry. Handling an infected animal or carcass can produce a slow-growing ulcer at the point of initial contact and swollen lymph nodes. When inhaled, the symptoms include the sudden development of a headache with accompanying high fever, chills, body aches (particularly in the lower back), and fatigue. Ingestion of the organism produces a sore throat, abdominal pain, diarrhea, and vomiting. Other symptoms can include eye infection and the formation of skin ulcers. Some people also develop pneumonia-like chest pain. An especially severe pneumonia develops from the inhalation of one type of the organism, which is designated as *Francisella tularensis* biovar *tularensis* (type A). The pneumonia can progress to respiratory failure and death. The symptoms typically tend to appear three to five days after entry of the microbe into the body.

The infection responds to antibiotic treatment and recovery can be complete within a few weeks. Recovery produces a long-term immunity to re-infection. Some people experience a lingering impairment in the ability to perform physical tasks. If left untreated, tularemia can persist for weeks, even months, and can be fatal. The severe form of tularemia can kill up to 60% of those who are infected if treatment is not given.

A vaccine consisting of a living, but weakened form of the bacterium is available for tularemia. To date it has been administered only to those who are routinely exposed to the bacterium (e.g., researchers). This is because the potential risks of the vaccine are statistically greater than the risk of acquiring the infection.

SEE ALSO Bacterial biology; Bioterrorism; Vaccines.

Typewriter and printer analysis

Criminals may type a document like a ransom note or a threatening letter in the mistaken belief that, unlike handwriting, typed script cannot be readily identified. However, the forensic document examiner may well be able to extract some valuable **evidence** from a typed document. The advent of modern office technology has brought about some important changes in this kind of work. Most documents today are produced on modern **laser** printers and photocopiers that are difficult to distinguish from one another. Manual typewriters are much more individual as machines and the investigator can glean far more information from a manually typed document than from a printed document.

While it is unusual to find a manual typewriter in a modern office, some people still keep these machines for personal use. They are also still found in some developing countries. Therefore, the forensic examination of typewritten documents can still be important. A manual typewriter has many moving parts that tend to deteriorate over time and introduce tiny faults into a printed document. The document examiner looks for these faults when trying to tie a document to a particular machine that may already be available as an item of evidence, perhaps having been found at a suspect's address.

Typewriters produce letters with standard typefaces, but the size, shape, and styling of the letters may vary with the make and model of the machine. There are databases with identifying information on the letters produced by different typewriters and a comparison may be informative. If a suspect machine is present, the investigator will use it to produce a comparison document to see how closely it resembles the questioned document. He or she will try to reproduce the conditions, such as paper, age of the typewriter ribbon, and so on, that were used to produce the original. A side-by-side visual comparison of the two documents may be sufficient to decide whether they have been produced by the same machine.

Manual typewriters in which the individual characters are fixed to the end of a type bar can produce a number of individual characteristics, such as misaligned or damaged letters, as the letters begin to age. There may also be subtle variations in the pressure applied to the page by different keys which will show up as differences in how heavily inked the letters are. The investigator will also look for tiny variations in the spacing between the letters.

Italian police officers display seized counterfeit Iraqi dinar and U.S. $100 banknotes at a central police station in Rome in 2003. The seized counterfeit currency was elaborately detailed and printed on a high-quality printer.

Electric typewriters are more modern than manual machines and the letters are produced with either a daisy wheel or a golf ball. The most important feature of these two elements, from a forensic point of view, is that they start to deteriorate with increased use. Faults develop which are transferred to the typing on the paper and the examiner may be able to detect tiny flaws within the print. These same flaws will show up in a comparison document produced with the same machine and so can be used to help identify it.

Typewriter ribbons can be quite informative to the document examiner. The letters are stamped out on the paper as an image of the ink of the ribbon. Therefore the ribbon may bear an image of some of the letters and words of the document. The roller or platen of the typewriter may also contain information, because an image of the text may have been transferred to it. Tiny imperfections in the roller may also be transferred onto the document. Analysis of carbon paper, used to create copies, and correction papers may also reveal fragments of text from the document under investigation.

In most offices and homes, typewriters have now been replaced by printers. The first printers, which are not much seen now, were dot matrix printers. These were then superseded by ink jet and laser printers. It is relatively easy to determine whether a document was produced with a dot matrix, ink jet, or laser printer. Beyond this, however, it can be very hard to distinguish one make and model of printer from another. Printers are mass produced and they have fewer moving parts than typewriters which makes it hard to extract much identifying evidence that can tie a document to a particular machine. However, there may be tiny scratches on the drum of a laser printer which may be transferred onto the document.

Sometimes the investigator wants to determine whether a document is an original or a photocopy. Modern photocopiers have much the same mechanism as a laser printer. Minute faults on the camera lens, drum, or other part of the mechanism may be transferred onto the document. Similarly, specks of dust on the glass sheet where the paper to be copied is placed may transfer so called "trash marks" onto the copy. In this way, it might be possible to match a copy to a particular photocopier.

It was reported in late 2004 that, in an effort to assist governments trying to combat crimes such as counterfeiting, some color laser printer and copier manufacturing companies, such as Xerox, have begun utilizing technology that prints faint information, including the serial number of the machine, on every document it prints in small yellow dots that are virtually invisible to the naked eye. Though this technology is useful to those trying to combat crime, it also has privacy ramifications.

SEE ALSO Document forgery; Ink analysis.

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Ultraviolet light analysis

Ultraviolet (UV) light technologies are used for multiple purposes in forensic investigations, including authenticating paintings and other fine art, authenticating signatures, analyzing **questioned documents**, illuminating latent fingerprints at crime scenes and **trace evidence** on clothing, analyzing ink stains, and revealing residual stains of body **fluids**.

Ultraviolet light analysis and other optical examination techniques are recommended by the Federal Bureau of Investigation guidelines as the first choice to examine biologically contaminated **evidence**. This is because ultraviolet analysis is not destructive. It allows precise images and preliminary **identification** of the evidence before other analytical methods, such as **luminol** or washing solutions, are applied.

Body fluids such as **saliva**, **semen**, vaginal fluids, urine, and perspiration give off fluorescent light when illuminated by a source of ultraviolet light, which is a very efficient method for detecting such stains in a crime scene or in objects collected from the scene, such as clothing, towels, bed sheets, or decorative items. Even dried stains become fluorescent under UV light.

Forensic technicians also use UV light technologies, such as ultraviolet monochromators or optical **spectroscopy**, to detect the presence of illegal or controlled substances or their residues in unidentified samples, or to determine how many types of ink or pens were used in a forged document.

Ultraviolet reflectance spectrography generates images from ultraviolet radiation in a technique known as RUVIS. This technique allows the detection of latent fingerprints on nonporous surfaces without dusting or chemical treatment as well as of those previously treated with superglue fumes (cyanoacrylate vapor). RUVIS produces clear detailed images that can be either photographed or filmed, depending on the equipment in use. The RUVIS technique basically consists of the generation of UV light by an external source, which is focused on the surface containing latent prints. The UV light is diffusely reflected from the **fingerprint** residues on the nonporous surface toward an optical filter and passes through an objective lens into an image intensifier that converts it into visible light, thus producing the fingerprint image. Latent fingerprints are those that are invisible to the naked eye and must be detected by optical devices before being photographed. For forensic purposes, all technical data involving the picture is also recorded, such as the type of camera, lens, film, shutter speed, camera position, angle, and distance from the object. These records ensure the reproducibility of the image by independent analysts, thus preventing accusations of image manipulation to force a print match.

SEE ALSO Alternate light source analysis; Isotopic analysis; Laser; Luminol; Monochromatic light.

Forensic scientists using an ultraviolet light source to examine a piece of clothing. © JIM CRAIGMYLE/CORBIS

Unabomber case and trial

On April 13, 1996, Theodore (Ted) Kaczynski was arrested at his tiny cabin in the woods outside Lincoln, Montana. The arrest brought to a close a nearly 18-year-long manhunt for an elusive figure known as the Unabomber. By the time the manhunt ended, the **FBI**, the U.S. Postal Service, the Bureau of Alcohol, Tobacco, and Firearms (**ATF**), and even the U.S. Forestry Service had amassed thousands of volumes of information, including some 9,000 **evidence** photos, in connection with a series of explosive devices, mostly mail bombs, that killed three people and injured many others. On January 22, 1998, Kaczynski pled guilty to these crimes and began serving a life sentence in a Colorado prison. Thus ended the career of a troubled man who had entered Harvard at age 16, completed his master's and Ph.D. by age 25, and taught mathematics for two years at the University of California at Berkeley before dropping out to live primarily off the land, his distrust of technology festering and growing until it erupted in criminal action.

The Unabomber case began on May 25, 1978, when a Northwestern University professor became suspicious of a parcel that had been returned to him by the postal service but that he had never mailed. He called campus security, and when a campus police officer opened the package, it exploded in his hand, although he suffered only slight injuries. The university contacted the ATF, which began that day to compile what would become a lengthy forensic record of the bomber's handiwork. The bomb was the work of an amateur, made from items that could be found in a home workshop. It consisted of a 9-inch-long piece of metal pipe filled with explosive powders. The triggering device was primitive, a nail held by rubber bands that was intended to strike match heads when the box was opened. The box was made of wood, as were the plugs at the ends of the pipe.

On May 9, 1979, a Northwestern University graduate student escaped serious injury when he opened a cigar box that exploded. This bomb was more sophisticated than the first, for the bomber had replaced the nail and rubber band trigger mechanism with a battery-operated filament wire that ignited the **explosives**. Again, the bomb consisted of common items: tape, wires, a fishing line, a lamp cord, and wooden dowels. On November 15, 1979, a bomb triggered by an altimeter began to smolder in the cargo hold of an American Airlines flight 444. The bomb did not explode because instead of explosives it contained barium nitrate, a powder often used to create green smoke in fireworks. On June 10, 1980, when the president of United Airlines opened a book he had received in the mail, he was injured when a bomb in its hollowed-out pages exploded. This bomb differed from the earlier ones because it had a "signature," the initials FC punched into the metal, which authorities would later learn stood for Freedom Club. At this point the FBI coined the term UnAbom to refer to the targets so far: *Uni*versities and *A*irlines *Bom*bings.

The Unabomber laid low for 16 months, until October 8, 1981, when a bomb found on the campus of the University of Utah was disarmed before it did any damage. In May 1982, a secretary at Vanderbilt University was seriously injured when she opened a package containing a bomb that the postal service was to have returned (like the first bomb) to an electrical engineering professor at Utah's Brigham Young University. Two months later, on July 2, an engineering professor at Berkeley was seriously injured after he

The building belonging to Theodore Kaczynski (also known as the Unabomber) is delivered to the site of his trial. Forensic investigators discovered evidence of bombmaking materials inside the hut. © CORBIS SYGMA

lifted the handle on a strange piece of equipment in a faculty lounge, triggering an explosion.

Again, there was a hiatus, almost three years. Then on May 15, 1985, a Berkeley graduate student was seriously injured in a computer lab when he opened a three-ring binder that exploded. Forensics showed that the bomber had graduated to more lethal explosives, a mix of ammonium nitrate and aluminum powder. The bomb's shrapnel consisted of tacks, nails, and bits of lead. Stamped on the end seal of the bomb's pipe were the initials FC. Less than a month later, on June 13, a similar bomb showed up at a Boeing plant in Auburn, Washington. A mailroom clerk thought that the package looked suspicious and called the authorities, who dismantled the bomb, where again they found the FC logo. Just two days later, on June 15, a psychology professor at the University of Michigan and his assistant were injured when the latter triggered an explosion when he opened a book the professor had received in the mail. The first death occurred on December 11, 1985, when the owner of a computer store in Sacramento, California, noticed in the parking lot a block of wood with nails protruding from it. When he picked it up, it exploded with enormous force. Forensic examination showed that the bomb consisted of three 10-inch pipes filled with potassium sulfate, potassium chloride, ammonium nitrate, and aluminum powder. Again, the shrapnel consisted of sharp chunks of metal, nails, and splinters.

At this point, authorities were no closer to catching the bomber than they had been in 1978, but a significant clue emerged in February 1987, when a secretary at a Salt Lake City, Utah, computer firm spotted a stranger loitering outside. From her description, sketch artists created the now-famous sketch of a man wearing a hooded sweatshirt and aviator sunglasses thought to be the Unabomber, who had placed in a block of wood in the parking lot a bomb that seriously injured the company's vice president. Forensics showed that the Unabomber was continuing to hone his skills, for this bomb contained a new, more sensitive triggering device.

The bombings then stopped for six years. They returned with new force in June 1993. On June 22, a geneticist at the University of California at San Francisco was seriously injured when he opened a wooden box inside a padded envelope he had received in the mail. A similar package mailed on the same date, June 18, arrived at the office of a Yale

University computer science professor on June 23. Again, when he opened the box, roughly the size of a shoebox, it exploded with devastating force. That same day, the world received its first communication from the Unabomber in the form of a letter to the editor of the *New York Times* in which he took responsibility for the two most recent bombings, identified FC as the initials of Freedom Club, and promised further communications in the future.

Authorities were scrambling to solve the case, and the UNABOM task force, made up of the FBI, the ATF, and the U.S. Postal Service, was born. The task force, though, could not prevent two further lethal bombs. On December 10, 1994, an advertising executive thought mistakenly to have had a hand in trying to refurbish the image of Exxon after the *Exxon Valdez* oil spill disaster was killed when he opened a package at his home. Again, the FC logo was found in the rubble, along with the remains of a wooden box. Then on April 24, 1995, the president of the California Forestry Association was killed when he opened a package addressed to his predecessor.

In time, the identity of the Unabomber would be discovered less through clues found at the crime scenes than through clues contained in his own writing. In 1995, he sent rambling and insulting letters to various scientists. In them he warned the recipients to abandon their research, making clear his opposition to modern science and technology. The most important of these letters was the one he wrote to the *New York Times*, threatening further violence and claiming that both the bomb-making expertise and membership of the Freedom Club were growing. He also attempted to strike a startling deal: He would stop his activities if the *Times* or some other well-known newspaper published his 35,000-word "Manifesto."

The *Times* and the *Washington Post* consulted with the FBI before deciding to publish the manifesto, a lengthy rant against progress, the Industrial Revolution, and modern technology. The authorities hoped that if the manifesto was published, someone would recognize the ideas or the writing style and come forward with information about the author's identity. They were correct, for David Kaczynski read the Manifesto and concluded that its likely author was his older brother Ted. David asked a private investigator to compare samples of Ted's writing with the manifesto. The investigator in turn took the samples to linguistic specialists, who agreed that the same person wrote the manifesto and the writing samples.

Six weeks later, Ted Kaczynski was arrested. His Montana cabin was a treasure trove of evidence, containing over 700 items that amounted to a small bomb factory and thousands of pages of his journal. During nearly two years of legal maneuvering, his attorneys hoped to enter an insanity plea, but Kaczynski refused to be examined by psychologists. He relented only after he petitioned the court to represent himself and the court ruled that it would agree only if he was found psychologically fit to do so. Facing unassailable forensic evidence and a possible death penalty, Kaczynski pled guilty to the charges.

SEE ALSO ATF (United States Bureau of Alcohol, Tobacco, and Firearms); Bomb (explosion) investigations; Handwriting analysis.

Uncertainty analysis in forensic science

Many decisions within **forensic science** are made in the face of uncertainties. As the world becomes increasingly complex, and along with it the complexity of crimes and their investigations, there is an escalating need by forensic scientists to provide more and better statistical information in order to more effectively fight criminals. One of the major tasks confronting the forensic science community is to carefully plan so that the quantity and quality of information obtained will meet the requirements to solve crime and convict criminals. However, any mathematical value that is calculated to estimate an actual value involves an uncertainty. Although uncertainty exists with regard to the quantity and quality of information, it can be minimized by using critical thinking, objectivity, and systematic measurement and examination of the facts.

Uncertainty with regards to mathematical statistics is the estimated amount or percentage by which an observed or calculated value may differ from the actual value. In other words, the uncertainty of a calculated result is a measure of the accurateness (or goodness) to the actual value. Without such a comparative measure, it would be impossible to judge the fitness (or goodness) of the value as a basis for making informed decisions relating to forensic science. For example, in the investigation of a drug bust, a forensic chemist might find from his chemical analysis of a white powder that $35.0 \pm 1.0\%$ of the contents of the tested powder is the **narcotic** drug cocaine. The plus-or-minus ($\pm$) one percent value (which is sometimes called a margin of error) is the uncertainty associated with the chemist's result; that is, the actual value could vary from 34.0–36.0% of cocaine, or one percent on either side of the value 35.

In this particular case, the chemist is wise to account for the fact that the equipment and instruments used to measure the concentration of cocaine in the tested powder are not perfectly accurate, so uncertainty arises in the measured value. Thus, uncertainty analysis in the field of forensic science, or in any other field for that matter, involves the procedures, methods, and tools of systematically accounting for every factor contributing to such uncertainties. It covers a wide range of topics that include probability and statistical variables, mathematical relationships and equations, and design and sensitivity of experiments.

The forensic purpose of uncertainty analysis is to evaluate the result of a particular measurement, in a particular laboratory, at a particular time; and as a consequence of knowing that such measurements are not totally accurate, to assign assumptions and approximations to those results. The most widely accepted and commonly used statistical approach to modeling uncertainty is probability theory, which is the branch of mathematics that deals with measuring or determining quantitatively the likelihood that an experiment or event will have a particular outcome.

A common probability measure used to calculate uncertainty is called the confidence interval, which is based on multiple runs of the same analysis. Thus, a confidence interval is a range around a measurement that shows how precise the measurement has been made. For instance, the forensic chemist who found out that 35.0 $\pm$ 1.0% of the tested substance is cocaine might also report that after repeated laboratory analysis of the substance there is a 95% certainty that the concentration of cocaine within the tested substance lies between 34.0 and 36.0 percent. The level of significance—in this case 95%—is a statistical term for defining how confident a measurement is contained within the confidence interval. In this case, the chemist is 95% confident that the actual concentration of cocaine (within the tested sample) lies between 34.0 and 36.0%. There are other confidence intervals based on different levels of significance, such as 90% or 99%. With a 95% confidence interval, the chemist has a 5% chance of being wrong (and a 95% change of being correct); with a 90% confidence interval, a 10% chance of being wrong; and with a 99% confidence interval, a 1% chance of being wrong.

Evaluation of uncertainty is becoming more important within forensic science. Forensic test laboratories are increasingly required to include uncertainty analyses in measurement results through quality management standards such as the ISO 9000 series (where ISO is the common short name for the International Organization for Standardization, the world's largest developer of standards). Several organizations, such as the National Conference of Standards Laboratories and the International Standards Organization are currently investigating ways to standardize and simplify the approach to uncertainty analysis within forensic science.

SEE ALSO Forensic science; Quality control of forensic evidence; Statistical interpretation of evidence.

United States Army Medical Research Institute of Infectious Diseases (USAMRIID)

Forensic science is carried out by civilian and military personnel. The aims can be different. While civilian law enforcement officers are typically concerned with the investigation of an illness outbreak, accident, or death, the military's concern can be on the use of chemical and biological agents as weapons.

For biological agents, one important driving factor behind military forensic science is vaccine development. In the United States, the principal laboratory for research into the medical aspects of biological warfare is the United States Army Medical Research Institute of Infectious Diseases (USAMRIID).

The facility is operated by the Department of Defense and serves mainly to develop **vaccines** to infectious diseases, other treatments such as drugs, and tests to detect and identify disease-causing microorganisms.

While developed for use in the laboratory, USAMRIID is mandated to explore the use of the treatments and tests in the real world of the battlefield. The research conducted at USAMRIID is defensive in nature. Infectious microbes are investigated only to develop means of protecting soldiers from the use of the microbes by opposition forces during a conflict. Investigations can thus focus on unraveling the course of events of an illness outbreak or use of a biological agent, and thererfore are forensic in nature.

The infectious disease research expertise at USAMRIID is also utilized to develop strategies and **training** programs regarding medical defense against infectious microorganisms. For example, the agency regularly updates and publishes a handbook that details the various medical defenses against biological warfare or terrorism. This handbook, now in its fourth edition, is available to the public.

While some of the research conducted at USAMRIID is classified, other research findings of the resident civilian and military scientists are used to benefit the larger public community. USAMRIID and its counterpart U.S. Army Medical Research Institute of Chemical Diseases (USAMRICD) trains more than 550 military medical personnel each year on biological and chemical defense measures. Furthermore, over 40,000 military and civilian medical professionals have attended an annual course on the medical management of biological casualties from 1999 to 2002.

The Office of the Surgeon General of the Army established USAMRIID on January 27, 1969. The facility replaced the U.S. Army Medical Unit (USAMU), which had been operating at the Fort Detrick, Maryland location since 1956. The USAMU had a mandate to conduct research into the offensive use of biological and chemical weapons. This research was stopped by U.S. President Richard Nixon in 1969. In 1971 and 1972, the stockpiled biological weapons were destroyed.

The defensive research that USAMU had been conducting, such as vaccine development, was continued by USAMRIID. In 1971 the facility was reassigned to the U.S. Army Medical Research and Development Command. Also in 1971, the centerpiece laboratory was completed. Construction of the high laboratory, which was designed to house and study highly infectious and dangerous microorganisms, cost $14 million.

Laboratories have a rating system with respect to the types of microbes that can safely be studied. There are four levels possible. A typical university research lab with no specialized safety features (i.e., fume hood, biological safely cabinet, filtering of exhausted air) is a Biosafety Level 1. Progression to a higher level requires more stringent safety and biological controls. A Biosafety Level 4 laboratory is the only laboratory that can safely handle microbes such as the **Ebola virus**, *Bacillus anthracis* (the cause of **anthrax**), the Marburg virus, and hantavirus.

USAMRIID has a 10,000 square foot Biosafety Level 4 facility and 50,000 square feet of Biosafety Level 3. It is the largest high-level containment facility in the United States and is one of only three such units. The others are at the **Centers for Disease Control and Prevention** in Atlanta, Georgia, and San Antonio, Texas. A fourth level 4 laboratory is planned for the Rocky Mountain Lab in Hamilton, Montana.

Entry to the Level 4 area requires passage through several checkpoints and the keying in of a security code that is issued only after the person has been successfully vaccinated against the microorganism under study. All work in the level 4 lab is conducted in a pressurized and ventilated suit. Air for breathing is passed into the suit through a hose and is filtered so as to be free of microorganisms.

The USAMRIID facility also contains a Biosafety Level 4 patient ward. The ward can house people who have been infected during a disease outbreak or researchers who have been accidentally exposed to an infectious microbe. This ward was used in 1982 to care for two researchers from the Centers for Disease Control and Prevention who were exposed to rat blood contaminated with the virus that causes Lassa fever. The two researchers, along with three others thought to have been exposed to the virus, remained in the containment ward until they were determined to be free of infection.

Equipment is also available that allows the Biosafety Level 4 conditions to be mimicked in the field. Thus, an infected person can be isolated at the site of an outbreak and transported back to Fort Detrick for medical treatment and study of the infection.

The research staff at USAMRIID numbers over 500 and includes physicians, microbiologists, molecular biologists, virologists, pathologists, and veterinarians. Among the support staff who assist the researchers are laboratory technicians who have volunteered to be test subjects during clinical trials of vaccines and drugs.

USAMRIID scientists have the ability to rapidly identify approximately 85 infectious microorganisms. Work is underway to develop protection against 40 of the microbes. Vaccines are in various stages of development for 10 of the microbes including the highly infectious anthrax bacterium, and the Ebola and Marburg viruses.

Researchers and support staff can also respond to disease outbreaks. On short notice, forensic teams can journey to the site of the infection to begin an investigation. This response is often conducted in conjunction with forensic personnel from the Centers for Disease Control and Prevention.

One well-known USAMRIID response occurred in 1989, when an outbreak of an Ebola virus occurred at a primate holding facility in nearby Reston, Virginia. Some personnel even became infected with the virus, which was later determined to be a different variety from that which causes hemorrhagic Ebola fever in humans. The response of the USAMRIID personnel was subsequently detailed in bestselling books and inspired popular movies.

In the fall of 2001, several letters containing anthrax **spores** were sent to various locations in the eastern United States via the United States Postal Service. **Sequencing** of the genetic material from the spores determined that the source of the anthrax was a strain of the microbe that had been developed in the USAMRIID labs in the 1980s. Whether the bacteria actually used in the incidents came from USAMRIID or from another lab that acquired the bacteria from USAMRIID has not yet been established.

SEE ALSO Anthrax; Ebola virus; Pathogens; Vaccines.

Urban legends and myths SEE Pseudoscience and forensics

U.S. Supreme Court (rulings on forensic evidence)

Throughout the twentieth century, the court system wrestled with the issue of whether the testimony of forensic experts was a valid form of **evidence**. The essential problem was that modern science moves at a brisker pace than the judicial system. As new scientific techniques with applicability to forensics emerged, the courts often had no precedents on which to accept or reject them. Today, for example, the validity of fingerprint identification, with its axiom that the fingerprints of no two persons are alike, is largely taken for granted. But a century ago the courts were not so sure, for there was little research to buttress such a claim. At the opposite end of the twentieth century came DNA evidence, with statistical claims about the uniqueness of a person's genetic markers left behind at crime scenes in the form of blood, semen, skin cells, or hair. While justice plods, science sprints, often leaving the court system struggling to catch up as it tries to answer fundamental questions about the validity of scientific testimony and how to distinguish the claims of science from those of pseudoscience.

The United States Supreme Court has decided very few cases that directly bear on the admissibility of forensic testimony. Rather than addressing the issue of the validity of any particular branch of **forensic science**, the Court has limited itself to establishing ground rules for forensic testimony. Currently, it does so through the **Federal Rules of Evidence**, a set of broad principles used in federal trials. Most state courts have adopted these rules as well. The Federal Rules govern a number of issues pertaining to the relevance of evidence, but the key rule for forensic scientists is Rule 702, "Testimony by Experts," which applies to the testimony of any forensic scientist called to the witness stand: "If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, **training**, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case."

The Court entered the arena of forensic science in a 1923 case, *Frye v. United States*. Frye had been convicted of second-degree **murder**. His lawyer wanted to offer the testimony of a scientist who had conducted a systolic blood pressure deception test, today called a lie-detector or polygraph test, to demonstrate that his client was telling the truth. The trial court refused to admit the testimony, and the defendant appealed. In a remarkably brief and pointed decision, the Supreme Court affirmed the ruling of the lower court, famously stating: "Just when a scientific principle or discovery crosses the line between the experimental and demonstrable states is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs." In the Court's view, the systolic blood pressure deception test had "not yet gained such standing and scientific recognition."

Thus was born the so-called *Frye* standard, used in the years that followed by various lower courts to rule on the admissibility of such forensic tools as voiceprints, neutron activation, **gunshot residue** tests, bite mark comparisons, and blood grouping tests. The fundamental principle was "general acceptance in the particular field," making the scientific community itself the arbiter of whether a technique or procedure passed scientific muster. In a key case affirming the Frye standard in 1974, a U.S. Court of Appeals wrote in *United States v. Addison* that the standard "assures that those most qualified to assess the general validity of a scientific method will have the determinative voice." Thus, the Frye standard remained a well-settled principle for 70 years.

By the 1990s, though, the *Frye* standard was coming under pressure, largely because in 1975 the Federal Rules of Evidence were enacted, and nowhere did they mention the "general acceptance" test of *Frye*. The rules seemingly cleared the way for admitting scientific testimony based on new knowledge that had not necessarily gained general acceptance in the scientific community. Uncertainty over the question of whether the Federal Rules superceded the *Frye* standard had come to a head in 1993 when the Supreme Court heard the case of *Daubert v. Merrell Dow Pharmaceuticals*.

The case involved two children with serious birth defects. Daubert contended that the defects were caused by a Merrell Dow drug the mother had taken during pregnancy. He wanted to offer the scientific testimony of eight experts who had conducted animal studies and chemical structure analyses on the drug and concluded that it could cause birth defects. The company responded with published scientific epidemiological studies showing that the drug was not a risk factor for birth defects. The trial court, citing *Frye*, agreed with the company and ruled that the methods employed by the plaintiff's experts did not meet the standard of "general acceptance" under *Frye*. The Court of Appeals affirmed the trial court's ruling, but the U.S. Supreme Court reversed the Court of Appeals.

In its opinion, the Court undertook a detailed examination of whether the Federal Rules of Evidence superceded *Frye*. It concluded that *Frye's* 'general acceptance' is not a necessary precondition to the admissibility of scientific evidence" and that the Federal Rules "assign to the trial judge the task of ensuring that an expert's testimony both rests on a reliable foundation and is relevant to the task at hand." To guide the trial judge, the Court offered a flexible four-pronged test based on whether the theory or technique has been "tested"; whether it has been subjected to "peer review," usually through a peer-reviewed publication, so that the scientific community can detect flaws; what its "known or potential rate of error" is; and its "acceptability" in the relevant scientific community. Accordingly, the more stringent *Daubert* (pronounced "Dough-BEAR") standard replaced the earlier Frye standard. Judges, not the scientific community, were to determine reliability and relevance.

The Daubert standard came into play in a 1997 case, *General Electric Co. et al. v. Joiner*. After he was diagnosed with lung cancer, Joiner sued General Electric and Monsanto. He proffered expert testimony that the cancer was caused by his exposure to workplace chemicals the companies manufactured. The trial court ruled in favor of the companies' motion to exclude the testimony, saying that the testimony did not rise above "subjective belief or unsupported speculation." The Court of Appeals reversed the trial court, but the Supreme Court concluded that the trial court had acted appropriately under *Daubert* and that in failing to defer to the trial court's judgment that there was "too great an analytical gap between the data and the opinion" in the animal studies on which Joiner's expert testimony was based; the Court of Appeals had overstepped its boundaries. In other words, the trial court judge had exercised his proper role under the Daubert standard by acting as a "gatekeeper" for expert scientific testimony.

It remained for the Court to determine whether the *Daubert* standard applied just to "scientific" testimony or to any other type of technical, skill-based, or experience-based knowledge on which expert testimony is based. It did so in *Kumho Tire Co., Ltd., et al. v. Carmichael et al.* in 1999. Carmichael was driving a vehicle on which a tire blew out. When the vehicle overturned, one passenger died and others were injured. Carmichael sued the tire manufacturer, offering the testimony of a tire failure analyst who concluded that the tire blew out because of a manufacturing defect. Kumho moved to have the testimony excluded on the grounds that the expert's methodology failed to satisfy the requirements of Rule 702 of the Federal Rules of Evidence. The trial court granted the motion, ruling that the expert's testimony failed the four-pronged test outlined in *Daubert.* In reversing the trial court, the Court of Appeals ruled that the *Daubert* standard applied only to scientific testimony. While the Supreme Court reversed the Court of Appeals, agreeing with the trial court that the tire expert's procedures failed the *Daubert* standard, the Court explicitly stated that "The *Daubert* factors may apply to the testimony of engineers and other experts who are not scientists" and that "The *Daubert* 'gatekeeping' obligation applies not only to 'scientific' testimony, but to all expert testimony. Rule 702 does not distinguish between 'scientific' knowledge and 'technical' or 'other specialized' knowledge, but makes clear that any such knowledge might become the subject of expert testimony."

Since 1993, the *Daubert* standard, as fortified by *Kumho Tire*, has raised the question of whether any form of widely accepted forensic testimony can be challenged. In January 2002, for example, influential Philadelphia judge Louis H. Pollock caused consternation in the law enforcement community when he ruled that fingerprint analysis failed the Daubert standard, though in March 2002, he reversed himself. The likelihood remains that further *Daubert* challenges to forensic science will be mounted.

SEE ALSO Expert witnesses; Federal Rules of Evidence; *Frye* standard.

V

Vaccines

Investigations of the circumstances surrounding an illness outbreak can be a valuable means of determining how an infection is spread, its natural reservoirs, and in identifying subpopulations that display immunity to the infection. These forensic investigations can aid in the development of protective measures. Principle among protective measures are vaccines.

A vaccine is a medical preparation given to a person to provide immunity from a disease. Vaccines use a variety of different substances ranging from dead microorganisms to genetically engineered antigens to defend the body against potentially harmful antigens. Effective vaccines change the **immune system** by promoting the development of antibodies that can quickly and effectively attack disease causing microorganisms or viruses when they enter the body, preventing disease development.

The development of vaccines against diseases including polio, **smallpox**, tetanus, and measles is considered among the great accomplishments of medical science. Researchers are continually attempting to develop new vaccinations against other diseases. In particular, vigorous research into vaccines for acquired immune deficiency syndrome (AIDS), some cancer, severe acute respiratory syndrome (SARS), and avian influenza is currently underway.

The first successful vaccine was developed from cowpox as a treatment for smallpox. Coined by Louis Pasteur (1822–1895), the etymology of the term vaccine reflects this achievement. It is taken from the Latin for cow (*vacca*) and the word vaccinia, the virus that causes cowpox.

This first effective vaccine developed treated smallpox, a virulent disease that killed thousands of its victims and left thousands of others disfigured. In one of the first forms of inoculation, ancient Chinese people developed a snuff made from powdered smallpox scabs that was blown into the nostrils of uninfected individuals. Some individuals died from the therapy; however, in most cases, the mild infection produced offered protection from later, more serious infection.

In the late 1600s, European peasants employed a similar method of immunizing themselves against smallpox. In a practice referred to as "buying the smallpox," peasants in Poland, Scotland, and Denmark reportedly injected the smallpox virus under the skin to obtain immunity.

Lady Mary Wortley Montagu, the wife of the British ambassador to Turkey, brought information on immunization back to Europe in the early 1700s. Montague reported that the Turks injected a preparation of small pox scabs into the veins of susceptible individuals. Those injected generally developed a mild case of smallpox from which they recovered rapidly. Montague convinced King George I to allow trials of the technique on inmates in Newgate Prison. Although some individuals died after receiving the injections, the trials were successful enough that variolation, or the direct injection of smallpox, became accepted medical practice. Variolation also was credited with protecting United States soldiers from smallpox during the Revolutionary War.

Edward Jenner (1749–1823), an English country physician, observed that people who were in contact with cows often developed cowpox, which caused pox sores but was not life threatening. Those people never developed smallpox. In 1796 Jenner tested the hypothesis that cowpox could be used to protect humans against smallpox. He injected a healthy eight-year-old boy with cowpox obtained from a milkmaid's sore. The boy was moderately ill and recovered. Jenner then injected the boy twice with the smallpox virus, and the boy did not get sick.

Modern knowledge of the immune system suggests that the virus that causes cowpox is similar enough to the virus that causes smallpox that the vaccine simulated an immune response to smallpox. Exposure to cowpox **antigen** stimulated the boy's immune system, producing cells that attacked the original antigen as well as the smallpox antigen. The vaccine also conditioned the immune system to produce antibodies more quickly and more efficiently against future infection by smallpox.

During the two centuries since its development, the smallpox vaccine gained popularity, protecting millions from contracting the disease. In 1979, following a major cooperative effort between nations and several international organizations, world health authorities declared smallpox the only infectious disease to be eradicated from the planet.

In 1885 Louis Pasteur (1822–1895) saved the life of Joseph Meister, a nine year old who had been attacked by a rabid dog. Pasteur's series of experimental rabies vaccinations on the boy proved the effectiveness of the new vaccine.

Pasteur's rabies vaccine, the first human vaccine created in a laboratory, was made of an extract gathered from the spinal cords of rabies-infected rabbits. The live virus was weakened by drying over potash. The new vaccination was far from perfect, causing occasional fatalities and temporary paralysis. Individuals had to be injected 14 to 21 times.

The rabies vaccine has been refined many times. In the 1950s, a vaccine grown in duck embryos replaced the use of live virus, and in 1980, a vaccine developed in cultured human cells was produced. In 1998, the newest vaccine technology—genetically engineered vaccines—was applied to rabies. The new DNA vaccine cost a fraction of the regular vaccine. While only a few people die of rabies each year in the United States, more than 40,000 die worldwide, particularly in Asia and Africa. The less expensive vaccine will make vaccination far more available to people in less developed nations.

In the early 1900s polio was extremely virulent in the United States. At the peak of the epidemic, in 1952, polio killed 3,000 Americans, and 58,000 new cases of polio were reported.

In 1955 Jonas Salk (1914–1995) developed a vaccine for poliomyelitis. The Salk vaccine, a killed virus type, contained the three types of poliovirus that had been identified in the 1940s. In the first year the vaccine was distributed, dozens of cases of polio were reported in individuals who had received the vaccine or had contact with individuals who had been vaccinated. This resulted from an impure batch of vaccine that had not been completely inactivated. By the end of the incident, more than 200 cases had developed and 11 people had died.

In 1961, an oral polio vaccine developed by Albert B. Sabin (1906–1993) was licensed in the United States. The Sabin vaccine, which uses weakened, live polio viruses, quickly overtook the Salk vaccine in popularity in the United States, and is currently administered to all healthy children. Because it is taken orally, the Sabin vaccine is more convenient and less expensive to administer than the Salk vaccine.

Advocates of the Salk vaccine, which is still used extensively in Canada and many other countries, contend that it is safer than the Sabin oral vaccine. No individuals have developed polio from the Salk vaccine since the 1955 incident. In contrast, the Sabin vaccine has a very small, but significant, rate of complications, including the development of polio. However, there has not been one new case of polio in the United States since 1975, or in the Western Hemisphere since 1991. Although polio has not been completely eradicated, there were only 144 confirmed cases worldwide in 1999.

Developing a vaccine against the influenza virus is problematic because the viruses that cause the flu constantly evolve. Scientists grapple with predicting what particular influenza strain will predominate in a given year. When the prediction is accurate, the vaccine is effective. When they are not, the vaccine is often of little help. However, the flu shot has had enough success that pediatricians are now recommending the vaccine for children older than six months.

Since the emergence of AIDS in the early 1980s, research for a treatment for the disease has resulted in clinical trials for more than 25 experimental vaccines.

These range from whole-inactivated viruses to genetically engineered types. Some have focused on a therapeutic approach to help infected individuals to fend off further illness by stimulating components of the immune system. Others have genetically engineered a protein on the surface of HIV to prompt immune response against the virus; and yet others attempted to protect uninfected individuals. The challenges in developing a protective vaccine include the fact that HIV appears to have multiple viral strains and mutates quickly.

In January, 1999, a promising study was reported in *Science* magazine of a new AIDS vaccine created by injecting a healthy cell with DNA from a protein in the AIDS virus that is involved in the infection process. This cell was then injected with genetic material from cells involved in the immune response. Once injected into the individual, this vaccine "catches the AIDS virus in the act," exposing it to the immune system and triggering an immune response. This discovery offers considerable hope for development of an effective vaccine. As of 2005, a vaccine for AIDS had not been proven in clinical trials.

Stimulating the immune system is considered key by many researchers seeking a vaccine for cancer. Currently numerous clinical trials for cancer vaccines are in progress, with researchers developing experimental vaccines against cancer of the breast, colon, and lung, among others. Promising studies of vaccines made from the patient's own tumor cells and genetically engineered vaccines have been reported. Other experimental techniques attempt to penetrate the body in ways that could stimulate vigorous immune responses. These include using bacteria or viruses, both known to efficiently circulate through the body, as carriers of vaccine antigens. These bacteria or viruses could be treated or engineered to make them incapable of causing illness.

The classic methods for producing vaccines use biological products obtained directly from a virus or a bacteria. Depending on the vaccination, the virus or bacteria is either used in a weakened form, as in the Sabin oral polio vaccine; killed, as in the Salk polio vaccine; or taken apart so that a piece of the microorganism can be used. For example, the vaccine for *Streptococcus pneumoniae*, which causes pneumonia, uses bacterial polysaccharides, carbohydrates found in bacteria which contain large numbers of monosaccharides, a simple sugar. The different methods for producing vaccines vary in safety and efficiency. In general, vaccines that use live bacterial or viral products are extremely effective when they work, but carry a greater risk of causing disease. This is most threatening to individuals whose immune systems are weakened, such as individuals with leukemia. Children with leukemia are advised not to take the oral polio vaccine because they are at greater risk of developing the disease. Vaccines which do not include a live virus or bacteria tend to be safer, but their protection may not be as great.

The classical types of vaccines are all limited in their dependence on biological products, which often must be kept cold, may have a limited life, and can be difficult to produce. The development of recombinant vaccines—those using chromosomal parts (or DNA) from a different organism—has generated hope for a new generation of man-made vaccines. The hepatitis B vaccine, one of the first recombinant vaccines to be approved for human use, is made using recombinant yeast cells genetically engineered to include the **gene** coding for the hepatitis B antigen. Because the vaccine contains the antigen, it is capable of stimulating **antibody** production against hepatitis B without the risk that live hepatitis B vaccine carries by introducing the virus into the blood stream.

As medical knowledge has increased—particularly in the field of DNA vaccines—researchers are working toward developing new vaccines for cancer, melanoma, AIDS, influenza, and numerous others illnesses. Since 1980, many improved vaccines have been approved, including several genetically engineered (recombinant) types which first developed during an experiment in 1990. These recombinant vaccines involve the use of so-called "naked DNA." Microscopic portions of a viruses's DNA are injected into the patient. The patient's own cells then adopt that DNA, which is then duplicated when the cell divides, becoming part of each new cell. Researchers have reported success using this method in laboratory trials against influenza and malaria. These DNA vaccines work from inside the cell, not just from the cell's surface, as other vaccines do, allowing a stronger cell-mediated fight against the disease. Also, because the influenza virus constantly changes its surface proteins, the immune system or vaccines cannot change quickly enough to fight each new strain. However, DNA vaccines work on a core protein, which researchers believe should not be affected by these surface changes.

The measles epidemic of 1989 was a graphic display of the failure of many Americans to be properly immunized. A total of 18,000 people were infected, including 41 children who died after developing measles, an infectious, viral illness whose complications include pneumonia and encephalitis. The epidemic was particularly troubling because an effective, safe vaccine against measles has been widely distributed in the United States since the late 1960s. By 1991, the number of new measles cases had started to decrease, but health officials warned that measles remained a threat.

SEE ALSO Pathogens; United States Army Medical Research Institute of Infectious Diseases (USAMRIID).

Variola virus

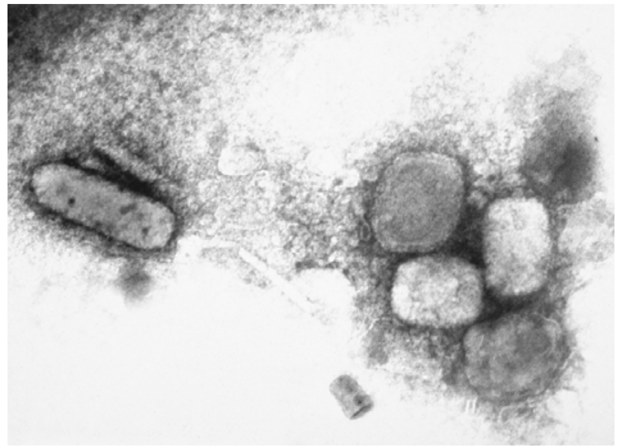
Variola virus (or *variola major*) is the virus that causes **smallpox**. The virus is one of the members of the poxvirus group (*Poxviridae*) and it is one of the most complicated animal viruses. The variola virus is extremely virulent and is among the most dangerous of all the potential biological weapons.

The variola virus particle is shaped like a biconcave (concave on both sides) brick about 200 to 400 nm (nanometers) long. Its inner compartment contains a highly compressed double strand of deoxyribonucleic acid as well as about 100 proteins and 10 viral enzymes. The enzymes are used in nucleic acid replication.

The variola virus attaches to membrane receptors on the exterior of the host cell. The exact mechanisms involved in the binding to and penetration of the host membrane are not known. As it enters the cell, however, the virus loses its exterior membrane coat. Once inside the cell, the interior membrane layer is removed and the virus's proteins, enzymes, and **DNA** are released into the cytoplasm of the host cell where viral replication and assembly takes place. The production of variola virus by the host cell usually results in host cell death.

Variola virus infects only humans and can be easily transmitted from person to person via the air. Inhalation of only a few virus particles is sufficient to establish an infection. Transmission of the virus is also possible if items such as contaminated linen are handled. The common symptoms of smallpox include chills, high fever, extreme tiredness, headache, backache, vomiting, sore throat with a cough, and sores on mucus membranes and on the skin. As the sores burst and release pus, the afflicted person can experience great pain. Males and females of all ages are equally susceptible to infection. Prior to smallpox eradication approximately one third of patients died—usually within a period of two to three weeks following appearance of symptoms.

The origin of the variola virus in not clear. However, the similarity of the virus and cowpox virus has prompted the suggestion that the variola virus is a mutated version of the cowpox virus. The mutation likely allowed the virus to infect humans. If such a mutation did occur, then it is possible that when early humans became more agricultural and less nomadic, there may have been selective pressure for the cowpox virus to adapt the capability to infect humans.



A micrograph shows the variola virus, the virus that causes smallpox, a potentially fatal disease which is preventable by vaccination. © CDC/PHIL/CORBIS

Vaccination to prevent infection by the variola virus was established in the 1700s. English socialite and public health advocate Lady Mary Wortley Montagu popularized the practice of injection with the pus obtained from smallpox sores as a protection against the disease. This technique became known as variolation. Late in the same century, Edward Jenner successfully prevented the occurrence of smallpox by an injection of pus from cowpox sores. This was the first vaccination. Vaccination against smallpox has been very successful; the variola virus is the only pathogenic virus that has been eliminated from the natural environment. Routine vaccination against smallpox was discontinued in the 1970s and considered globally eradicated in 1980. The last recorded case of naturally occurring smallpox infection was in 1977 in Somalia, Africa.

SEE ALSO Ebola virus; Pathogens; Smallpox.

Video evidence

The use of surveillance **cameras** and **closed-circuit television (CCTV)** for security and crime prevention has been growing in recent years. Shopping malls, car parks, offices, airports, and many other

Video evidence of the theft of a Picasso masterpiece from a London gallery in 1997. © BEN GOTT/CORBIS SYGMA

public and private places are often fitted with such systems, which means that an increasing number of crimes are now being caught on camera. Such cameras are often small and very discreet, so the perpetrators have no idea that they and their actions are being recorded. Video images relating to a crime can be used in court as **evidence**, but effective forensic video analysis is a specialized and highly technical task.

When collecting video evidence, the investigators must take as much care as they would in collecting any other form of evidence. Videotapes can readily be wiped or recorded over, so the first task is to preserve the evidence from a camera by preventing this. For analog video evidence, the record tab must be removed or moved to a saved position. For digital video evidence, write protection has to be in place. The **chain of custody** of the evidence, from collecting the tape from the camera to its receipt in the **processing** lab, must be carefully adhered to, because questions may be asked in court about whether the video evidence could have been tampered with. Storage should be in a climate-controlled room, because extremes of temperature can damage a video tape.

The images from a surveillance camera or closed-circuit TV system are often blurred, grainy, and of low resolution. Lighting conditions, tape wear, and deficiencies in the camera system all contribute to poor quality pictures. Enhancing such images, without altering them, is challenging. The effort may, however, be well worthwhile if a crucial car number plate or a suspect may thereby be identified.

The video analysis lab will contain a monitor that can produce large images from the tape, a playback deck, a printer, and equipment that can digitize the signal from the original tape so that it can be processed by a computer. Before any analysis is actually carried out, the integrity of the tape should be reviewed and careful notes made of any damage. The video evidence must be protected throughout from external hazards such as magnetic fields or static electric charges that may harm it. It is also important not to over-play the tape, as this can also impair its quality.

There are various software packages that can enhance an image from a video camera and present them either as video tape, still images, or prints for the court. There are many image formats that can be used to do this work, but one of the most popular is the tagged image file format (.tif file). Everything the forensic video analysis technician does to the image must be carefully recorded, because this is sure to be questioned in court. Computer images can be readily manipulated and so everything that has been done to the evidence must be accounted for so that its integrity is preserved.

If a suspect has been detained, video evidence can be used to help identify them. They can be taken back to the original location of the camera and rerecorded standing or walking in the same position. This second image can be compared with the original and an **identification** or an elimination can often be usefully made. The original image can also be used to give an idea of the actual height and size of a suspect.

Video evidence played an important role in the investigation of the **murder** of two-year-old James Bulger in Liverpool, England, in 1993. A surveillance camera in a shopping mall clearly shows the child being separated from his mother and then being led to his death by the two boys who were later convicted of the killing. The tape was repeatedly shown on television and its poignancy has helped fix this especially tragic case in the memory of the British public. In another case, video footage from cameras in a West London shopping mall was intensively studied by police to solve the doorstep shooting of TV presenter Jill Dando in 1999. Although the key suspect did not appear in these images, they were a powerful aid to reconstruction of the crime as they provided sharp, clear images of much of the last hour of Miss Dando's life. Another famous piece of video evidence is the recording of Diana, Princess of Wales, leaving a hotel in Paris just minutes before the car accident that was to end her life in 1997.

SEE ALSO Digital imaging.

Eugène-François Vidocq

7/24/1775–4/30/1857
FRENCH
POLICE DETECTIVE

In the first half of the nineteenth century, French police detective Eugène-François Vidocq turned crime fighting into a scientific endeavor by using record-keeping, ballistic science, and shoe impressions to apprehend criminals. Vidocq's dramatic success in reducing the French crime rate helped to popularize **forensic science** methods. He served as the model for many fictional detectives, including Arthur Conan Doyle's Sherlock Holmes.

Vidocq was born in Arras, France, the first child of a baker and his wife. Notoriously weak for the ladies from an early age, Vidocq killed a man in a duel over a woman in 1790. The teenager escaped imprisonment only because the judge in the case permitted him to join the army. He subsequently served with distinction before returning home on leave in 1795 and discovering his unfaithful wife with another man.

Vidocq then deserted from the army and joined a band of card sharks. Arrested and jailed, he forged a pardon for a prisoner with a family and was caught. Vidocq escaped and joined a band of smugglers, but again was arrested because he lacked identity papers. In 1798 Vidocq was sentenced to serve eight years in the galleys, special prisons for hardened criminals who were required to wear leg and arm chains at all times and to don leaded boots whenever they left their cells. Vidocq escaped and, upon being caught, was sent to the brutal prison of La Force.

Facing a likely slow death, Vidocq offered his services as a police spy in 1809. He won the confidence of the authorities under circumstances never explained, and went to work for the Criminal Division of the Paris Prefecture of Police. In October 1812, Vidocq founded and became the first chief of the Brigade de la Sûreté or security police.

With the Sûreté, Vidocq established a plainclothes bureau that would concentrate exclusively on the investigation and detection of non-political crimes. Its membership would be composed of men familiar with the methods and techniques of criminals. To aid his investigators, Vidocq established more than 60,000 files that identified the aliases, appearances, all previous convictions, and methods of operation of every robber, thief, forger, and confidence artist. He may have been the first police official to realize that criminals often gave themselves away by the repeated use of identifiable techniques.

In order to gather information, Vidocq used informants. Often, he donned a disguise to infiltrate criminal gathering places and acquire information, usually portraying "Jean-Louis," a sixty-year-old criminal merchant from the province of Brittany, complete with a distinctive accent, gray hair, drooping mustache, and old-fashioned pre-Revolutionary clothes.

François-Eugène Vidocq, French adventurer and detective.

Vidocq reasoned that most criminals were careless and succeeded only because the authorities' methods were even more undisciplined. He argued that the detective who won convictions did so because he saw and listened, then utilized anything he learned that was out of the ordinary. Accordingly, Vidocq would visit the scene of a crime to look for indicators about the perpetrator and to join in the initial search for **evidence**. He matched boots to footprints, physically taking the boots from a suspect and placing them in the soil indentation (the technology did not exist then to make impressions). He later became the first to make plaster-of-paris casts of foot and shoe impressions. Vidocq took bullets and physically placed them in the barrel of a pistol to make a primitive **ballistics** examination in 1822.

To halt forgers, Vidocq used his own money to hire chemists to develop indelible ink and unalterable bond paper. He also utilized the new technique of **handwriting analysis**. Although Vidocq recognized the value of fingerprints, he never found an ink suitable for fingerprinting and, as a result, never pursued this method of **identification**.

Vidocq's success in solving the crimes that befuddled the uniformed police did not endear him to police authorities. Pugnacious and passionate, he left the government in 1827 because of a political dispute. His memoirs, published in 1829 and highly embellished, gave Vidocq an international reputation as the world's greatest detective.

Vidocq returned to office from 1830 to 1833, before resigning because of his advanced age and his third wife's failing health. In 1834, he founded the first of the modern detective agencies, Les Bureau des Renseignements, aimed at professional and business people who did not trust the competency of the police to solve crimes. He died of a stroke in Paris, having spent much of his money on efforts to rehabilitate criminals and charm women.

SEE ALSO Crime scene investigation; Handwriting analysis.

Viral biology

Virology is the discipline of microbiology that is concerned with the study of viruses. Knowledge of the basics of viral biology, viral reproduction (viral replication), and the ability to identify potential virus-related pathologies are increasingly important skills for some forensic scientists. There are a number of different viruses that challenge the human **immune system** and that may produce disease in humans. Although virologists are the scientists most directly concerned with viral biology, with the rise of terrorism and global health issues such as the evolving H5N1 influenza (commonly called bird flu), forensic scientists now find that their work overlaps interests in **epidemiology** and/or national security.

Viruses are essentially nonliving repositories of nucleic acid that require the presence of a living prokaryotic cell (where **DNA** is present in the cytoplasm) or eukaryotic cell (where DNA is present within the nucleus) for the replication of the nucleic acid. They can exist in a variety of hosts. Viruses can infect animals (including humans), plants, fungi, birds, aquatic organisms, protozoa, bacteria, and insects. Some viruses are able to infect several of these hosts, while other viruses are exclusive to one host.

Viral replication refers to the means by which virus particles make new copies of themselves. All viruses share the need for a host in order to replicate their deoxyribonucleic acid (DNA) or ribonucleic acid (RNA). The virus commandeers the host's existing molecules for the nucleic acid replication process. There are a number of different viruses. The differences include the disease symptoms they cause, their antigenic composition, type of nucleic acid residing in the virus particle, the way the nucleic acid is arranged, the shape of the virus, and the fate of the replicated DNA. These differences are used to classify the viruses and have often been the basis on which the various types of viruses were named.

The classification of viruses operates by use of the same structure that governs the **classification of bacteria**. The International Committee on Taxonomy of Viruses established the viral classification scheme in 1966. From the broadest to the narrowest level of classification, the viral scheme is: Order, Family, Subfamily, Genus, Species, and Strain/type. To use an example, the virus that was responsible for an outbreak of Ebola hemorrhagic fever in a region of Africa called Kikwit is classified as Order Mononegavirales, Family Filoviridae, Genus *Filovirus*, and Species *Ebola Zaire*.

In the viral classification scheme, all families end in the suffix *viridae*, for example Picornaviridae. Genera have the suffix *virus*. In the family Picornaviridae there are five genera: enterovirus, cardiovirus, rhinovirus, apthovirus, and hepatovirus. The names of the genera typically derive from the preferred location of the virus in the body (for those viral genera that infect humans). As examples, rhinovirus is localized in the nasal and throat passages, and hepatovirus is localized in the liver. Finally, within each genera there can be several species.

As noted above, there are a number of criteria by which members of one grouping of viruses can be distinguished from those in another group. For the purposes of classification, however, three criteria are paramount. These criteria are the host organism or organisms that the virus utilizes, the shape of the virus particle, and the type and arrangement of the viral nucleic acid.

An important means of classifying viruses concerns the type and arrangement of nucleic acid in the virus particle. Some viruses have two strands of DNA, analogous to the double helix of DNA that is present in prokaryotes such as bacteria and in eukaryotic cells. Some viruses, such as the Adenoviruses, replicate in the nucleus of the host using the replication machinery of the host. Other viruses, such as the Poxviruses, do not integrate in the host genome, but replicate in the cytoplasm of the host. Another example of a double-stranded DNA virus is the Herpesviruses. Other viruses only have a single strand of DNA such as the Parvoviruses, which can replicate their DNA in the host's nucleus. The replication involves the formation of what is termed as a negative-sense strand of DNA, a blueprint for the subsequent formation of the RNA and DNA used to manufacture the new virus particles.

The genome of other viruses, such as Reoviruses and Birnaviruses, is comprised of double-stranded RNA. Portions of the RNA function independently in the production of a number of so-called messenger RNAs, each of which produces a protein that is used in the production of new viruses. Other viruses contain a single strand of RNA. In some of the single-stranded RNA viruses, such as Picornaviruses, Togaviruses, and the Hepatitis A virus, the RNA is read in a direction that is termed "+ sense." The sense strand is used to make the protein products that form the new virus particles. Other single-stranded RNA viruses contain what is termed a negative-sense strand. Examples are the Orthomyxoviruses and the Rhabdoviruses. The negative strand is the blueprint for the formation of the messenger RNAs that are required for production of the various viral proteins.

Still another group of viruses have + sense RNA that contains the code for a DNA intermediate. The intermediate is used to manufacture the RNA that is eventually packaged into the new virus particles. The main example is the Retroviruses (the Human Immunodeficiency Viruses belong here). Finally, a group of viruses consist of double-stranded DNA that contains the code for an RNA intermediate. An example is the Hepadnaviruses.

One aspect of virology is the identification of viruses. Often, the diagnosis of a viral illness relies, at least initially, on the visual detection of the virus. Samples are prepared for electron microscopy using a technique called negative staining, which highlights surface detail of the virus particles. For this analysis, the shape of the virus is an important feature.

Any particular virus will have an attached shape. For example, viruses that specifically infect bacteria, the so-called bacteriophages, look similar to the Apollo lunar-landing spacecraft. A head region containing the nucleic acid is supported on a number of spider-like legs. Upon encountering a suitable bacterial surface, the virus acts like a syringe, to introduce the nucleic acid into the cytoplasm of the bacterium.

Other viruses have different shapes. These include spheres, ovals, worm-like forms, and even pleomorphic (irregular) arrangements. Some viruses, such as the influenza virus, have projections sticking out from the surface of the virus. These are crucial to the infectious process. As new species of eukaryotic and prokaryotic organisms are discovered, no doubt the list of viral species will continue to grow.

Viruses cannot replicate by themselves. They require the participation of the replication equipment of the host cell that they infect in order to replicate. The molecular means by which this replication takes place varies, depending upon the type of virus. Viral replication can be divided into three phases: initiation, replication, and release.

The initiation phase occurs when the virus particle attaches to the surface of the host cell, penetrates into the cell, and undergoes a process known as uncoating, where the viral genetic material is released from the virus into the host cell's cytoplasm. The attachment typically involves the recognition of some host surface molecules by a corresponding molecule on the surface of the virus. These two molecules can associate tightly with one another, binding the virus particle to the surface. A well-studied example is the haemagglutinin receptor of the influenzae virus. The receptors of many other viruses have also been characterized.

A virus particle may have more than one receptor molecule, to permit the recognition of different host molecules, or of different regions of a single host molecule. The molecules on the host surface that are recognized tend to be those that are known as glycoproteins. For example, the human immunodeficiency virus recognizes a host glycoprotein called CD4. Cells lacking CD4 cannot, for example, bind the HIV particle.

In the replication, or synthetic, phase the viral genetic material is converted to deoxyribonucleic acid (DNA) if the material originally present in the viral particle is ribonucleic acid (RNA). This so-called reverse transcription process needs to occur in retroviruses, such as HIV. The DNA is imported into the host nucleus where the production of new DNA, RNA, and protein can occur. The replication phase varies greatly from virus type to virus type. However, in general, proteins are manufactured to ensure that: the cell's replication machinery is harnessed to permit replication of the viral genetic material; the replication of the genetic material does indeed occur; and the newly made material is properly packaged into new virus particles.

Replication of the viral material can be a complicated process, with different stretches of the genetic material being transcribed simultaneously with some of these **gene** products required for the transcription of other viral genes. Also, replication can occur along a straight stretch of DNA, or when the DNA is circular (the so-called "rolling circle" form). RNA-containing viruses must also undergo a reverse transcription from DNA to RNA prior to packaging of the genetic material into the new virus particles.

In the final stage, the viral particles are assembled and exit the host cell. The assembly process can involve helper proteins, made by the virus or the host.

Release of viruses can occur by a process called budding. A membrane "bleb" containing the virus particle is formed at the surface of the cell and is pinched off. For herpes virus this is in fact how the viral membrane is acquired. In other words, the viral membrane is a host-derived membrane. Other viruses, such as bacteriophage, may burst the host cell, spewing out the many progeny virus particles. But many viruses do not adopt such a host destructive process, as it limits the time of an infection due to destruction of the host cells needed for future replication.

Although precise mechanisms vary, viruses cause disease by infecting a host cell and commandeering the host cell's synthetic capabilities to produce more viruses. The newly made viruses then leave the host cell, sometimes killing it in the process, and proceed to infect other cells within the host. Because viruses invade cells, drug therapies have not yet been designed to kill viruses, although some have been developed to inhibit their growth. The human immune system is the main defense against a viral disease.

Bacterial viruses, called bacteriophages, infect a variety of bacteria, such as *Escherichia coli*, a bacteria commonly found in the human digestive tract. Animal viruses cause a variety of fatal diseases. Acquired immune deficiency syndrome (AIDS) is caused by the human immunodeficiency virus (HIV); hepatitis and rabies are viral diseases; and hemorrhagic fevers, which are characterized by severe internal bleeding, are caused by filoviruses. Other animal viruses cause some of the most common human diseases. Often, these diseases strike in childhood. Measles, mumps, and chickenpox are viral diseases. The common cold and influenza are also caused by viruses. Finally, some viruses can cause cancer and tumors. One such virus, human T-cell leukemia virus (HTLV), was only recently discovered and its role in the development of a particular kind of leukemia is still being clarified.

Edward Jenner (1749–1823) is credited with developing the first successful vaccine against a viral disease, with his vaccine for **smallpox**. A vaccine works by eliciting an immune response. During this immune response, specific immune cells, called memory cells, are produced that remain in the body long after the foreign microbe present in a vaccine has been destroyed. When the body again encounters the same kind of microbe, the memory cells quickly destroy the microbe. **Vaccines** contain either a live, altered version of a virus or bacteria, or they contain only parts of a virus or bacteria, enough to elicit an immune response.

In 1797, Jenner developed his smallpox vaccine by taking infected material from a cowpox lesion on the hand of a milkmaid. Cowpox was a common disease of the era, transmitted through contact with an infected cow. Unlike smallpox, however, cowpox is a much milder disease. Using the cowpox pus, he inoculated an eight-year-old boy. Jenner continued his vaccination efforts through his lifetime. Until 1976, children were routinely vaccinated with the smallpox vaccine, called vaccinia. Reactions to the introduction of the vaccine ranged from a mild fever to severe complications, including (although very rarely) death. In 1977, when the last naturally occurring case of smallpox appeared and the global eradication of smallpox was complete, vaccinia vaccinations for children were discontinued, although vaccinia continues to be used as a carrier for recombinant DNA techniques. In these techniques, foreign DNA is inserted in cells. Efforts to produce a vaccine for HIV, for instance, have used vaccinia as the vehicle that carries specific parts of HIV.

SEE ALSO Bacterial biology; Careers in forensic science; Ebola virus; Pathogens; Vaccines; Variola virus.

Rudolf Ludwig Carl Virchow

10/13/1821–9/5/1902
GERMAN
PATHOLOGIST, PHYSICIAN

Rudolf Carl Virchow was the founder of the school of cellular **pathology**, which forms the basis of modern pathology. Pathologists examine tissues and organs to identify and study the effects of disease upon the body. Forensic pathologists examine tissues and organs for legal purposes and crime solving, such as determining the **cause of death**, and documenting disease processes or bodily injuries.

Virchow, an only child, was born in a small rural town in Germany. His early interest in the natural sciences and broad humanistic training helped him get high marks throughout school. In 1839, his outstanding scholarly abilities earned him a military fellowship to study **medicine** at the Freidrich-Wilhelms Institute in Berlin, Germany. Virchow had the opportunity to study under Johannes Müller, who encouraged many German physicians to use experimental laboratory methods in their medical studies. Gaining experience in experimental laboratory and diagnostic methods, Virchow received his medical degree in 1843 from the University of Berlin and went on to become company surgeon at the Charité Hospital in Berlin.

As a young scientist, Virchow became a powerful speaker for the new generation of German physicians. He viewed medical progress as coming from three main sources: clinical observations, including examination of the patient; animal experimentation to test methods and drugs; and pathological anatomy, especially at the microscopic level. He also insisted that life was the sum of physical and chemical actions and essentially the expression of cell activity. Although these views caused some older physicians to condemn Virchow, he received his medical license in 1846.

Two years later, Virchow was sent to Prussia to treat victims of a typhus epidemic. Seeing the desperate condition of the Polish minority, he recommended sweeping educational and economic reform and political freedom. From that point on, he argued that to provide any benefit for the sick, one must treat the ills of society. Acting on his convictions, Virchow fought in the uprisings of 1848 and became a member of the Berlin Democratic Congress. Unfortunately, his strong political and social conscience cost him his university post. Virchow finally left Berlin for the more liberal atmosphere of the University of Würzburg.

It was at Wüzrburg that Virchow embarked on his highest level of scientific achievement—his development of cellular pathology. In 1855, Virchow published his journal article on cellular pathology. "*Omnis cellula e cellula*," he wrote, meaning all cells arise from cells. Essentially, his article generalized the concept of cell theory and modernized the entire medical field. The cell became the fundamental living unit in both healthy and diseased tissue. He used the microscope to bring the study of disease down to a more fundamental level; disease occurred because healthy living cells were altered or disturbed. In 1859, Virchow's book *Cell Pathology* became a classic textbook that would influence generations of physicians. Although Virchow's work carries lasting significance, Virchow rejected the germ theory developed

Rudolf Virchow looking through a magnifying glass.

by Louis Pasteur, arguing instead that diseased tissue resulted from the breakdown of order within cells and not from the invasion of a foreign body. Scientists have since discovered that disease results from both circumstances.

SEE ALSO Autopsy; Pathology.

Virus SEE Viral biology

Virus, computer SEE Computer virus

Visible microspectrophotometry

Visible microspectrophotometry is a very useful tool in the forensic analysis of many kinds of **trace evidence**. It combines a microscope with a spectrophotometer so that the light absorption properties of a very small sample can be recorded. The technique is particularly valuable in the investigation of hair, textile **fibers**, and paint, which are typically of microscopic dimensions. A fiber, for instance, may have a diameter of only around 20 micrometers.

The chemical bonds within the molecular components of trace **evidence** interact with light in a characteristic manner. They will absorb, transmit, or reflect specific frequencies of visible light. When human eyes see a piece of cloth as blue, for example, this means that although white light falls upon the material, all the color frequencies making it up except blue are absorbed by the dye molecules in the material. It is therefore the blue frequencies of light that are reflected back. A yellow fiber contains different dye molecules, which reflect back only yellow frequencies. Visible spectrophotometry is a more sophisticated and highly accurate way of recording exactly what color an object is.

When an opaque or translucent item of trace evidence is inserted into the visible microspectrophotometer, it is exposed to a range of visible frequencies. The frequencies where it reflects, absorbs, or transmits, depending on the mode of the instrument, are recorded at a detector as a spectrum, or fingerprint, of that material. Comparisons can be made with materials whose visible spectra are held in reference databases. It is also possible to compare a piece of trace evidence with a control sample. A textile fiber found at the scene of the crime can be compared with one found on a suspect's clothing, for instance. If their visible spectra are identical, then they likely come from the same source. The same is true of hairs and paint flakes. Visible microspectrophotometry is also a useful and non-destructive way of analyzing colored inks in the investigation of **questioned documents**.

SEE ALSO Micro-fourier transform infrared spectrometry; Spectroscopy.

Voice alteration, electronic

In most cases, voice alteration technologies are employed to obscure an individual's identity. This can complicate the forensic **identification** of the individual. Forensic specialists who examine spoken or written materials in relation to legal matters and crimes are known as forensic stylists or forensic linguists. Forensic linguists frequently deal with **evidence** containing altered voices. Crude voice alteration can be achieved by physical training. Actors and singers, for example, can train their voices so that the speech or song "projects" to all areas of the theater. Also, accents can be learned and mimicked with reasonable accuracy.

In this natural process the vocal cords function as the source of the sounds and the vocal tract functions as the filter that can alter the frequency and cadence of the speech. The results is the rising and falling tones and intensity of spoken words.

However, the use of electronic technology can achieve accurate vocal alterations that are not otherwise possible. For example, vocal cords can be trained to be able to adopt different pitches—that is, to be capable of vibrating at different frequencies, to produce sounds that have different tones. However, electronic alterations of pitch can widen the vocal deceptions that are possible. For example, a man's voice can be altered to sound convincingly like a woman's.

The alteration of pitch can also be deliberately done electronically by detecting the frequency pattern of the speaker, and of the particular phrase being spoken. On a screen, the pattern appears as a series of waves and troughs. The arrangement of the waves and troughs is characteristic to the word being spoken. For example, the word "cat" will produce a different pattern than the word "invisible." By applying an electronic filter (or "window"; actually one or more mathematical equations, or algorithms) to the frequency pattern, waves and troughs can be selectively eliminated or shifted up and down to produce a different frequency. An experienced technician or sophisticated software program can alter a word so as to change the sound of the word (i.e., a higher or lower tone) without distorting the sound of the word. Thus, the altered speech is still recognizable and interpretable, but can sound like it is being spoken by another person.

Electronic voice alteration can be subtle or extreme. The latter is associated with the almost incomprehensible voices of anonymous witnesses. This type of voice alteration is actually a voice disguise. The intention is not to mimic a voice, but to scramble the voice patterns to make the speaker impossible to identify.

There are several different electronic means of voice alteration. One type is known as speech inversion. Here, the frequency signal is in effect turned inside out around a designated frequency. Put another way, the parts of the speech that are "high" are made to sound "low," and visa versa.

A voice can also be electronically jumbled, so that it sounds like gibberish. But **codes** assigned to sections of the speech allow the listener (who has the electronic codes) to put the words back in their proper order.

Another means of electronic voice alteration is known as speech encryption. Here, speech is digitized and the digital signal manipulated to make the text of the speech unrecognizable to the listeners ear. But the speech can be decoded, or decrypted, at the receiving end to yield the original recognizable speech.

Hardware and software voice encryption systems are available. Machines connected to a telephone can alter a person's speech during the telephone conversation. Anyone eavesdropping on the conversation would be incapable of understanding what was being said. However, a legitimate listener, having a machine on his or her phone, would be capable of decrypting the conversation.

The United States government and military uses a telephone conversation scrambling software program and hardware called Secure Telephone Unit, Generation III (STU III).

Scrambling digital electronic information in relation to time can also accomplish voice alteration. An example includes the delay of information. While an effective means of altering a voice, the method can produce an echo, and so is unpleasantly distracting to listen to.

SEE ALSO Linguistics, forensic stylistics; Telephone recording system; Telephone tap detector.

Voice analysis

Voice analysis was first used in World War II for military intelligence purposes. Its use in forensic investigation dates back to the 1960s and relies on the fact that each person's voice has a unique quality that can be recorded as a voiceprint, rather like a fingerprint, on an instrument called a sound spectrograph. Suspects knowingly or unknowingly leave recordings of the voices on the telephone, voice mail, answering machines, or hidden tape recorders, and these samples can be used as **evidence**. Forensic voice analysis has been used in a wide range of criminal cases such as **murder**, rape, drug dealing, bomb threats, and terrorism.

Each person's voice is different because the anatomy of the vocal cords, vocal cavity, and oral and nasal cavities is specific to the individual. Added to that, each person coordinates the muscles of the lips, tongue, soft palate, and jaw differently to produce words. The teeth also have an impact in the way speech is formed. The body's voice-producing apparatus is like an organ pipe producing notes, a tube in which sound waves vibrate, producing sounds which can readily be recorded.

The sound spectrograph records a voiceprint in terms of the frequencies and intensities of the sounds made by an individual while speaking. A good mimic may sound like the person they are imitating, but the voiceprint will be quite different. Of course, a person's voice changes with age, but the voiceprint remains distinctive.

Voiceprint samples may be obtained through covert police operations, such as by investigators wearing hidden microphones or putting surveillance equipment on a suspect's phone. As with fingerprints and **shoeprints**, samples for comparison can be taken from a suspect, by court order if necessary. The investigator will ask them to speak the same words as those that were recorded on the voice evidence that has been collected. This may be a 911 call from a murderer or a bomb threat call. There is always the possibility that the suspect will try to disguise his or her voice, but the voiceprint expert will probably be able to allow for this.

The investigator has two complementary ways of making an **identification** through voice analysis. First, he or she will listen to the evidence sample and the sample taken from the suspect, comparing accent, speech habits, breath patterns, and inflections. Then a comparison of the corresponding voiceprints is made. There is no international standard for the minimum number of points of identity needed in this comparison, but ten to twenty speech sounds that correspond are often taken as good proof of identification.

It has been argued that voiceprints may not be as individual as fingerprints. Certainly the technology for analysis is probably not as well developed. However, in one analysis of 2,000 cases by the Federal Bureau of Investigation, the error rate in both false identification and false elimination of suspects was found to be very low.

Voice identification played a key role in the investigation of the crimes of Peter Sutcliffe, the so-called Yorkshire Ripper, who murdered several women in the North of England in the late 1970s. Tapes purporting to be from the Ripper were sent to the police team involved in the case, taunting them for their lack of success in catching him. Voice analysis was at first inconclusive, but it now looks as if the tapes were probably the work of a hoaxer.

Voice analysis has also been applied to the investigation of tapes said to be made by Osama bin Laden, the world's most-wanted terrorist. Since the terror attacks in New York and Washington on September 11, 2001, bin Laden has apparently issued a number of video and audiotapes. Corresponding words on the tapes, like "America," can be compared, but the voiceprints do not match exactly because the same person will never say a word in exactly the same way each time. If there is enough similarity, however, an identification can be made even if it is tentative, especially if there is other evidence. Of course, bin Laden speaks in Arabic, but there is software to handle this and other languages. It may be significant that the most recent utterances by bin Laden have been by audio rather than video tape, raising the possibility that he has been dead for some time and the tape has been made by someone else hoping to raise the morale of al Qaeda. The tape is of poor quality and difficult for analysts to work with. It is unlikely, however, that a mimic could fool a voice analysis expert, even under these conditions. Yet there is the possibility that the tape has been created from previous ones that feature bin Laden's real voice, with new information pasted in to update it. The final possibility is that the tape has been made by one of his sons; parents and children tend to sound similar and may give similar voiceprints. The identification of bin Laden looks as if it will be an ongoing challenge to the forensic voice analysts.

SEE ALSO Linguistics, forensic stylistics.

August Vollmer

3/7/1876–11/4/1955
AMERICAN
POLICE CHIEF

August Vollmer was a pioneer in the science of forensic investigations. The founder of "professional policing," he was born in New Orleans, Louisiana, on March 7, 1876. Vollmer held a variety of jobs in his early years, including firefighting, a coal and feed business, a private in the military, and a mail carrier. In 1905, he became the town marshal of Berkeley, California, and by 1909 he was made the chief of police for Berkeley.

In the wake of years of police corruption and brutality throughout the United States, Vollmer sought to increase the professionalism of police. During his tenure as police chief, Vollmer began to revamp the Berkeley Police Department by making changes that would transform policing across the nation. Vollmer instituted police **training**, advocated using college-educated officers, and promoted the use of new technology for fighting crime such as fingerprinting, polygraph machines, and crime laboratories. In addition, Vollmer equipped the Berkeley Police Department with radio communication and in 1914 established the first automobile patrol in the United States.

Vollmer was elected as the president of the California Police Chiefs Association in 1907, and in 1922 he became the president of the International Association of Chiefs of Police. During his tenure as president, Vollmer suggested changes for policing nationwide. Many suggestions mirrored the policies and programs Vollmer instituted in Berkeley, such as increased use of technology and science and providing training for police. Vollmer also advocated using female officers more frequently and encouraged universities to increase their study of human behavior. Vollmer also contended that the goal of policing should be crime prevention. Throughout his life, both before and after retirement, Vollmer assisted police departments outside of Berkeley in improving their policing strategies. Vollmer helped revamp the San Diego Police Department, and completed several surveys of local police departments throughout the United States, including Los Angeles, Chicago, Detroit, Kansas City, Minneapolis, Santa Barbara, Piedmont, Syracuse, Dallas, and Portland. The surveys were used to help departments consider ways to reconstruct their police departments. Drawing on these surveys, Vollmer also authored a "Report on Police" for the Wickersham Commission in 1931.

In conjunction with his emphasis on the importance of education in policing, Vollmer taught police administration courses during the summer at the University of California. Additionally, he took leave as Police Chief of Berkeley from 1929–1931 and taught courses at the University of Chicago. When Vollmer retired as chief in 1931, he took on a position as a professor of police administration at the University of California Political Science Department where he continued to teach until 1937. During his years at the University of California, he wrote *Crime and the State Police* in 1935 and the *Police and Modern Society* in 1936. Vollmer also helped develop **criminology** courses at the university.

After retiring from his position at the University of California in 1937, he continued to play an active role in the field of criminal justice by founding the American Society of Criminology, and in 1941 served as its president. He also collaborated with Alfred E. Parker in 1937 to write *Crime, Crooks and Cops*, and in 1949 he authored *The Criminal*. After a long and successful career in policing and criminal justice, August Vollmer took his own life on November 4, 1955, at the age of 79.

SEE ALSO Criminology; Fingerprint; Literature, forensic science in; Polygraphs.

Juan Vucetich

7/20/1858–1/25/1925
CROATIAN
POLICE OFFICIAL

Juan (Josip) Vucetich was a Croatian-born Argentinean anthropologist and police official who pioneered the use of fingerprinting. In 1882, at the age of 24, he left his birthplace of Lesina and immigrated to Argentina. He was one of the front-runners of scientific dactyloscopy (**identification** by fingerprints).

Fingerprints were already used on clay tablets for business transactions in ancient Babylon and more recently in the fourteenth century for identification purposes. But in 1788 J. C. Mayers recognized that friction ridges are unique. Until 1890, however, the technology used for individualization was the anthropometric method designed by the French criminalist **Alphonse Bertillon** (1853–1914), based on the size of body, head, and limbs.

In the 1880s Argentine police considered it necessary to create a department that would take care of identifying individuals and commissioned doctor Augusto P. Drago to study the method established by the Bertillon. Subsequently, the Police of the City of Buenos Aires created a division dedicated to anthropometric identification. While Drago was establishing anthropometric identification in Buenos Aires, Vucetich was investigating fingerprints in the nearby La Plata Office of Identification and Statistics.

Inspired by an article from the French *Revue Scientifique* that reported on the English scientist Francis Galton's (1822–1911) experiments with fingerprints and their potential use in identification, Vucetich started to collect impressions of all ten fingers to include with the anthropometric measurements he took from arrested men. His intense study led him to confirm that fingerprints could be classified by groups. In 1891 Vucetich devised his own **fingerprint** classification method by means of impressions. He also invented the necessary elements to obtain the best possible quality of fingerprints and implemented every resource to systematize the method. It wasn't until 1894, however, that his superiors were convinced that **anthropometry** measurements were not necessary in addition to full sets of fingerprint records. By this time Vucetich had refined his classification system and was able to categorize a large number of fingerprint cards into small groups that were easily searched.

Vucetich's new recognition procedure of the classification system was originally called Icnofalangometría or Galtonean method and was later changed to dactiloscopy at the suggestion of another fingerprint pioneer, Francisco Latzina. It consisted of 101 types of fingerprints that Vucetich personally had classified based on Galton's incomplete taxonomy. On September 1, 1891, Vucetich's method began to be applied officially for the individualization of 23 felons, and in March 1892 Vucetich opened the first fingerprint bureau at San Nicholas, Buenos Aires.

Within a short time of the bureau being set up, the first conviction by means of fingerprint **evidence** in a **murder** trial was obtained. In June 1892 a colleague of Vucetich's, Inspector Eduardo Alvarez, took digital impressions from a crime scene at Necochea. Eventually, Vucetich was able to identify Francisca Rojas, who had murdered her two sons and cut her own throat in an attempt to blame a neighboring ranch worker. Rojas's bloody print was left on a door post of her hut, taken to the fingerprint bureau for comparison with the inked fingerprint impressions of the ranch worker, and eventually proved Rojas's identity as the murderer.

The insight obtained by the police department through Vucetich's simple and efficient fingerprinting identification method encouraged the government to widen the filiations procedure and in 1900 the first identification cards were issued. Argentinean police adopted Vucetich's method of fingerprinting classification and it was widely spread to police forces all over the world for being scientifically efficient and superior to the existing methods.

Vucetich published all his methods, theories, and findings, which eventually were translated in the book *General Instructions for the Anthropometric System and Digital Impressions*. His work *Dactiloscopía Comparada* (Comparative Dactyloscopy) came out in 1904 and is considered to be his masterpiece, which led him to receive awards and honors from around the world.

Juan Vucetich created the most flawless system of fingerprint classification and is credited as being the first person to use a **latent fingerprint** to solve a crime. His work and perseverance went beyond his commitment. He made investigational trips to India and China trying to find out the origins of identification by fingerprints, and he attended scientific congresses and published numerous books based on his findings.

While Juan Vucetich's system is still used in most Spanish countries, William Henry's system of fingerprint classification, which was officially adopted by Scotland Yard as their identification system in 1901, continues to be in use in the United States and in Europe. A majority of the identification bureaus around the world use either the Vucetich or the Henry classification system. International organizations such as **Interpol** now use both methods.

Juan Vucetich died in the city of Dolores, province of Buenos Aires. He donated his files and his library to the Faculty of Judicial and Social Sciences of the National University of La Plata, which served to create the museum that bears his name. In the honor of Vucetic, La Plata Police Academy has been named "Escuela de policia Juan Vucetic."

SEE ALSO Anthropology; Anthropometry; Fingerprint; Interpol.

W

Charles E. Waite

1865–1926
AMERICAN
FORENSIC SCIENTIST

Forensic scientist Charles E. Waite was involved in a number of landmark advancements in the science of **ballistics** over the course of his career. He was the first person to compile a catalog of information on **firearms**, and was part of the group of scientists who adapted the **comparison microscope** for use in ballistics comparison. Waite also was a co-founder of the Bureau of Forensic Ballistics.

During the 1910s Waite was working as a special investigator for the New York Attorney General's office. It was at this point that he became involved in a case that would prove pivotal to his career. In 1915, an illiterate farmer in rural New York was accused of a double **murder**. Investigators hired a firearms expert who claimed that the bullets used in the murders matched the gun found in the farmer's house. Stielow, the farmer, was convicted to the murders and sentenced to death. However, the New York governor requested a reinvestigation of the case, and Waite was assigned to the job. He worked with microscopy expert Max Poser to examine the fatal bullets along with bullets test fired from Stielow's gun, studying the bullets with **microscopes**. They ultimately determined that Stielow's gun could not have been used in the murders. The man was pardoned and released.

Waite's experience with the Stielow case inspired him to look into developing a scientific system of cataloging ballistics information in order to prevent future mistakes. For a number of years he collected data, visited firearms manufacturers, and traveled around the United States and Europe. Waite, with the help of Calvin Goddard, created a database of information that was the first of its kind in the area of ballistics.

In 1925 Waite and fellow scientists Calvin Goddard, Phillip O. Gravelle, and John H. Fisher opened the Bureau of Forensic Ballistics in New York, New York. Their goal was to offer firearms **identification** services to agencies across the U.S. About this same time, Waite and the group also adapted the comparison microscope so that it could be used for bullet comparison. This capability made it much easier for examiners to identify matching bullet striations.

SEE ALSO Ballistic fingerprints.

War crimes trials

War crimes are offenses against the laws of engagement of war, such as killing or mistreating civilians or prisoners of war. After World War II (1939–1945), the principle of punishing those involved in war crimes became established although it is a concept that is still evolving in many ways. Suspects are tried by their own civilian or military courts or by international tribunals. Such trials have now been extended to cover genocide and crimes against humanity. Currently many war crimes trials, which tend to be very lengthy complex affairs, are ongoing or planned, such as the one that hears the charges against Saddam Hussein and his followers in Iraq. The first war crimes trials relied mainly on witness statements and documentary **evidence**. In more recent times, however, **forensic science** has begun to play a more important role in the prosecution of war crimes.

The Nuremberg Trials of 1945 tried many Nazi leaders, including Hermann Goering and Joachim von Ribbentrop, and were conducted by a tribunal consisting of representatives from Britain, the United States, the U.S.S.R., and France. German dictator Adolf Hitler (1889–1945) escaped trial by committing suicide shortly before the end of the war. Japanese war criminals from World War II were also tried by a tribunal in Tokyo. Large amounts of evidence were brought to bear, showing the extermination of civilians, especially Jews, mistreatment and **murder** of prisoners of war, looting, and the use of slave labor during the war years.

Nuremberg established a precedent and a model from which lessons could be drawn. Later, several Americans were tried for crimes committed in the Vietnam War and, in the 1990s, the United Nations set up a tribunal in The Hague to gather evidence for prosecutions against those accused of atrocities in the break-up of Yugoslavia. The highest-ranking official to be tried by this court is former Yugoslavian President Slobodan Milosevic, whose trial began in 2002. In the year 2000, rape, which was very common in the Yugoslav conflict, was established as a war crime. Meanwhile another tribunal in Tanzania has been investigating the Hutu massacres of the Tutsis in Rwanda in 1994, and one in Sierra Leone is trying those accused of atrocities during that country's civil war of the 1990s. In 1998, the United Nations General Assembly voted for a permanent international court for trying war crimes. The judges of the International Criminal Court, based in The Hague, were sworn in in 2003, and charged with trying war crimes, genocide, and crimes against humanity.

Modern war crimes trials depend upon witness statements, documentary evidence, and forensic evidence. Much of the forensic work carried out in places such as Bosnia, Afghanistan, and Iraq has involved the investigation of mass graves. This kind of work is very different for the forensic scientist compared to what is required in routine crime investigations. However, the principles of collecting, preserving, and analyzing evidence remain the same, although they are more difficult to achieve. Many places where atrocities have been committed in the recent past are still unsafe, and the investigative agencies must consider the safety of their personnel. There may be logistic problems in transport and in setting up laboratory space and equipment. The investigators attempt to work with local people and take care to respect their customs. There is also no guarantee that the crime scene, most likely a mass grave, has been kept secure and evidence preserved since the atrocities were committed.

An important part of the forensic work done in war crime investigations is **identification** of people who have disappeared during a conflict. Not only does this provide key trial evidence, but it also brings some comfort and closure to the loved ones of those who have gone. Identified remains can then be given a proper burial. However, there is often a conflict between the needs of the trial and the needs of families. The former require evidence of the scale of the war crime rather than the establishment of the identity of each victim. The family wants to know what happened to the individual.

Establishing identity begins with a physical description of the missing person provided by a close relative or friend. This includes details about the person's physical appearance such as height, hair color, teeth, tattoos, scars, as well as about items they may have been carrying or wearing at the time of their disappearance, such as jewelry, eyeglasses, shoes, and clothing.

Bodies and remains are then exhumed from the mass grave, usually by forensic archaeologists and forensic anthropologists. Documents found on a body may provide a lead for identification. Postmortem (after death) and antemortem (around the **time of death**) data can then be compared. Sometimes photographs of clothing worn by the deceased can be identified by the family. In the modern era, **DNA** analysis can provide confirmation of identity but this is a very expensive way of investigating a mass killing. Teeth and bones survive long after other tissues have decomposed and may yield DNA that can be compared to that of relatives. Such identity investigations are always, necessarily, incomplete. Not all of the bodies originally present in a mass grave will be recovered on **exhumation**, and not all of these will be identified. Around 30,000 people were missing in Bosnia by the time the conflict there was resolved in 1995. Since then, about 15,000 bodies have been recovered, of which 9,000 have been identified. DNA analysis contributed to identification in around 3,000 cases. The same has been found in the investigation

At an identification center in Tuzla, 2002, a forensic expert takes samples from a bone for future identification of one of almost 3,500 dead Bosnians. Former Yugoslav leader Slobodan Milosevic was charged with crimes against humanity. © REUTERS/CORBIS

of war crimes in Rwanda where the sheer scale of the killings, half- to three-quarters of a million people, makes a full forensic examination almost impossible. It is possible that forensic science may never uncover the full horror of some war atrocities.

The above approach has been adopted by the International Forensics Program for the Physicians for Human Rights group during its investigation of the 1995 massacre of Srebrenica in Bosnia and has led to the identification of many of the victims. The investigators have exhumed over 400 bodies; many had bullet wounds in the **skull** and ligatures around the wrists, important **physical evidence** for a war crimes trial. The Program has carried out similar investigations in many countries around the world including Afghanistan, Israel, Kosovo, and Rwanda.

Other evidence from a mass grave may be important to a war crimes trial. The investigators will try to establish if the victims belonged to a particular religious or ethnic group. This can help define whether the perpetrators are guilty of genocide, the targeting of a specific group in society for destruction. The team will also try to establish patterns in the killing, whether the same methods were used at different sites and whether the killers tried to cover their tracks and destroy evidence. By building a picture of what happened at the various scenes, the investigators may also try to establish if a crime against humanity has been committed. This encompasses a wide range of acts: mass murder, enslavement, deportation, rape, and torture committed on a large scale against civilians. Documentary evidence of planning of such crimes may be found which can back up these forensic findings.

Lessons learned from other forensic investigations of war crimes and crimes against humanity may now be put to work in Iraq. As of April 2005, more than 250 mass graves have been discovered in the country since the removal of Saddam in 2003. Evidence from these sites will be vital in his trial and is also eagerly awaited by Iraqis wanting to know what happened to their loved ones. However, there are huge challenges for the investigators. Saddam's atrocities occurred over a 30-year period and many, if not most, of the corpses will now be badly decomposed. Victims were often transported over hundreds of miles for **interrogation** and execution, so a geographical link to help in identification is unlikely. Much documentation, which could have provided valuable evidence, has been destroyed or looted. Furthermore, 24-hour security, essential once a forensic investigation is underway, cannot currently be guaranteed at the sites.

The graves themselves have been located either by survivors of the massacres, or by witnesses. In some cases, people have just come across shallow graves. Some Iraqis, wanting to investigate the possible fate of disappeared relatives, started to investigate the graves themselves, but in a disorganized manner that was likely to destroy evidence. Many have since been persuaded to await a professional forensic investigation. While there are moves afoot to set this program in motion, there are huge difficulties involved. The medico-legal system in Iraq is in chaos, because of the war and ongoing conflict. Iraq has many forensic pathologists, but no forensic anthropologists. There is also a tradition of using **circumstantial evidence** such as documents found on the body, or clothing, for identification rather than dental records or x-rays. There are opportunities for international collaborations to provide support and **training** to Iraqi forensic scientists. First, however, the basic needs of the discipline need to be attended to. Work has begun on two mass graves, but there is an ongoing problem in protecting the sites to preserve the evidence.

SEE ALSO Anthropology; Archaeology; Disappeared children of Argentina; DNA mixtures, forensic interpretation of mass graves; Identification of war victims in Croatia and Bosnia.

War forensics

Modern forensic techniques for human **identification** as well as **crime scene investigation** protocols are also applied to the investigation of war crimes, aiding with assessing and characterizing the burden of proof against individuals before both national and international courts. Forensic techniques are essential in gathering **physical evidence** for the indictment, arrest, and prosecution of war criminals, and to the localization and identification of people who disappeared in times of war. The Hague Conventions of 1899 and 1907 established the Laws and Customs of War, and defined which breaches of these laws should be qualified and punished as war crimes. The use of poisonous weapons, wanton destruction of cities without military necessity, attacks on religious and cultural institutions, attacks of undefended civilian communities, and looting of public or private property are among war crimes defined by the Hague Conventions.

The International Military Tribunal, created in 1945, further defined war crimes in its Nuremberg Charter as any violations of the laws or customs of war, such as executions of captured military personnel or civilians without a judicial process, **murder** or ill-treatment of prisoners of war, deportation of civilians from occupied territories, looting of public and private property, killing of hostages, and any kind of devastation unjustified as military strategic necessity. The Geneva Conventions of 1949, which codified the International Humanitarian Law, included for the first time a list of serious offenses in times of war for which individual offenders should be criminally accountable. The Geneva Conventions also described the ethics to be followed by all military forces of signatory countries in relation to the 1) wounded and sick on land; 2) wounded and sick at sea; 3) prisoners of war; and 4) civilians in the occupied territories. The Geneva Convention also described other serious offenses liable for punishment under international law, including torture or inhuman treatment, unethical medical experimentation on prisoners, willful killings, willful inflicting of unnecessary suffering, slave labor, deprivation or injury to body or health, the extensive destruction or the unlawful arbitrary appropriation of property not justified by military necessity, forcing a prisoner of war or a civilian to serve in the forces of a hostile army, denial of a fair and regular trial to prisoners of war or civilians, and the taking of hostages.

In 1977, the protections of the Geneva Convention were extended to include violence against or wanton attack of civilians in non-defended communities, the transfer of an occupying power or of part of its population to an occupied territory, unjustified delays in the repatriation of prisoners of war, attacks to historic monuments, and perfidious (false) use of the Red Cross or Red Crescent emblems. The protocol also determined that states must prosecute or extradite to other states willing to prosecute, individuals accused of war crimes, and of crimes against humanity. The implication of the International Laws and Customs of War is to empower each signatory state with the legal right to search, arrest, and prosecute individuals indicted as war criminals (e.g., for crimes committed in the context of war).

Additional protocols in 1977 defined the rules for internal armed conflicts or civil wars, but did not offer provisions for criminal liability under the international law, leaving it to local jurisdictions. The crimes described for civil wars are: murder, torture, mutilation, rape, enforced prostitution, indecent assault, summary executions, collective punishments, looting, outrages upon personal dignity, and violence to life and person.

Crimes Against Humanity (CAH) were first defined in the Hague Convention of 1907, consisting of those acts that breached the Law of Humanity but are not limited to the context of war between nations. The provisions of CAH state that all signatory states have the duty to prosecute or to extradite offenders under such indictment, regardless of where the crime was committed. The Hague Convention also established that no one is immune from criminal liability, including heads of states. For instance, the trials against the Chilean dictator Augusto Pinochet were first held in Spain, although the crimes were committed in Chile, during his military regime. Claims of obedience to superior orders or political offense exception are inadmissible under the Laws of Humanity. The Crimes Against Humanity were established for the first time as international law by the International Military Tribunal in the Nuremberg Charter of 1945.

Although in some instances, Crimes Against Humanity overlap in their description with the Geneva Convention definition of War Crimes, as in the cases of genocide and other war crimes, they are not restricted alone to either times of war, or to the war crime definition of genocide. CAH provides criminal liability for cases in which atrocities are committed without the intent to destroy in whole or in part a given population and also targets any group committing widespread or systematic violations. Recent examples of such violations are those committed by the Hutus in Rwanda in 2002 and those underway, beginning in 2003, in East Congo by Rwandan Hutu militias against Congolese women and children. Such violations include rape and torture of women and children, sex enslavement, looting, and massacres of defenseless Congolese rural communities.

The challenges met by forensic investigators to gather **evidence** in zones of conflict are numerous, as illustrated by the Balkan conflicts of the last two decades. Primary crime scenes and graves were destroyed by the perpetrators, and human remains or body parts were scattered or transferred to secondary mass graves. Identification of victims and forensic corroboration of testimonial reports is complex and ongoing. Many locations containing mass graves are mined and difficult for investigators to access. Local authorities often create obstacles or impede gathering evidence by international investigators, especially in areas of Serbia.

An international team of forensic experts organized by Physicians for Human Rights (PHR) and working under the United Nations War Crimes Commission began the **exhumation** of two mass graves at Ovcara, near the city of Vukovar, Serbia. In spite of the fact that the forensic team had a written permit from Serbian authorities from Knin, local Serbian authorities in Vukovar passed a resolution through the Regional Council to ban the exhumation. The first evidence collected (three male skeletons) showed that the remains were of Croats and some ballistic studies were already underway when the local ban occurred. The information gave the International Criminal Tribunal for the Former Yugoslavia legal argument to commit to guarding the gravesites until 1996, when experts were able to return. However, land mines were planted by Serbian militias in the surrounding areas, which had to be localized and removed before the exhumation work was resumed. Two hundred bodies were then found, and identification proved that they were all Croat patients of the Vukovar Hospital, executed by bullets to the head. The expert team consisted of 33 pathologists, 24 forensic anthropologists, forensic photographers, x-ray and fluoroscope experts, evidence technicians, electricians, drivers, translators, and local workers.

Mass grave excavation starts with a previous assessment of its boundaries and the gathering of surface evidence, such as bullet cases, signs of tools or machinery used to dig the grave, scattered rags, or personal belongings in the adjacent bushes or woods, etc. The surface of the grave is then mapped, marked and photographed, and (in rainy seasons) trenches are dug around its boundaries to drain the water. Layers of soil are then carefully removed, until the first bodies are exposed and photographed before being removed for **autopsy** and **pathology** analysis. The outer bodies are usually more skeletonized than those underneath them, or those closer to the center of the grave, because body **fluids** and moisture that concentrate in these areas do favor **adipocere** formation or body fat saponification. In the case of the Vukovar Hospital patients, investigators found, even after five years, well-preserved remains with flesh and skin displaying tattoos, along with recognizable faces.

As a standard procedure, corpses are photographed in the position they were found inside the grave, before being carefully moved to reveal, for instance, if their hands were tied behind their backs. The victims were then photographed again after removal from the gravesite. If bullets are found inside the grave, they are also photographed and collected for identification. When the death was not due to shooting but poisoning, gassing, hanging, beating, or other cause, autopsy and laboratorial tests are performed to determine the *causa mortis* (**cause of death**). Several different *causa mortis* have been identified in remains of the same mass grave. In many mass graves, babies have been found in the arms of their mothers.

In Croatia and Bosnia, between 25–70% of the bodies found in mass graves were of women and children. Among those mass graves investigated by the United Nations War Crimes Commission, at Sirsca, 150 bodies were found, at Lazette 130, in Kibuye 500, and in Vukovar 200. Mass graves have also been exhumed in Rwanda, Argentina, Brazil, Iraqi, Kurdistan, Ethiopia, Mexico, Guatemala, and in several parts of Eastern Europe. The forensic evidence they yield has instrumented trials in several local and international tribunals in support of witnesses, testimony, and helped to indict war criminals and those accused of crimes against humanity.

To make a case of genocide, for instance, investigators and prosecutors have to supply evidence that a given religious or ethnic group was systematically persecuted and executed, such as the case of Jews and Roma people in World War II (1939–1945) or the Bosnian Muslims and Kosovars in the Balkans in the early 1990s. The Third and Fourth Geneva Conventions require the proper identification, registration, and burial of victims of war in individual graves. However, dead combatants are sometimes temporarily buried in collective graves by their comrades to be later recovered and transported. This does not constitute a crime. The United Nations Resolution 3074 of 1973 instructs all states to cooperate with war crime investigations, and to facilitate the safe access of forensic teams to suspicious sites. Nevertheless, much still must be done to empower international institutions and tribunals to chase and prosecute war criminals, and to enforce international law.

Forensic science is also used to identify the remains of soldiers. The remains of unidentified American soldiers from World War I, World War II, and the Korean conflict lie in honored tombs at Arlington National Cemetery. In 1973, Congress authorized the creation of a tomb for an unknown soldier from the Vietnam conflict. Yet internment of the remains of a soldier was delayed until 1984, as authorities awaited additional information about the circumstances of death of the potential unknown soldier. A single set of remains classified as "unknown" was finally interred in 1984, but was exhumed in 1998 when it was believed that the use of mitochondrial **DNA** testing could lead to identification of the soldier. He was finally identified as Air Force 1st Lt. Michael Joseph Blassie, a pilot who was shot down near An Loc, Vietnam, in 1972. To date, no other set of remains has been classified as "unknown," and the sarcophagus at Arlington remains empty.

United States Army engineers use highly sensitive metal detectors to search for the remains of GIs missing in action (MIA) between Tay Ninh and the Vietnam-Cambodia border. © STEVE RAYMER/ CORBIS

SEE ALSO Adipocere; Anthropology; Archaeology; Autopsy; Ballistics; Exhumation; Pathology; Skeletal analysis; War crimes trials.

August von Wassermann

2/21/1866–3/16/1925
GERMAN
BACTERIOLOGIST

August von Wassermann discovered a **blood serum** test that enabled physicians to determine if a patient has syphilis, a potentially lethal disease which, in some persons, has a long latency period during which no symptoms are detectable.

Wassermann was born in Bamberg, Germany to Dora (Bauer) and Angelo Wassermann, a banker. Wassermann received his secondary education in Bamberg and studied **medicine** at several German and Austrian universities. Wassermann married Alice von Taussig in 1895 and the couple eventually had two sons. He received his M.D. degree in 1888 at the University of Strasbourg. In 1890, Wassermann began work at the Institute for Infectious Diseases in Berlin, which was directed by the famous bacteriologist Robert Koch.

Although Wassermann did important work on tetanus, cholera, diphtheria, and tuberculosis, he is best known for his discovery of a blood serum test (now called the Wassermann test) that showed if a patient was infected with syphilis. The bacterium that causes syphilis, *Treponema pallidum*, can lay dormant in a person's body for many years, even a lifetime, without ever manifesting overt symptoms. Syphilis can be spread by sexual intercourse or from a pregnant mother to her fetus. Therefore, people who are infected with the bacterium need to be identified, so they can be treated and do not spread the disease unintentionally.

In 1906, Wassermann and Albert Neisser developed a syphilis test for the blood serum of patients. Serum is the pale yellow fluid that is one of the constituents of blood. People with syphilis produce a specific **antibody**, which is a molecule in the blood serum produced by the body's **immune system** to attack the syphilis bacterium. When a patient's blood serum with the syphilis antibody is introduced into a mixture of beef heart extract, animal blood serum, and washed red blood cells, the patient's antibody combines with parts of the mixture to create visible clumps of cells, which demonstrate the presence of the antibody and thus, the presence of the syphilis bacterium. Wassermann's test helped doctors detect syphilis in babies and adults in order to treat the disease more effectively at an earlier stage in its development. The Wassermann test is a useful, inexpensive screening procedure. However, if positive, it must be confirmed with a more specific blood test.

From 1903 to 1909, in collaboration with Wilhelm Kolle, Wassermann wrote the six-volume *Handbuch der pathogenen Mikroorganismen*, a book detailing disease-producing microorganisms. Wassermann was named the director of the department of experimental therapy at the Kaiser-Wilhelm Institute in Berlin in 1913. In 1924, he was diagnosed with kidney disease, and he died in Berlin the following year. Wassermann continued to direct the department of experimental therapy up until his death.

SEE ALSO Serology.

Water contamination

In a forensic examination, a prime task is to discern the primary cause of illness or death. In some instances, a gunshot wound for example, the cause may be readily apparent; in other cases, such as those involving contaminated food or water, there may be no visual signs of the **cause of death**. Knowledge of the nature of the contamination is essential for the forensic examiner.

Water is known as the universal solvent. This means that a great many compounds will dissolve in water. Still others that do not dissolve can become suspended in water, or, if immiscible (incapable of mixing, i.e., gasoline and alcohol), can partition in the immediate vicinity of water.

Many of these compounds can be nutrients for a variety of microbiological life forms. Other microbes may be more dormant in the water, but still capable of growing when exposed to a more nutrient-rich environment. In the latter case, the water becomes the conduit between the organism's natural habitat and humans.

Water contamination is a concern, since the organisms present can cause disease. Typically, these pathogenic organisms are normally residents of the intestinal tract of warm-blooded animals, including humans. Examples include Salmonella, Shigella and Vibrio. In addition, certain types of the intestinal bacterium ***Escherichia coli*** can cause infections. A particularly noxious form of *E. coli* designated O157:H7 can be devastating. O157:H7 contamination of the municipal water supply of Walkerton, Ontario, Canada, in the summer of 2000 sickened over 2,000 people and killed seven others. The intestinal tract also contains viruses (i.e., rotavirus, enterovirus, and coxsackievirus) that can contaminate water and cause disease.

A number of protozoan microorganisms can contaminate water. The two most prominent are members of the genera Giardia and Cryptosporidium. These microorganisms normally live in the intestinal tract of animals such as beaver and deer. The increasing

Emergency drinking water arrives to aid Walkerton, Ontario, residents whose water supply was contaminated in 2000. After five people died, forensic evidence obtained form both the victims and the water supply showed contamination with the *E-coli* bacteria.

contamination of water by these protozoans reflects the increasing encroachment of urban areas on wilderness.

Municipal drinking water is usually treated to minimize the risk of the contamination of the water with the above microbes. The benefits of water treatment have been reaped for millennia. Thousands of years ago, it was known that the storage of drinking water in metal jugs preserved the water's quality due to the antibacterial effects of the metal ions (although this property was not known until centuries later). Similarly, the protection of water quality by the boiling of the water, which kills the noxious microorganism, has long been known. "Boil water orders" are still routinely issued in municipalities when the water quality is suspect.

Water that is obtained from wells is often protected from contamination by the natural filtering action of the soil and rocky underlayers that the water percolates down through. However, if a well cover or internal casing is broken, then the well water can be directly contaminated.

Surface water supplies are especially prone to contamination, from run-off and the deposition of feces in the water from birds and animals. Surface water that is used as the drinking water supply for an individual or a community should be rigorously treated to ensure that microorganisms, debris, and chemicals have been removed prior to use of the water.

One popular treatment is chlorination. Addition of antibacterial disinfectant compounds, particularly chlorine or derivatives of chlorine, to water has been practiced for over a century. Other treatments that kill bacteria include the use of a gas called ozone and shining ultraviolet light through the water to disrupt the bacterial genetic material. The refinement of filters now allows even viruses to be excluded from filter-treated water.

The killing of the protozoan microorganisms has proved to be challenging, as both Giardia and Cryptosporidium form dormant and chemically resistant structures called cysts during their life cycles. The cyst forms are resistant to chlorine and can pass

Members of Greenpeace take water samples from a canal in the industrial area of Santiago, October 17, 2001. Greenpeace claims that every citizen has the right to know what pollutants industries are pumping into the waters. © REUTERS/CORBIS

through the filters typically used in water treatment plants. Contamination of the water supply of Milwaukee, Wisconsin, with Cryptosporidium in 1993 sickened over 400,000 people and killed at least 47 people.

Water contamination can also involve **inorganic compounds**. Gasoline, oil, pesticides, and other noxious chemicals can also contaminate water. These can be especially insidious, since, unlike microorganisms, they can persist in the water for a long time.

Until relatively recently, water contamination was an accidental occurrence. However, particularly since the domestic terrorist attacks of September, 11, 2001, the vulnerability of water supplies to deliberate sabotage has been recognized.

Pathogenic microorganisms or the toxic by-products of the organisms can be added to water. Drinking the contaminated water can be fatal. While this form of **bioterrorism** is unlikely in a municipal water supply, because the quantities of microorganisms and **toxins** that would be needed, contamination of an individual well is entirely possible.

Descriptions of symptoms including diarrhea, vomiting, headache, or muscle ache can alert a forensic investigator to the possibility of a contamination event.

SEE ALSO Bioterrorism; *Escherichia coli*; Pathogens.

Weapon size SEE Caliber

Weapons and ammunition, examination and identification SEE Ballistics

Dr. Cyril H. Wecht

3/20/1931–
AMERICAN
PHYSICIAN

As of 2005, Cyril Harrison Wecht served as the **coroner** for Allegheny County, Pennsylvania. Formerly the Chairman of the Department of Pathology at Saint Francis Central Hospital in Pittsburgh, Wecht also serves as the President of its medical staff and is actively involved as a medical-legal and **forensic science** consultant, author, and lecturer.

Cyril Harrison Wecht was born in Pittsburgh, Pennsylvania. He attended high school in Pittsburgh (1943–1948, Highest Honors, Valedictorian) and studied at the University of Pittsburgh (1948–1952, B.S.) and the University of Buffalo School of Medicine (1952–1954). Wecht received his medical degree from the University of Pittsburgh School of Medicine (1956). He studied at the University of Pittsburgh School of Law (1957–1959), received his law degree from the University of Maryland School of Law (1962), and his Juris Doctor degree from the University of Pittsburgh School of Law (1962).

Wecht served as chief forensic pathologist from 1966 to 1970 and as Coroner of Allegheny County from 1970 to 1980. After 16 years away from the post, Wecht reclaimed the role of Allegheny County Coroner in 1996.

He is certified by the American Board of Pathology in anatomic, clinical, and forensic pathology, and is also a Fellow of the College of American Pathologists and the American Society of Clinical Pathologists.

Wecht is a Clinical Professor at the University of Pittsburgh Schools of Medicine, Dental Medicine, and Graduate School of Public Health, and holds positions as an Adjunct Professor at the Duquesne University School of Law, School of Pharmacy, and School of Health Sciences.

He has served as President of the American College of Legal Medicine, the **American Academy of Forensic Sciences**, and served as Chairman of the Board of Trustees of the American Board of Legal Medicine and the American College of Legal Medicine Foundation.

Wecht has lectured at numerous medical, law, and other graduate schools, as well as many colleges and universities, and numerous professional organizations and governmental agencies, including Harvard Law School, Yale Medical School, the FBI Academy, and the Medical Division of the CIA.

The author of more than 500 **professional publications**, Wecht is also an editorial board member of more than 20 national and international medico-legal and forensic scientific publications; editor of the five-volume set *Forensic Sciences*; co-editor of the two three-volume sets *Handling Soft Tissue Injury Cases* as well as *Preparing and Winning Medical Negligence Cases*.

Wecht has organized and conducted postgraduate medico-legal seminars in more than fifty countries throughout the world in his capacity as Director of the Pittsburgh Institute of Legal Medicine. He has performed approximately 15,000 autopsies and has supervised, reviewed, or has been consulted on about 35,000 additional postmortem examinations.

Wecht has testified in more than 1,000 civil, criminal, and workers compensation cases in state and federal courts in more than 30 states and several foreign countries.

As an expert in forensic medicine, Wecht has appeared as a frequent guest on numerous national television and radio shows, discussing various medico-legal and forensic scientific issues, including medical malpractice; alcohol and drug abuse; the assassinations of President John F. Kennedy, Senator Robert F. Kennedy, and Reverend Martin Luther King; the death of Elvis Presley; the Sheppard, O.J. Simpson, JonBenet Ramsey, and Diallo cases; the Chandra Levy death investigation; and Laci Peterson homicide.

His expertise has also been utilized in high profile cases involving Mary Jo Kopechne, Sunny von Bulow, Jean Harris, Dr. Jeffrey McDonald, the Waco Branch Davidian fire, and Vincent Foster. A comprehensive study of these cases are discussed from the perspective of Wecht's own professional involvement in his books.

Wecht has received numerous awards and honors from various educational, professional, community, and governmental organizations, including County Detectives' Association of Pennsylvania, Deputy Sheriffs' Association of Pennsylvania, Vectors, New York Society of Forensic Sciences, American College of Legal Medicine, National Junior Chamber of Commerce, and the American Legion. He has been invited as a Distinguished Professor to lecture in several foreign countries, and is an Honorary Life Member of the National Academies of Legal Medicine of France, Spain, Belgium, Yugoslavia, Mexico, Columbia, and Brazil.

SEE ALSO FBI (United States Federal Bureau of Investigation); Kennedy assassination; Pathology; Simpson (O. J.) murder trial.

Michael Welner

FORENSIC PSYCHIATRIST

Michael Welner, founder and chairman of The Forensic Panel (a national forensic consultation group), is a clinical associate professor of psychiatry at New York University School of Medicine, and an adjunct professor of law at Duquesne University.

In 1996, he launched *The Forensic Echo*, a practitioner written forensic journal designed to combine cutting edge technology in **forensic science** with expert commentary, case studies, and investigative reportage.

Early in his career as a forensic psychiatrist, Welner recognized the need for a different approach to forensic examination than was typically provided by so-called "hired gun" experts. He held that the way to fair and precise assessment of criminal culpability (or the lack thereof) was to institute a peer-reviewed system for thorough, accurate, objective forensic assessments. This led to the creation of The Forensic Panel in 1998. The Panel's headquarters is in New York City; it is the first, and only, peer-reviewed expert forensic consultation practice in the United States. The peer-review process is this: members conduct their assessments and synthesize their findings. They then present their conclusions to renowned, expert peers through the use of a formal protocol intended to minimize examiner bias and maximize examiner objectivity.

Welner's goal, that of scientific neutrality in the criminal sentencing (and in all aspects of the law enforcement system) process, is achieved within the context of his nationally acclaimed Forensic Panel: to bring depth of understanding, diligence, extensive use of scientific methodology, and objectivity to the process of forensic examination.

More recently, Michael Welner has self-funded The Depravity Scale Project, the end product of which is the Depravity Scale, leading to a forensic definition of the concept of evil. The Scale is an historical assessment tool designed to codify definition of such concepts as "atrocious, cruel, heinous, depraved, and vile" in order to ensure fair and consistent application of the their use during criminal sentencing.

The American Psychiatric Institute publicly recognized Welner for excellence in medical education in 1997, and noted that his consistent innovations in clinical practice have had far-reaching beneficial effects on the practice and the profession of forensic psychiatry. Michael Welner is a frequent consultant to the court system throughout the nation.

SEE ALSO American Academy of Forensic Sciences; Careers in forensic science; Criminal profiling; Expert witnesses; Psychological profile.

Wendy's chili finger

In March 2005, a woman claimed to have found part of a severed finger in a bowl of chili at a Wendy's restaurant in San Jose, California. The woman claimed to have discovered the finger (actually two sections of finger tissue) after eating a portion of the chili containing the severed tissue. The woman alleged to have put a portion of the finger tissue in her mouth and then spat it out. After vomiting, she notified restaurant employees, who then called the police. A **medical examiner** identified the tissue as part of a human finger.

The charges and claims generated far reaching and intense negative publicity for the third largest U.S. hamburger chain; sales dropped nationwide.

After a forensic investigation that included analysis of every step in the food production chain and "trace-back" analysis of elements discovered in the finger tissue, authorities suspected that the initial complaint was a fraud intended to intimidate the restaurant chain into a potentially lucrative financial settlement for the initial complainant.

Forensic trace element analysis showed that the finger had not been cooked with the ingredients in the chili, and therefore, must have been placed in the chili after it was cooked.

Ultimately, the woman who claimed to have found the finger was arrested, initially on one count of grand theft stemming from an unrelated real estate transaction and on one count of attempted grand theft for the allegations made against the Wendy's restaurant. The woman's long history of suing large corporations, along with claims against other restaurant chains, cast doubt on her claim with investigators. As of April 2005, the resolution of larceny charges against the woman remained pending.

Initially started as a public health investigation, the case was soon turned over to criminal forensic investigators. Along with the official investigation, the Wendy's chain hired their own team of detectives and forensic experts to test and verify the integrity of their **food supply** and processing. The chain also offered an award eventually boosted to $100,000 for information about the origin of the finger.

By mid-May 2005, the finger had been identified as that from an associate of Ayala's husband, who had lost the digit in an industrial accident in December 2004.

SEE ALSO Food supply.

Charles H. Wick

AMERICAN
RESEARCH PHYSICAL SCIENTIST

Charles H. Wick, team leader of the Edgewood Chemical Biological Center (ECBC), is a physical scientist who has made significant contributions to **forensic science**. Although his 30–year professional career has spanned both the public sector and the military, his better-known work in the area of forensic science has occurred in concert with the Department of Defense (DOD).

After earning four degrees from the University of Washington, Wick worked in the private sector (civilian occupations) for twelve years, leading to a patent, numerous publications, and international recognition among his colleagues.

In 1983, Wick joined the Vulnerability/Lethality Division of the United States Army Ballistic Research Laboratory, where he quickly achieved recognition as a team leader and principal investigator. It was at this point that he made one of his first major contributions to forensic science and to the field of antiterrorism; his team was the first to utilize current technology to model sub-lethal chemical, biological, and nuclear agents. This achievement was beneficial to all areas of the Department of Defense, as well as to the North Atlantic Treaty Organization (NATO), and gained Wick international acclaim as an authority on individual performance for operations conducted on a nuclear, biological, and chemical (NBC) battlefield.

During his career in the United States Army, Wick rose to the rank of Lieutenant Colonel in the Chemical Corps. He was a Unit Commander for twelve years, a staff officer for six years (he was an ARCOM Staff Chemical Officer for two rotations), Deputy Program Director Biological Defense Systems, and retired from the position of Commander of the 485th Chemical Battalion in April of 1999.

Wick has continued to work for the DOD as a civilian at ECBC. His most notable achievement, and one which earned him the Department of the Army Research and Development Award for Technical Excellence and a Federal Laboratory Consortium Technology Transfer Award in 2002, was his involvement in the invention of the Integrated Virus Detection System (IVDS), a fast-acting, highly portable, user-friendly, extremely accurate and efficient system for detecting the presence of, screening, identifying, and characterizing viruses. The IVDS can detect and identify the full spectrum of known, unknown, and mutated viruses, from AIDS to foot and mouth disease, to West Nile Virus, and beyond. This system is compact, portable, and does not rely upon elaborate chemistry.

Throughout his career, Wick has made lasting and important contributions to forensic science and to the field of antiterrorism. He has written more than forty-five civilian and military publications and has received myriad awards and citations, including twenty-five decorations and awards for military and community service, two United States Army Achievement Medals for Civilian Service, the Commander's Award for Civilian Service, and the Technical Cooperation Achievement Award.

SEE ALSO Air and water purity, forensic tests; Analytical instrumentation; Chemical and biological detection technologies; Chemical warfare; Ebola virus.

Alexander S. Wiener

AMERICAN
PHYSICIAN

In 1940 Alexander Wiener and **Karl Landsteiner** discovered the Rhesus, or Rh, factor in **blood** group typing, during the course of a series of scientific experiments. The two scientists injected guinea pigs and rabbits with the red blood cells of rhesus monkeys, and discovered that the experimental animals produced an **antibody** that agglutinated (caused the red blood cells to clump together) the rhesus red cells. In addition, they discovered that the antibody in the rabbits and guinea pigs' **serum** also agglutinated blood samples equivalent to approximately 85% of the human population. The percentage rate was later found to correspond to approximately 85% of the Caucasian population and an even larger percentage of the Black and Asian populations.

The agglutination meant that blood cells of the members of the 85% population group contained the same factor as did the rhesus monkeys. Their blood was termed Rh positive (Rh+), and the blood of the remaining 15% was termed Rh negative (Rh−). The Rh antibody reaction was, by its nature, acquired and not present at birth; that is, red blood cells of

Rh+ individuals needed to be exposed to those of Rh− individuals in order for there to be an antibody reaction. The presence or absence of the Rh factor is of particular forensic importance in cases of disputed paternity, blood type and grouping inheritance, and genetic control. In everyday life, the presence or lack of the Rh factor has no bearing on health. It is only when the two blood types are mingled in an Rh-negative individual that problems ensue, since the Rh factor acts as an **antigen** in Rh− persons, causing the production of antibodies.

Wiener hypothesized that Rh **gene** inheritance occurred in the form of a single gene on a single DNA locus. Since blood type and presence or absence of the Rh factor are genetic traits that are easy to test, and the blood type of an individual is related to parental blood types, blood group typing may be used legally to establish paternity.

It has become understood, since Wiener and Landsteiner's discovery of the Rhesus factor in 1940, that the Rh system is far more complex than the presence or absence of a single factor. There are now known to be three genes that combine to create Rhesus antigens (C, D, and E), all of which are encoded on a single **chromosome** (chromosome 1). There are two possible alleles at each locus: C or c, D or d, and E or e. One haplotype which contains c/C, d/D, and e/E is inherited from each parent. The resulting Rhesus type of the individual depends on which genotype they inherit. If a person inherits at least one of the C, D, or E antigens, they are Rh+. If they inherit two sets of cde genes, they will be Rh−.

Wiener made a lasting contribution to **forensic science** in his discovery and advancement of the concept of the Rhesus factor. By using blood typing and blood grouping technologies, it has become increasingly possible to identify unique individuals, whether suspects or victims, from among the entire population of humans.

SEE ALSO Antibody; Antigen; Chromosome; DNA; Paternity evidence.

Wildlife forensics

Wildlife forensics is a relatively new field of criminal investigation. Its goals are to use scientific procedures to examine, identify, and compare **evidence** from crime scenes, and to link this evidence with a suspect and a victim, which is specifically an animal. Killing wild animals that are protected from hunting by laws, also called poaching, is one of the most serious crimes investigated by wildlife forensic scientists. Other crimes against wildlife include buying and selling protected animals and buying and selling products made from protected animals.

Confiscated luxury items made from animals on the endangered species list are stored by the U.S. Fish and Wildlife Service in Ashland, Oregon. © GALEN ROWELL/CORBIS.

The international organization that monitors trade in wild animals and plants is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which was established in 1963 and, as of 2004, includes 167 member countries. In the United States, the Endangered Species Act, which was authorized in 1973, protects endangered and threatened species and the U.S. Department of Fish and Wildlife has the authority to prosecute violations against protected species. Trent University in Ontario, Canada houses one of the largest wildlife **DNA** forensics departments in North America, incorporating an extremely active research facility.

The types of evidence analyzed by a wildlife forensics lab include any part of an animal including **blood** and tissue samples, carcasses, hair, teeth, bones, claws, talons, tusks, hides, fur, feathers, or

Wildlife rangers stack elephant ivory at Kenya Wildlife Headquarters during planning conference for Convention on International Trade in Endangered Species, Nairobi, Kenya. KHALIL SENOSI/AP WIDE WORLD PHOTOS. REPRODUCED BY PERMISSION.

stomach contents. Wildlife forensic scientists may also investigate materials used to kill or harm animals, such as poisons, pesticides, projectiles, and weapons. Products that are made from animals are also of interest, including leather goods and medicines, especially those from Asia.

One of the most critical problems facing wildlife forensic scientists is identifying a particular species from crime scene evidence. For example, wildlife forensic scientists may have to distinguish if a piece of leather on a watchband is made from a protected animal, like an elephant or a zebra, or if it comes from a non-protected animal, like a cow or a horse. They must be able to determine if a medicinal powder contains the pulverized remains of a protected animal, like a rhinoceros, a tiger, or coral. They must be able to differentiate between the roe of protected fish from farm-raised caviar.

A variety of scientific techniques allow wildlife forensic scientists to answer these types of questions. Techniques similar to those used in a police crime lab are used to identify and analyze parts of animals as well as bullets, shot casings, paint chips, soil, and **fibers** found at the crime scene. Experts in fingerprinting, **ballistics**, soil analysis, and hair comparisons examine evidence visually and with microscopic techniques. Pathologists examine carcasses for wounds in order to determine how the animal died and to distinguish natural death from human killing. Experts in the morphology, or the form, of animals can identify the species, and sometimes subspecies, of animals found at crime scenes. They can often determine the age and sex of animals as well as the time-since-death by careful observations of feathers, skulls and skeletons. Chemists may be asked to identify poisons and pesticides, characterize the contents of Asian medicines, and provide species **identification**, when possible. Molecular biologists use protein and DNA analyses to provide information about the identity of a sample. Genetics can be particularly useful when the sample is very small or unidentifiable from its morphology. Some answers that genetic tests may provide include identification of species, characterization of the familial relationships between animals, and evaluation of two different samples in order to determine if they originated from the same individual. In addition, geneticists may be able to provide environmental information about an animal.

Examples of criminal cases in which wildlife forensics have been used are extensive, but a few examples illustrate the importance of this field. A large proportion of the cases in the United States involve trafficking in fake caviar or caviar that is illegal to import. One man, who owned a caviar company in New York, sold the eggs of the American paddlefish, a protected species that lives in the Tennessee and Mississippi rivers, as caviar. DNA testing by wildlife forensic scientists verified that the roe was not Russian Sevruga, as labeled, but from the paddlefish. He was sentenced to two years in jail and fined $100,000. His company was additionally fined $110,000. In Wyoming, six carcasses of pronghorn antelope were discovered in a pit. The heads were removed, but no meat was taken. After a suspect was apprehended, wildlife forensic scientists were able to match DNA from the skulls of antelope in his custody to the DNA in the carcasses. The man was fined, served time in jail and his hunting license was suspended. In 1991, the sale of wild red drum (a fish) was banned in the state of Texas, however farm-raised red drum may still be sold legally. Using chemical assays to distinguish between the types of fats found in wild and farm-raised red drum, forensic scientists were able to identify the origin of red drum in the marketplace. Eventually, poaching rings were infiltrated and violators prosecuted in court. In 1998, an Iowa hunter returned from a safari to Africa with the **skull** of a brown hyena that he had shot. The brown hyena is an endangered species and after the man bragged about his kill, local wildlife agents seized the skull. Wildlife experts used morphology, comparing the skull to a series of hyena skulls, to identify the skull as illegal. The hunter was fined and his hunting license was revoked worldwide.

SEE ALSO DNA banks for endangered animals; DNA fingerprint; Fingerprint; Hair analysis; Paint analysis; Pathology; Soils.

Wine authenticity

Counterfeiting of wine has occurred for centuries, but since the 1990s both rumors of counterfeit wines and cases of fraud associated with wine increased drastically. Some believe that wine counterfeiting is a multi-million dollar industry associated with organized crime. Both the **FBI** and Scotland Yard have investigated cases of crime fraud. Industry experts estimate that about 5% of all wine sold is counterfeited.

A variety of testing methods can be used to ensure the authenticity of wine. Along with more traditional methods of inspection, chemical assays such as stable isotope analysis, **chromatography**, mineral content analysis, and **DNA** fingerprinting are being used by various wineries. A novel method that incorporates unique DNA codes into the label of wine bottles is also used to avoid counterfeiting.

Wine fraud occurs in many different forms. Often counterfeiters target the more expensive and older wines. Not only are sales of these wines financially profitable, but few people are familiar with the labels and other markings on these bottles so the fraud is harder to detect. Auctioneers and resellers sell expensive wines in large quantities, so the contents of a bottle or a case can be tampered with without anyone noticing for some time. One of the easiest scams involves replacing the contents of a case of expensive wine with bottles of less expensive wine. The cases are sold at auction houses without ever being opened and then stored for years in warehouses before being sold again. By the time someone decides to verify the contents, the counterfeiter is removed from the crime by both time and by layers of transaction.

Another common type of fraud involves replacing the contents of an expensive bottle of wine with a wine of a lesser quality. Using a two-pronged wine opener, corks can be removed and replaced with little damage. Capsules, which are the metal or plastic coverings sealing the corks in the bottle, can also be replicated and replaced. Recipes for duplicating expensive wines using inexpensive ingredients are known to experienced sommeliers (wine stewards) as well as counterfeiters. For example, blending a 1960 Pétrus with a Pomerol can mimic a 1961 Pétrus, which is one of the most expensive wines sold and usually costs more than ten times as much as the 1960. Other types of altering the contents of a wine bottle include adding sugar or other flavorings, and watering down the contents.

Blending was at the heart of a series of scandals in the Burgundy region of France in 2001. Several chateaux (vineyards) were blending burgundies with table wines from other regions of France, which is illegal. The winemakers involved confessed to making more than 10,000 cases of fraudulent wine during a ten-year period. Some of the wine was sold for as much as 300% profit.

Relabeling bottles of a less expensive wine with labels of a more expensive vintage is another common scam. In 2002 customs agents in China seized approximately 700 bottles of a wine that usually sells for $200 that had been relabeled as 1982 Chateau Lafite Rothschild, which sells for more than $5,700. The gang of counterfeiters had been selling the bottles for approximately $1,100 each.

In 1998 a wine auctioneer in Australia noticed that the bar code on some bottles of 1990 Penfolds Grange on the auction block were printed in black while genuine bottles have the code printed in red. Further investigation revealed that the labels had been forged and there were at least ten discrepancies between the original and the fake. One of the discrepancies included the misspelling of the word "pour" for "poor." Penfolds Grange 1990 is one of Australia's top wines and was named Wine of the Year by The Wine Spectator magazine in 1995. In 2005 it sells for more than $400 a bottle.

In 2000 a large wine fraud ring was broken up in Tuscany. More than 20,000 bottles of fake Tenuta San Guido 1994 and 1995 Sassicaia were discovered. Sassicaia is one of Italy's top wine producers known for its Super Tuscan. When the storage cellars of the gang were raided, another six million bottles of fake Chianti were seized. The police were alerted when a customer became suspicious that the price for the wine was too low. The counterfeiters tried to convince the customer that the original sale of the wine had fallen through and so they needed to sell it at a special price. Twelve people were arrested in connection with the incident.

A variety of techniques are used to determine the authenticity of wine. Traditional techniques involve careful observation of the bottle, its labels and its contents. This requires familiarity with both the wine and experience detecting counterfeits. Novel techniques of authentication rely on biochemical methods including stable isotope analysis, chromatography, mineral content analysis, and DNA fingerprinting.

General observation of the parts of the wine bottle and experience with wines are fundamental to the detection of counterfeit wines. The type of **glass** used to make the bottle should be consistent with the time period. Glass making has changed throughout the years and the type and manufacture of glass used should reflect these changes. The capsule should be consistent in color and markings with other examples from the same vintage. The corks should also be inspected. Since 1970, corks have been printed with the correct vintage and brand. Prior to 1970, casks were often shipped to resellers, who corked bottles themselves, so they may have printed their own corks. Labels may show damage such as peeling and staining, especially in older wines stored in the proper humid conditions. When old wines have labels in perfect condition, it may be a sign of relabeling. Spelling errors and font changes are key indicators of fraud. Wines that are imported into the United States have strip labels that show the name of the importer. These should also be consistent with the wine.

As grapes grow, they incorporate atoms of hydrogen, carbon, nitrogen and oxygen from their environment into proteins and carbohydrates. Each of these elements exists in more than one form called stable isotopes. Stable isotopes have the same number of protons and electrons but different numbers of neutrons. For example, carbon has two stable isotopes: one of them has 12 neutrons in the nucleus and the other has 13. The stable isotopes of carbon are referred to as ^{12}C and ^{13}C, respectively. About 98.9% of all carbon is ^{12}C, while 1.1% is ^{13}C, however these ratios change depending on geographic region and weather conditions. Nuclear magnetic resonance (NMR) is used to measure the stable isotope ratios of hydrogen in the alcohol of wines. Isotopic ratio mass spectrometry (IRMS) is used to measure the stable isotope ratios of carbon and oxygen.

Grapes grown in different regions during different years have different ratios of stable isotopes and these ratios remain constant when the grapes are processed into wine. The European Union houses a database containing the stable isotope ratios from all of its wine growing regions measured each year. Determination of stable isotope ratios from a bottle of wine can be compared to the values in the database in order to determine the origin of the grapes used to make the wine.

Chromatography is a technique that involves separating the components of a mixture, such as wine. An extremely sensitive form of chromatography, high-pressure liquid chromatography (HPLC) can measure the relative quantities of the pigments, called anthocyanins, which give wine its red color. The ratio of two particular forms of anthocyanin is often used as an indicator of the type of grape used to make the wine. Evidence shows that the ratio of these two forms of anthocyanin is determined by the genetic composition of the grapes and therefore indicates the type of grape used to make the wine. However, some chemists believe that concentrations of anthocyanin in wine are affected by processing. They have found that length of fermentation, exposure to varying temperatures and the addition of enzymes, can affect the anthocyanin ratios.

When grapes grow, they incorporate small amounts of metals from the soil into their skin and pulp. These metals are called trace metals and they include aluminum, calcium, copper, iron, potassium, magnesium, strontium, and zinc, among others. The concentration of these metals varies from location to

Testing wine in order to establish the properties on the product's identity card. © DUNG VO TRUNG/CORBIS SYGMA

location and so the concentrations of these metals incorporated into grapes varies depending on where they are grown.

In 2004 researchers from the University of Seville, Spain, developed a method to identify the trace metal composition of sparkling wines. They used atomic spectrophotometers to determine the elemental composition of the wine based on patterns of absorption of electromagnetic waves. Samples of cava from Spain and champagne from France were compared. The two wines are made using identical processes, but the regions from which the grapes originate differ. As a result, the trace mineral content also differs. For example, the ratio of strontium to zinc was always greater than 1 in cava and always less than 1 in champagne. The researchers showed that using the concentrations of 16 different trace **minerals**, they could identify the regional identity of the wine with perfect accuracy.

In the late 1990s a group of researchers from the University of California, Davis, developed a method to identify wine-grapes based on their genetic characteristics. They identified 17 different regions of DNA that varied greatly between different grape varieties. Collaborating with a research team from Montpellier, France, they assembled a database of genetic profiles for 300 different wine-grape varieties. In 2005, the database was expanded to include the more than 2,500 varieties of wine-grapes in existence.

Beginning in 2005 the research group in Montpellier began developing methods to perform DNA fingerprinting on wine. Using techniques similar to those used to study DNA from **mummies**, they believe that they will be able to extract and purify enough DNA from wine to compare it to the database of grape-wine genetic markers. Some scientists are skeptical of the technique however. Wine-grapes are heavily processed during the wine making process and the DNA may be too damaged to analyze.

In 2001 an Australian wine company, BRL Hardy, began labeling their wine with ink laced with DNA as a security measure against tampering. The technology was developed by a company called DNA Technologies for use in labeling souvenirs from the 2000 Sydney Olympics. DNA Technologies extracted DNA from one of BRL Hardy's 125-year-old grape vines. A segment of the vine DNA is then coated with a protective protein and imbedded into the neck label of the wine. Along with the DNA, optical taggants that emit unique spectral signatures in the presence of the proper excitation wavelengths are incorporated into the label. A handheld electronic scanner can then be used to test for the presence of the DNA label. BRL Hardy believes that the technology will discourage counterfeiting of its wines.

SEE ALSO Analytical instrumentation; DNA fingerprint; DNA sequences, unique; Fluorescence; Soils.

World Trade Center, 1993 terrorist attack

The World Trade Center (WTC) bombing of 1993 has since been overshadowed by the attack that brought the twin towers down on September 11, 2001. Yet, at the time it occurred, the attack loomed as large on the American landscape as the towers themselves once did on the Manhattan skyline. The attack killed six people and injured more than one thousand.

The law enforcement response to the tragedy involved a massive forensic investigation designed to determine the cause of the blast, the identities of

FBI and ATF agents entering the World Trade Center parking garage in New York after the 1993 bombing. © REUTERS/CORBIS

those responsible and, ultimately, to ascertain why, although Trade Tower One sustained a great deal of damage, it did not collapse. The forensic sleuthing involved the detailed examination of the blast scene, physical and chemical analyses of samples, and **forensic accounting** to trace a paper trail that led to the suspects.

At 12:18 P.M. on Friday, February 26, 1993, an explosion rocked the second level of the parking basement beneath Trade Tower One. The explosive material, as forensic investigators would later determine in their chemical analyses of samples retrieved at the site, was somewhere between 1,200 and 1,500 pounds (544–680 kg) of urea nitrate, a homemade fertilizer-based explosive.

The blast ripped open a crater 150 feet (46 meters) in diameter and 5 floors deep, rupturing sewer and water mains and cutting off electricity. Over the hours that followed, more than 50,000 people were evacuated from the Trade Center complex.

The first forensic analysis team to arrive was from the Federal Bureau of Investigation (**FBI**). The bureau brought in two examiners from the FBI Laboratory Explosives Unit. Over the week that followed, a team of more than 300 law-enforcement officers (including forensic specialists) from various agencies throughout the country would sift through some 2,500 cubic yards of debris weighing more than 6,800 tons.

At the same time that this forensic investigation began, government authorities rushed to protect against physical, chemical, and biological hazards associated with the blast. The explosion had exposed raw sewage, asbestos, mineral wool, acid, and fumes from automobiles. Meanwhile, small electrical fires burned, and pieces of concrete and sharp metal hung threateningly from distended beams.

On Saturday, authorities installed seismographic equipment, cleared the area, and conducted a test run of an empty subway train. The results showed that with a few adjustments, the area could be rendered safe for the operation of the Port Authority Transportation system (PATH) on Monday, thus preventing a virtual shutdown of lower Manhattan. The Environmental Protection Agency and the Occupational Safety and Health Administration began taking steps to clean up biological and chemical debris.

Meanwhile, the forensic investigation expanded, with two chemists each from the FBI, **ATF** (Bureau of Alcohol, Tobacco, and Firearms), and the New York Police Department collecting and studying residue from the blast area. In the course of this work, investigators found a key piece of **evidence**: a 300-pound (136-kg) fragment of a vehicle that, based on the damage it had sustained, must have been at the epicenter of the blast. Sewage contamination had rendered it unusable for residue analysis, but recovery of a vehicle identification number allowed the vehicle to be traced.

Authorities traced the vehicle to a Ryder truck rental facility in Jersey City, New Jersey, where it had been reported stolen. On Monday, while FBI special agents were at the Jersey City facility to interview personnel there, a Ryder clerk received a call from a man identified as Mohammed Salameh. The latter demanded the return of his $400 deposit for the van in question, and the Ryder clerk arranged for him to return and collect the deposit on March 4, 1993. When Salameh arrived, he was arrested.

A search of Salameh's belongings led investigators to Nidal Ayyad, a chemist working for the Allied Signal Corporation in New Jersey. Forensic accounting of toll records and receipts helped lead to a safe house in Jersey City, New Jersey, where authorities found traces of nitroglycerine and urea nitrate. They also uncovered evidence that Salameh and Ayyad had obtained three tanks of compressed hydrogen gas. In the course of searching a storage room rented by Salameh, investigators found large caches of urea, sulfuric acid, and other chemicals commonly used in making bombs. On March 3, the *New York Times* received a letter that claimed responsibility for the bombing. A subsequent forensic investigation of **DNA** samples matched Ayyad with the **saliva** on the envelope flap.

A forensic investigation was conducted to examine how such a massive blast failed to collapse the tower. The consensus opinion is that the location of the explosion, on the second level of the underground parking lot, acted to diffuse the intensity of the explosion. When the concrete floor of that level ruptured, much of the force of the blast was directed downward into the lower levels of the parking garage.

SEE ALSO Architecture and structural analysis; Bomb (explosion) investigations; Bomb damage, forensic assessment; Explosives; September 11, 2001, terrorist attacks (forensic investigations of).

World Trade Center, 2001 attack upon SEE September 11, 2001, terrorist attacks (forensic investigations of)

Theodore George Wormley

4/1/1826–1/2/1897
AMERICAN
MICROCHEMIST

Over the course of his career, Theodore G. Wormley became known as distinguished microchemist and toxicologist, frequently writing, teaching, and consulting on the subjects of chemistry, poisons, **toxicology**, and **medicine** to local, national, and international audiences. He spent more than forty years teaching at universities in Ohio and Pennsylvania, and also worked as a chemist for the state of Ohio. Wormley is the author of the 1867 *The Micro Chemistry of Poisons*, a book that became known as a standard on the subject at that time.

Wormley was born in Wormleysburg, Pennsylvania, in 1826. He attended Dickinson College, where his interest in science and mathematics grew. To pursue these interests, Wormley left Dickinson to attend Philadelphia Medical College, where he earned a medical degree in 1849. He then opened his own medical practice in Columbus, Ohio.

Within just a few years of opening his own practice, Wormley also began working as a professor. He was hired as a professor of chemistry and natural sciences at Capitol University in Columbus, a position he held for thirteen years. During the same time, Wormley took on a second professorship, teaching chemistry and toxicology at Starling Medical College. He left Starling in 1877 to take the position of professor of chemistry and toxicology at the University of Pennsylvania, a position he held until his death. And while Wormley was teaching students the intricacies of chemistry and toxicology, he also spent a great deal of time studying and researching the topics of poisons and chemicals. Wormley's expertise on these subjects made him a frequent consultant and witness on criminal cases and trials.

In addition to his work as an educator, Wormley also held a number of positions within the Ohio state government. In 1867, he was appointed as the state gas commissioner of Ohio, and in 1869 he became the state chemist of the Ohio Geological Survey. In that role Wormley developed chemical methods to analyze coal, iron ores, clays, **soils**, slags, and limestone.

Wormley was also a prolific writer, publishing articles and books about chemistry, medicine, and toxicology. His best-known work is *The Micro Chemistry of Poisons*, published in 1867. In the book Wormley discusses the chemical compositions of poisons. His wife drew many of the accompanying illustrations.

SEE ALSO Poison and antidote actions; Toxins.

Wound assessment

The assessment of wounds is an important part of both an **autopsy** and the medical examination of a living victim. The **medical examiner** will make a careful note of each wound and its location on the body. Wounds, or injuries, are generally classified as being due to either blunt force or sharp force trauma. Blunt force would be applied by weapons which do not have a cutting edge, such as baseball bats, clubs, or fists, while sharp force trauma comes, as the name suggests, from weapons such as knives.

An abrasion or scrape is the mildest kind of wound caused by blunt force trauma. It involves only the epidermis, or outer layer of the skin, and bleeds little, if at all. A contusion or bruise involves leakage of **blood** from tiny vessels in the deeper layers of the skin. A laceration is a form of blunt force trauma in which the skin is actually broken.

When it comes to sharp force trauma, the examiner distinguishes between incised wounds and stab wounds. The former are wider than they are deep. Stab wounds are deeper than they are wide and often lead to significant blood loss.

It is not just the nature of the wounds on a victim but their pattern that may be significant. Contusions and lacerations widely scattered over the arms, legs, and torso may be indicative of torture or struggle. If the victim tries to defend himself, there may be wounds on their arms and hands. **Hesitation wounds** are common in cases of suicide. These are small nicks and cuts inflicted, typically on the wrists, as someone tries to get up the courage to make a fatal cut.

Should a potential murder weapon like a knife or gun be available, the examiner will try to determine whether it was capable of making the wounds being assessed. In the case of a fractured **skull** caused by a blunt instrument, x rays of the injury can be very useful to see if the injury maps onto the dimensions of the weapon.

SEE ALSO Body marks.

Wounds, defensive SEE Defensive wounds

Brian Wraxall

12/6/1943–
AMERICAN
FORENSIC SEROLOGIST

Forensic serologist Brian G.D. Wraxall is widely recognized as the co-developer in 1966, along with Brian J. Culliford, of the immunoelectrophoretic technique for haptoglobin typing in bloodstains. Wraxall is also credited, along with **Mark Stolorow**, with developing the **multisystem method** for the parallel testing of isoenzyme systems in 1978. During that same year, the team of Wraxall and Stolorow were also recognized as the first forensic scientists to develop methods for typing **blood serum** proteins. Currently, Wraxall is the executive director of the Serological Research Institute in California, a company that provides consultation, laboratory analysis, and court testimony to the **forensic science** community.

Wraxall grew up in England during the middle part of the twentieth century where from 1958 to 1962 he attended King Edward VI Grammar School in the town of Totnes in Devon County. (The school later became known as King Edward VI College.) Even at this young age, Wraxall was interested in biology and chemistry, receiving school certificates in both subjects. Beginning in 1962, he worked as a laboratory chemist for Western Countries Brick Company in Torquay, Devon, and later as a senior scientific officer for the Metropolitan Police Laboratory in London, England. During this twelve-year period, Wraxall specialized in **serology**, where he delved into the research and development of **electrophoresis** methods that specifically involved blood enzymes and proteins in body **fluids** and bloodstains. In 1966, Wraxall and Culliford developed a technique of immunoelectrophoresis for haptoglobin typing in bloodstains. At this time, Wraxall and Culliford published the paper "Haptoglobin Types in Dried Bloodstains" in *Nature*, which was followed by additional scientific papers over the next few years.

In 1969, Wraxall received a higher national certificate in applied biology—specializing in biochemistry, microbiology, and physiology—from the Borough Polytechnic College in London, England. Eight years later, in 1977, Wraxall began working as a consultant for the Bloodstain Analysis project (funded by the Law Enforcement Assistance Administration) for Beckman Instruments and The Aerospace Corporation. One year later, Wraxall and Stolorow developed a Bloodstain Analysis System (BAS), or the multisystem method, for simultaneously testing generic (**identification**) markers—such as ACP1 (acid phosphatase 1, soluble), ADA (adenosine deaminase), AK (adenylate kinase), EsD (esterase D), GloI (glyoxalase I), and PGM (phosphoglucomutase)—using one of three different electrophoretic trials. The BAS method resulted in the efficient identification of genetic characteristics (or phenotypes) of organisms with respect to their environment when only a very small amount of materials are available as **evidence** in criminal cases. As a result, Wraxall introduced, along with other scientists, the paper "Final Report: Bloodstain Analysis System" (The Aerospace Corporation, September 1978).

At this same time, Wraxall and Stolorow also developed methods for typing blood serum proteins such as Hp (haptoglobin) and Gc (glycoprotein C). As a result, the pair published the paper "An Efficient Method to Eliminate Streaking in the Electrophoretic Analysis of Haptoglobin in Bloodstains" in the *Journal of Forensic Science.*

In 1978, Wraxall became employed for the Serological Research Institute (SERI) located in Richmond, California, first as a technical leader and later as its chief forensic serologist. SERI is a non-for-profit corporation that has served the legal and forensic sciences communities since 1978 with a number of support services. Wraxall is currently the executive director of the Serological Research Institute, where he coordinates the work of providing forensic, serological, and **DNA** analysis services. During his years with SERI he has taught various **training** courses that involve: identification and typing of biological evidence in such specific topics as bloodstain analysis; electrophoresis; **semen** identification and analysis; genotyping of immunoglobulins (Ig), heavy chain (GM) and light chain (KM) allotypes; and DNA (deoxyribonucleic acid) typing.

Also while employed with SERI, Wraxall attended the University of California at Berkeley where he studied molecular biology in 1990. Later, in 2002, Wraxall graduated from Hamilton University—located in Evanston, Wyoming—with a bachelor's of science degree in biological sciences.

For most of his professional career, Wraxall has worked as a consultant with respect to expert testimony for both the prosecution and the defense sides of courtroom cases involving both civil and criminal matters. In preparation for these court cases and in direct testimony during these cases, Wraxall lent his proficiency in forensic serology throughout various U.S. courts involving the examination and explanation of biological evidence. His expertise covers a broad range of case material involving the presence of **trace evidence** such as the phenotyping of bloodstains in polymorphic systems (involving antigens, enzymes, and proteins); the phenotyping of stains of body fluids; and the extraction and analysis of DNA from hairs, bodily fluids, and skeletal materials.

Wraxall has published numerous scientific papers from 1967 to the present day including "Use of Prostate-Specific Antigen (PSA) to Measure Semen Exposure Resulting from Male Condom Failures: Implications for Contraceptive Efficacy and the Prevention of Sexually Transmitted Disease" in *Contraception* (2003). He has also presented various papers throughout his career including "Advances on DNA in Forensic Testing" for the Legal Secretaries 2nd Quarterly Conference (Modesto, California, 2003) and "Roles of Markers in Forensics" for the Evaluation of Markers of Intercourse in Trials of Vaginal Barriers (Conrad, Washington, D.C., 2003).

SEE ALSO Bloodstain evidence; DNA; DNA sequences, unique; Mitochondrial DNA analysis; Mitochondrial DNA typing; Multisystem method; Paternity evidence; RFLP (restriction fragment length polymorphism).

X

Xylotomy

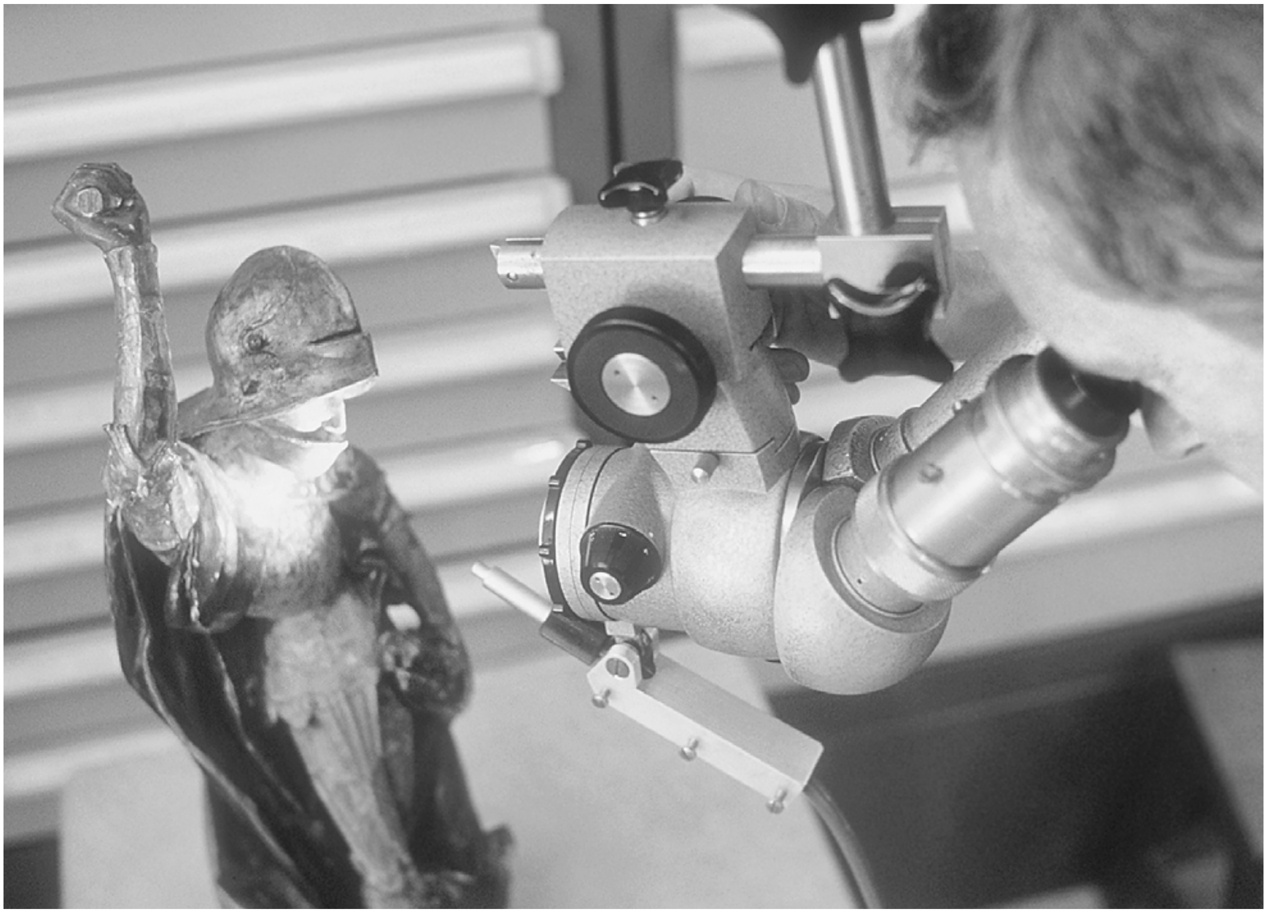
Xylotomy is the cutting of thin sections of wood specimens for microscopic examination. Wood splinters, chips, or fragments can be important items of **trace evidence** in some crimes. Typically, the forensic botanist will cut the sections from the wood sample with a very sharp knife mounted on a jig called a microtome. The sections are then stained so that features such as cells and grain direction can be seen under the high-powered microscope.

It is not always possible to identify a tree species from this kind of fragment examination. However, comparison with known samples will give an idea of the type of timber involved. If a suspect has used a piece of wood to assault someone, the suspect's clothing may carry splinters. The forensic investigator can compare these splinters with the weapon to try to make an association. Similarly, doors and windows may be damaged on entering or leaving a crime scene. Splinters found on the suspect's clothes can be compared with samples from the entry and exit sites of the scene.

Wood analysis played a crucial part in one famous case, the kidnapping and **murder** of the infant son of aviator Charles Lindbergh from his New Jersey home in 1932. The ransom note left at the scene suggested the kidnapper was poorly educated and of German descent. This was not much to go on, given there were no fingerprints on the note. However, a homemade wooden ladder was left at the scene and had been used to gain access to the child's nursery. Arthur Koehler, an expert in wood and wood products, examined the ladder and determined it was made of Ponderosa pine, North Carolina pine, birch, and fir. He suggested that the fir section was actually a piece of flooring. Microscopic examination revealed marks made by a planing machine. Planed wood samples from mills around the country were compared to the ladder samples. The timber was tracked down to a company in the Bronx. Lindbergh had paid out a ransom and bills with the corresponding serial numbers also turned up in this location, narrowing down the search for the kidnapper.

Bruno Richard Hauptmann, a carpenter of German descent, was later arrested in connection with the crime. Examination of his home revealed a missing floorboard and nail holes corresponding to those in the piece of fir used in the ladder. The final piece of incriminating **evidence** was the presence of a wood plane which made smoothing marks matching those found on the ladder.

SEE ALSO Dendrochronology; Lindbergh kidnapping and murder.



A conservator inspects a small 15th century wooden statue at the Louvre laboratories in Paris, France.

Y

Y chromosome analysis

In the human, there are normally 46 chromosomes, two sex chromosomes and 22 **chromosome** pairs for which one copy is inherited from each parent at conception. The sex chromosomes are called the X and the Y chromosome. Everyone needs at least one X chromosome to survive. Females normally have two X chromosomes whereas males typically have one X and one Y chromosome. In the absence of a Y chromosome, babies will develop as females. When the Y chromosome is present, they will develop as males.

The Y chromosome is different from all of the other chromosomes in a couple of different ways. First, it contains the fewest number of genes of any chromosome, far fewer than chromosome 21, the next smallest chromosome. Second, the vast majority of the Y chromosome is composed of heterochro-matin, a form of **DNA** that does not contain functional genes. Third, the genes that are present on the Y chromosome are critically important in sexual development.

As only males have a Y chromosome, and the presence of the Y chromosome determines male sexual development, the pattern of inheritance is that fathers uniformly transmit the Y chromosome to their sons at conception, and never to their daughters. This allows a tracing of inheritance patterns for genes and other markers on the Y chromosome from father to son down through many generations.

Because the Y chromosome has so much non-coding DNA, there are many different DNA sequence variants that may be identified on the Y chromosome. These non-coding DNA sequences have a very high rate of mutation, and many potentially informative short tandem repeat (STR) sequences that permit a detailed study of paternity and other forensic testing based on DNA sequences.

The Y chromosome has a distinctive pattern of **fluorescence** (light emission) naturally and also when using certain organic dyes. These properties can be exploited in various ways to identify the presence of **semen** based on natural fluorescence, or to identify Y-bearing **sperm** and separate them from X-bearing sperm. Furthermore, chromosomal analysis for the sex chromosomes can be used to predict the sex of a baby prenatally. As of 2005, it is not considered ethical to use chromosome analysis prenatally to facilitate sex selection for parents who desire either a boy or a girl unless there is a sex-linked genetic disease risk.

SEE ALSO Fluorescence; Sex determination; STR (short tandem repeat) analysis.

Z

Frits Zernike

7/16/1888–3/10/1966
DUTCH
PHYSICIST

Frits Zernike was a pioneer in **forensic science**; his invention of the phase-contrast microscope enabled scientists to study living tissue samples under magnification for the first time. Zernike won the 1953 Nobel Prize in physics for his invention.

Zernike's background in statistical mathematics and thermodynamics was responsible for his groundbreaking discovery. A conventional microscope utilizes ordinary light, and under these instruments living tissues, particularly transparent ones, are not visible unless stained. Yet staining usually kills the specimen or produces artifacts that are impossible to differentiate from the specimen. The phase-contrast technique can reveal variations in opacity as well as variations in the thickness of transparent objects.

Born on July 16, 1888, in Amsterdam, Zernike was the son of two mathematicians, Carl Frederick August Zernike and Antje Dieperink Zernike. Early in life he was recognized for his mathematical abilities. He received both his B.S. and his Ph.D. in physics from the University of Amsterdam, and he worked at an astronomy laboratory while pursuing his graduate studies. His doctoral thesis, "Critical Opalescence, Theoretical and Experimental," quickly established him as a leader in his field. In 1915 he was appointed lecturer in theoretical physics at the University of Groningen. In 1920, he was promoted to professor, where he remained for the rest of his career.

It was while working in the field of astronomy that Zernike first discovered the advantages of phase-contrast techniques. Irregularities on the surfaces of the curved mirrors of telescopes were a common problem at that time; these mirrors sometimes produced "ghost" images and Zernike hypothesized that they were caused by out-of-phase wavelengths. If he could somehow bring direct and diffracted images back into phase, perhaps these aberrations would disappear. He developed a glass plate with tiny grooves etched in it to be placed in the focal plane of the telescope; he called this a phase plate. His experiment worked: when looking through the phase plate, the out-of-phase areas became clearly visible. Zernike published these findings in 1934, and by 1935 he was applying these same principles to **microscopes**, which he knew had optical problems that were similar to telescopes.

Although the practical applications of Zernike's findings seem obvious now, it was some years before he could find a manufacturer for a phase-contrast microscope. He first approached the German company, Carl Zeiss, in 1932. Finally, in 1941, Carl Zeiss agreed to produce the instrument. But it was not until American troops arrived in Germany in 1945 and discovered photomicrographs taken by a phase-contrast microscope that

Zernike's instrument received worldwide attention. When he won the Nobel Prize in 1953, the phase-contrast microscope was cited as being a key to insights into cancer research.

Though the phase-contrast microscope is considered his crowning achievement, Zernike is also known for other work. Early in his career he invented the Zernike galvanometer, an instrument used to detect and measure small electrical currents. The Zernike polynomials are a method he developed regarding the wave theory of light, and are widely used by mathematicians. He also made many improvements in infrared and ultraviolet **spectroscopy**, as well as in the construction of the electromagnet.

Although Zernike stayed at his alma mater for his entire career, he was a visiting professor of physics at the Johns Hopkins University in Baltimore in 1948. In 1950 he was elected to the Royal Microscopical Society of London, and he was presented with the Rumford Medal of the British Royal Society in 1952.

Zernike married Dora van Bommel van Vloten in 1929. The couple had two children; his wife died in 1944. In 1954, Zernike married L. Koperberg-Baanders. He retired in 1958 and died in Groningen on March 10, 1966.

SEE ALSO Microscopes; Spectroscopy.

Zoonoses

Zoonoses are diseases of microbiological origin that can be transmitted from animals to people. The causes of the diseases can be bacteria, viruses, parasites, and fungi.

As of 2005, the best scientific evidence available suggested that the cornonavirus responsible for severe acute respiratory syndrome (SARS) was originally transmitted from animal hosts. Also, the avian flu, which until 2004 was resident in poultry, has caused a number of human deaths and now appears able to be transmitted both from poultry to felines and, ominously in terms of a global epidemic, from human to human.

Zoonoses are relevant for humans because of their species-jumping ability. Because many germs that can transfer from species to species are found in domestic animals and birds, agricultural workers and those in food processing plants are at risk. From a research standpoint, zoonotic diseases are interesting as they result from organisms that can live in a host innocuously while producing disease upon entry into a different host environment.

Humans can develop zoonotic diseases in different ways, depending upon the microorganism. Entry through a cut in the skin can occur with some bacteria. Inhalation of bacteria, viruses, and fungi is also a common method of transmission. As well, the ingestion of improperly cooked food or inadequately treated water that has been contaminated with the fecal material from animals or birds presents another route of disease transmission.

A classic historical example of a zoonotic disease is yellow fever. The construction of the Panama Canal took humans into the previously unexplored regions of the Central American jungle, where mosquitoes ferried the yellow fever virus from monkeys to man. When mosquitoes fed upon an infected monkey (the disease's natural host), the virus passed into the mosquito (the vector), which in turn, infected humans with their bite. Only after mosquito prevention measures were employed about 1910, with techniques such as the use of mosquito netting to cover tents and water supplies, were efforts successful in carving the canal through the jungle.

A number of bacterial zoonotic diseases are known. A few examples are **Tularemia**, which is caused by *Francisella tulerensis*, Leptospirosis (*Leptospiras spp.*), Lyme disease (*Borrelia burgdorferi*), Chlaydiosis (*Chlamydia psittaci*), Salmonellosis (*Salmonella spp.*), Brucellosis (*Brucella melitensis*, *suis*, and *abortus*, Q-fever (*Coxiella burnetti*), and Campylobacteriosis (*Campylobacter jejuni*).

Zoonoses produced by fungi include Aspergillosis (*Aspergillus fumigatus*). Well-known viral zoonoses include rabies and encephalitis. The microorganisms called Chlamydia cause a pneumonia-like disease called psittacosis.

Within the past two decades two protozoan zoonoses have emerged. These are Giardia (also commonly known as "beaver fever"), which is caused by *Giardia lamblia* and Cryptosporidium, which is caused by *Cryptosporidium parvum*. These protozoans reside in many vertebrates, particularly those associated with wilderness areas. The increasing encroachment of human habitations with wilderness is bringing the animals, and their resident microbial flora, into closer contact with people.

Cows at a farm in Washington state are quarantined after another cow at the farm is found infected with bovine spongiform encephalopathy (BSE), better known as “mad cow” disease. Authorities tracked the infected cow to a source in Canada.

Similarly, human encroachment is thought to be the cause for the emergence of devastatingly fatal viral hemorrhagic fevers, such as Ebola, Marburg, and Rift Valley fever. While the origin of these agents is not definitively known, zoonotic transmission is virtually assumed.

Outbreaks of “mad cow” disease (bovine spongiform encephalopathy or BSE) among cattle in the United Kingdom in the 1990s (the latest being in 2001) has established a probable zoonotic link between these animals and humans, involving the disease causing entities known as **prions**. While the story is not fully resolved, the current evidence supports the transmission of the prion agent of mad cow disease to humans, where the similar brain degeneration disease is known as variant Creutzfeld-Jacob disease.

The increasing incidence of these and other zoonotic diseases has been linked to the increased ease of global travel. Microorganisms are more globally portable than ever before. This, combined with the innate ability of microbes to adapt to new environments, has created new combinations of microorganism and susceptible human populations.

SEE ALSO Centers for Disease Control and Prevention (CDC); Mad cow disease investigation; Pathogens.

SOURCES CONSULTED

Books

Aitken, C.G.G., and D. A. Stoney, eds. *The Use of Statistics in Forensic Science*. New York: E. Horwood, 1991.

Aitken, C.G.G., and Franco Taroni. *Statistics and the Evaluation of Evidence for Forensic Scientists*. Chichester: Wiley, 2004.

Allan, Tony. *The Troubles in Northern Ireland*. Heinemann Library, 2004.

Amirall, Jose R., and Kenneth G. Furton. *Analysis and Interpretation of Fire Scene Evidence*. Boca Raton, FL: CRC Press, 2004.

Aretha, David. *Steroids and Other Performance-Enhancing Drugs*. Berkeley Heights: Enslow Publishers, 2005.

Ashbaugh, D. R. *Quantitative-Qualitative Friction Ridge Analysis: An Introduction to Basic and Advanced Ridgeology*. Boca Raton, FL: CRC Press, 2000.

Ausubel, Frederick M., et al. *Current Protocols in Molecular Biology*. New York: John Wiley & Sons, 2005.

Barberm, Jacqueline. *Fingerprinting (Great Explorations in Math and Science)*. Berkeley: University of California Press, 2000.

Barnett, Peter D. *Ethics in Forensic Science: Professional Standards for the Practice of Criminalistics*. Boca Raton, FL: CRC Press, 2001.

Bartlet, John G., et al. *2004 Pocket Book of Infectious Disease Therapy*. 12th ed. Philadelphia, PA: Lippincott Williams & Wilkins, 2004.

Bartlet, John G., et al. *A Guide to Primary Care of People with HIV/AIDS*. Rockville, MD: Department of Health and Human Services, Health Resources and Services Administration HIV/AIDS Bureau, 2004.

Bartlet, John G., et al. *Bioterrorism and Public Health: An Internet Resource Guide*. Princeton, NJ: eMedguides.com, Inc.; Montvale, NJ: Thomson/Physicians' Desk Reference, 2002.

———. *The Guide to Living with HIV Infection*. Baltimore, MD: Johns Hopkins University Press, 2001.

Bass, Bill, and Jon Jefferson. *Death's Acre: Inside the Legendary Body Farm*. London: Time Warner Books, 2004.

Beavin, Colin. *Fingerprints: The Origins of Crime Detection and the Murder Case that Launched Forensic Science*. New York: Hyperion, 2001.

Bevel, Tom, and Ross M. Gardner. *Bloodstain Pattern Analysis*. Boca Raton, FL: CRC Press, 2001.

Bhushan, Vikas *First Aid for the USMLE Step 1: 2005*. New York: McGraw-Hill, 2004.

Block, E. B. *Science vs. Crime: The Evolution of the Police Lab*. Cragmont Publications, San Francisco, 1979.

———. *The Wizard of Berkeley*. Coward-McCann, New York, 1958.

Bodziak, W. J. *Footwear Impression Evidence*. New York: Elsevier, 1999.

Brach, Raymond M., and Patrick F. Dunn *Uncertainty Analysis for Forensic Science*. Tucson, AR: Lawyers & Judges Publishing Company, 2004.

British Medical Association. *Drugs in Sport: The Pressure to Perform*. London: BMJ Press, 2002.

Brodie, Fawn. *Thomas Jefferson: An Intimate History*. New York: Norton, 1974.

Brown, Michael F. *Criminal Investigation: Law and Practice*, 2nd ed. Boston: Butterworth-Heinemann, 2001.

Byrd, Mike. *Crime Scene Evidence: A Guide to the Recovery and Collection of Physical Evidence*. Wildmar: Staggs Publishing, 2001.

Caddy, Brian, ed. *Forensic Examination of Glass and Paint: Analysis and Interpretation*. New York: Taylor & Francis, 2001.

Campbell, Andrea. *Forensic Science: Evidence, Clues, and Investigation*. Philadelphia: Chelsea House Publishers, 2000.

Cassidy, M. J. *Footwear Identification*. Ottawa: Public Relations Branch of the Royal Canadian Mounted Police, 1980.

Cole, Michael D. *The Analysis of Controlled Substances (Analytical Techniques in the Sciences)*. New York: John Wiley & Sons, 2003.

Cole, Simon A. *Suspect Identities: A History of Fingerprinting and Criminal Investigation*. Boston: Harvard University Press, 2002.

Cooper, Cynthia L., and Sam Reese Sheppard. *Mockery of Justice: The True Story of the Sheppard Murder Case*. Boston: Northeastern University Press, 1995.

Cotchett, Joseph W., and Fulton Haight. *California Courtroom Evidence*. 4th ed. Carlsbad, CA: Parker Publications Division, 1995.

Culliford, Bryan J. *The Examination and Typing of Bloodstains in the Crime Laboratory*. Washington: National Institute of Law Enforcement and Criminal Justice, 1971.

Cuthbert, C. R. M. *Science and the Detection of Crime*. London: Hutchinson, 1958.

Dabney, Virginius. *The Jefferson Scandals: A Rebuttal*. New York: Dodd, Mead, 1981.

Daeid, Niamh Nic. *Fire Investigation*. Boca Raton, FL: CRC Press, 2004.

Davies, Geoffrey. *Forensic Science*. 2nd ed., rev. and expanded. Washington, DC: American Chemical Society, 1986.

DeForest, P. H. Lee, and R. Gaensslen. *Forensic Science: An Introduction to Criminalistics*. New York: McGraw Hill, 1983.

Department of Defense. *21st Century Complete Guide to U.S. Coast Guard Marine Accident Reports on Ships and Boats from 1947 to 1999*. Washington, DC: Progressive Management, 2002.

Di Maio, Vincent J. M., and Dominick J. Di Maio. *Forensic Pathology*. 2nd ed. Boca Raton, FL: CRC Press, 2001.

Eckert, W. G. *Introduction to Forensic Sciences*. Boca Raton, FL: CRC Press, 1997.

Eckert, W. G., and S. H. James. *Interpretation of Bloodstain Evidence at Crime Scenes*. Boca Raton, FL: CRC Press, 1989.

Evett, I. W., and B. S. Weir. *Interpreting DNA Evidence*. Sunderland, MA: Sinauer Associates, Inc., 1998.

Fairman, David L. *Legal Alchemy*. New York: W. H. Freeman, 1999.

Faith, Nicholas. *Blaze: The Forensics of Fire*. New York: St. Martin's Press, 2000.

Fenton, John. *Toxicology: A Case-Oriented Approach*. Boca Raton, FL: CRC Press, 2001.

Ferllini Timms, Roxana. *Silent Witness: How Forensic Anthropology Is Used to Solve the World's Toughest Crimes*. Willowdale, Ontario; Buffalo, NY: Firefly Books Ltd., 2002.

Finkelstein, Michael O. *Statistics for Lawyers*. 2nd ed. New York: Springer, 2001.

Fisher, Barry A. J. *Techniques of Crime Scene Investigation*. 7th ed. Boca Raton, FL: CRC Press, 2004.

Gaensslen, R. E. *Sourcebook in Forensic Serology*. Washington, DC: U.S. Government Printing Office, 1983.

———. *Sourcebook in Forensic Serology, Unit IX: Translations of Selected Contributions to the Original Literature of Medicolegal Examination of Blood and Body Fluids*. Washington, DC: U.S Dept. of Justice, National Institute of Justice, 1983.

Galton, F. *Finger Prints*. London: Macmillan, 1892.

Garrity, George, ed. *Bergey's Manual of Systematic Baxteriology: Volume 2: The Proteobacteria*. New York: Plenum Press, 2005.

Gastwirth, Joseph L., ed. *Statistical Science in the Courtroom*. New York: Springer, 2000.

Geberth, V. J. *Practical Homicide Investigation: Tactics, Procedures and Forensic Techniques*. Boca Raton, FL: CRC Press, 1996.

Genge, Ngaire. *The Forensic Casebook: The Science of Crime Scene Investigation*. New York: Ballantine Books, 2002.

Gerber, Samuel M., and R. Saferstein. *More Chemistry and Crime: From Marsh Arsenic Test to DNA Profile*. Washington, DC: American Chemical Society, 1997.

Goddard, K. W. *Crime Scene Investigation*. Reston, VA: Reston Publishing Company, 1977.

Goldstein, Dennis. *Polarized Light (Optical Engineering)*. New York: Marcel Dekker, 2003.

Grant, J. *Science for the Prosecution*. London: Chapman & Hall, 1941.

Griffiths, Anthony J. F. *An Introduction to Genetic Analysis*. 5th ed. New York: W. H. Freeman and Company, 1993.

Gurstelle, William. *Backyard Ballistics*. Chicago: Chicago Review Press, 2001.

Hamilton, Charles. *The Hitler Diaries: Fakes That Fooled the World*. Lexington: University Press of Kentucky, 1991.

Harris, Robert. *Selling Hitler*. New York: Pantheon, 1986.

Hatcher, Julian Sommerville. *Firearms Investigation*. Harrisburg, PA: Stackpole Co., 1957.

Hazelwood, Loren F. *Can't Live Without It: The Story of Hemoglobin in Sickness and in Health*. Huntington: Nova Publishers, 2001.

Hibbs, Alan R. *Confocal Microscopy for Biologists*. New York: Plenum Press, 2005.

Hofstadter, D. R. *Gödel, Escher, Bach: An Eternal Golden Braid*. New York: Basic Books Inc., 1979.

Hollas, J. Michael. *Modern Spectroscopy*. New York: John Wiley & Sons, 2004.

Homewood, S. L., D. L. Oleksow, and W. L. Leaver. *Questioned Document Evidence in Forensic Evidence*. California District Attorneys Association, 1999.

Houlihan, Barry. *Dying to Win: Doping in Sport and the Development of Anti-Doping Policy*. Strasbourg: Council of Europe Publishing, 1999.

Inman, Keith, and Norah Rudin. *Principles and Practice of Criminalistics: The Profession of Forensic Science*. Boca Raton, FL: CRC Press, 2001.

Jackson, Andrew R. W., and Julie M. Jackson. *Forensic Science*. Harlow, England; New York: Pearson Prentice Hall, 2004.

James, Stuart H., and William G. Eckert. *Interpretation of Bloodstain Evidence at Crime Scenes*. CRC Press, 1999.

James, Stuart H., and Jon J. Nordby, eds. *Forensic Science: An Introduction to Scientific and Investigative Techniques*. Boca Raton, FL: CRC Press, 2003.

Jeffreys, Harold, Sir. *Theory of Probability*. 3rd ed. New York: Oxford University Press, 1983.

Jones, Leland V., and E. Caroline Gabard. *Scientific Investigation and Physical Evidence; Handbook for Investigators*. Springfield, IL: C. C. Thomas, 1959.

Kind, Stuart S., and Overman, Michael. *Science against Crime*. Garden City, NY: Doubleday, 1972.

Kirk, P. L. *Crime Investigation*. Malabar, FL: Krieger Publishing Co., 1974.

Kirsch, Andrea, and Rustin S. Levenson. *Seeing through Paintings: Physical Examination in Art Historical Studies*. New York: Yale University Press, 2000.

Komarinski, Peter. *Automated Fingerprint Identification Systems*. Amsterdam, The Netherlands; Boston, MA: Elsevier Academic, 2005.

Lee, Henry C. *Physical Evidence in Forensic Science*. Tucson, AZ: Lawyers & Judges Pub. Co., 2000.

Lee, Henry C., and Robert Gaensslen. *Advances in Fingerprint Technology*. 2nd ed. Boca Raton, FL: CRC, 2001.

Lee, Henry C., and Howard A. Harris. *Physical Evidence in Forensic Science*. Tucson, AZ: Lawyers & Judges Pub. Co., 2000.

Lee, Henry C., and Jerry Labriola. *Famous Crimes Revisited*. Southbury, CT: Publishing Directions, 2001.

Lee, Henry C., and Thomas W. O'Neil. *Cracking More Cases: The Forensic Science of Solving Crimes*. Amherst, NY: Prometheus Books, 2004.

Lee, Henry C., Timothy Palmach, and Marilyn T. Miller. *Henry Lee's Crime Scene Handbook*. San Diego, CA; London: Academic Press, 2001.

Lenehan, Pat. *Anabolic Steroids and Other Performance Enhancing Drugs*. Boca Raton, FL: CRC Press, 2003.

Levine, Barry, ed. *Principles of Forensic Toxicology*. Washington, DC: AACC press, 2003.

Lewin, Benjamin. *Genes VI*. Oxford; New York: Oxford University Press, 1997.

Locard, Edmond. *L'Enquete Criminelle et les Methodes Scientifique*. Paris: Ernest Flammarion, 1923.

———. *Manuel de Tachnique Policiere*. Paris: Payot, 1923.

———. *Traité de Criminalistique*. Lyon: J. Desvigne, 1931.

Lodish, Harvey, et al. *Molecular Cell Biology*. New York: W. H. Freeman & Co., 2000.

Loftus, Elizabeth F. *Eyewitness Testimony*. Cambridge, MA: Harvard University Press, 1996.

Lyle, D. P. *Forensics for Dummies*. Hoboken, NJ: Wiley, 2004.

Lyman, Michael D. *Criminal Investigation: The Art and the Science*. 4th ed. Upper Saddle River, NJ: Pearson/Prentice Hall, 2005.

Markov, Georgi. *The Truth That Killed*. London: Weidenfeld and Nicolson, 1983.

McKenzie, Shirlyn B. *Clinical Laboratory Hematology*. Upper Saddle River, New York: Pearson Education, 2003.

Mycek, Mary Julia, Richard A. Harvey, and Pamela C. Champe. *Pharmacology*. 2nd ed. New York: Lippincott Williams & Wilkins, 2000.

May, Luke S. *Crime's Nemesis*. New York: Macmillan, 1936.

Mays, Larry W. *Water Supply Systems Security*. New York: McGraw-Hill Professional, 2004.

Meyers, Charles. *Silent Evidence: Firearms Forensic Ballistics and Toolmarks: Cases from Forensic Science*. Boone, NC: Parkway Publishers, 2004.

Saks, Michael J., et al. *Admissibility of Scientific Evidence*. Westlaw, 2004.

Michel, Lou, and Dan Herbeck. *American Terrorist: Timothy McVeigh and the Oklahoma City Bombing*. New York: ReganBooks, 2001.

Morn, Frank. *Foundations of Criminal Investigation*. Durham, NC: Carolina Academic Press, 2000.

Murphy, Douglas B. *Fundamentals of Light Microscopy and Electronic Imaging*. New York: Wiley-Liss, 2001.

Nickell, Joe, and John Fischer. *Crime Science: Methods of Forensic Detection*. Lexington: University Press of Kentucky, 1999.

Nordby, Jon J. *Dead Reckoning: The Art of Forensic Detection*. Boca Raton, FL: CRC Press, 2000.

O'Brien, Joanne. *A Matter of Minutes: The Enduring Legacy of Bloody Sunday*. Dublin, Ireland: Wolfhound Press, 2002.

Olson, Kent R. *Poisoning & Drug Overdose*. New York: McGraw-Hill Professional, 2003.

Owen, David. *Hidden Evidence: Forty True Crimes and How Forensic Science Helped Solve Them*. Buffalo, NY: Firefly Books, 2000.

Parker, James N., and Philip M. Parker, eds. *Asphyxiation: A Medical Dictionary, Bibliography, and Annotated Research Guide*. San Diego: Icon Health Publications, 2004.

Parker, James N., and Philip M. Parker, eds. *Barbiturates: A Medical Dictionary, Bibliography, and Annotated Research Guide*. San Diego: Icon Health Publications, 2004.

Pringle, Peter. *Those Are Real Bullets: Bloody Sunday, Derry, 1972*. New York: Grove Press, 2001.

Ramsland, Katherine M. *The Science Of Cold Case Files*. New York: Berkley Boulevard Books, 2004.

Ramsland, Katherine M. *The Forensic Science of CSI*. New York: Berkley Boulevard Books, 2001.

Redmayne, Mike. *Expert Evidence and Criminal Justice*. Oxford, England; New York, NY: Oxford University Press, 2001.

Redsicker, David R. *The Practical Methodology of Forensic Photography*. 2nd ed. Boca Raton, FL: CRC Press, 2000.

Rendell, Kenneth W. *Forging History: The Detection of Fake Letters and Documents*. Norman: University of Oklahoma Press, 1994.

Robertson, Bernard, and G. A. Vignaux. *Interpreting Evidence*. Chichester; New York: John Wiley & Sons, 1995.

Rollins, Barbara B., and Michael Dahl. *Ballistics (Forensic Crime Solvers)*. Mankato, MN: Capstone Press, 2004.

Rouessac, Francis, and Annick Rouessac. *Chemical Analysis: Modern Instrumentation Methods and Techniques*. New York: Wiley, 2000.

Saferstein, Richard. *Criminalistics: An Introduction to Forensic Science*. 7th ed. Upper Saddle River, NJ: Prentice-Hall, 2001.

Saks, Michael J., et al. *Admissibility of Scientific Evidence*. Westlaw, 2004.

Schwoeble, A. J., and David E. Exline. *Current Methods in Forensic Gunshot Residue Analysis*. Boca Raton, FL: CRC Press, 2000.

Shepherd, Richard. *Simpson's Forensic Medicine*. New York: Arnold, 2003.

Smith, Brian C. *Quantitative Spectroscopy: Theory and Practice*. Burlington: Academic Press, 2002.

Smith, Frederick P. *Handbook of Forensic Drug Analysis*. Amsterdam; Boston: Elsevier Academic Press, 2004.

Society of Automotive Engineers. *Airbag Technology 2002*. Warrendale, PA: Society of Automotive Engineers, 2002.

Steinberg, Martin H. *Disorders of Hemoglobin: Genetics, Pathophysiology and Clinical Management*. Cambridge: Cambridge University Press, 2001.

Struthers, J. Keith, and Roger P. Westran. *Clinical Bacteriology*. Washington, DC: ASM Press, 2003.

Sunshine, Irving. *Was It a Poisoning?: Forensic Toxicologists Searching for Answers*. Washington, DC: AACC Press, 2001.

Taft, Stanley W., and James W. Mayer. *The Science of Paintings*. New York: Springer, 2000.

Thygerson, Alton L. *CPR: Cardiopulmonary Resuscitation and First Aid for Choking*. Sudbury: Jones & Bartlett Publishers, 2001.

Tobin, William A. *Comparative Bullet Lead Analysis: A Case Study in Flawed Forensics*. Westlaw, 2004.

Trestrail, John H. *Criminal Poisoning: Investigational Guide for Law Enforcement, Toxicology, Forensic Scientists, and Attorneys*. Totowa, NJ: Humana Press, 2000.

Walsh, Dermot P. J. *Bloody Sunday and the Rule of Law in Northern Ireland*. Macmillan Press, 2000.

Warlow, Tom. *Firearms, the Law and Forensic Ballistics*, . 2nd ed. Boca Raton, FL: CRC Press, 2004.

Wecht, Cyril H. *Forensic Science and the Law: Investigative Evidence in Criminal and Civil Cases*. Boca Raton, FL: CRC Press, 2005.

White, P. C. *Crime Scene to Court: The Essentials of Forensic Science*. Cambridge: Royal Society of Chemistry, 2004.

Wonder, Anita Y. *Blood Dynamics*. Burlington: Academic Press, 2001.

Woodward, John D., Jr., Nicholas M. Orlans, and Peter T. Higgins. *Biometrics*. New York: McGraw-Hill/Osborne, 2003.

Yeatts, Tabatha. *Forensics: Solving the Crime*. Minneapolis, MN: Oliver Press, 2001.

Periodicals

Allard, J. E., and Kenneth G. Wiggins. "The evidential value of fabric car seats and car seat covers." *Journal of the Forensic Science Society*. 27(2), 93-101, 1987.

Almirall, Jose. "The Importance of Standards in Forensic Science." *Standardization News*. April 1, 1995.

Apuzzo, Matt. "Connecticut to Simulate Chemical Attack." *Government CustomWire*. July 23, 2004.

Arrillaga, Pauline. "New Evidence Points to Man's Suicide." *Rocky Mountain News*. February 1, 1998.

Banta, Bob. "Artists Shining Light on Crimes." *Austin American-Statesman*. September 22, 1997.

Biasotti, A. "A statistical study of the individual characteristics of fired bullets." *Journal of the Forensic Science Society*. 4(1), 133-40, 1959.

Bryant, Vaughn. "Book Review—Flora of the Shroud of Turin." *Palynos*. June, 2000.

Budowle, B., et al. "Forensics and mitochondrial DNA: applications, debates, and foundations." *Annual Review of Genomics and Human Genetics*. no. 4 (2003): 119-41.

Cain, Steve. "Examining Questionable Documents." *South Florida Investigators Association Journal*. May, 2000.

Ceccaldi, P. F. "From crime to evidence." *International Police Journal* 1974.

Chivers, C. J. "Beslan militants were drug-dependent, forensic study shows." *The New York Times*. October 18, 2004.

Cole, S. "What counts for identity? The historical origins of the methodology of latent fingerprint identification." *Science in Context*. 12(1), 139, 1999.

———. "Witnessing identification: latent fingerprinting evidence and expert knowledge." *Social Studies of Science*. 28(5-6), 687, 1998.

Committee on Child Abuse and Neglect. “Shaken baby syndrome: Rotational Cranial Injuries-Technical Report.” *American Academy of Pediatrics.* 2001;108:206-10.

Cook, R., et al. “A hierarchy of propositions: deciding which level to address in casework.” *Science & Justice.* 38(4), 231-239. 1998b.

———. “A model for case assessment and interpretation.” *Science & Justice.* 38(3), 151-156. 1998a.

Cordiner, S. J., P. Stringer, and P. D. Wilson, “Fiber diameter and the transfer of wool fiber.” *Journal of the Forensic Science Society.* 25(6), 425-426, 1985.

Coxon, A., Grieve, M., and Dunlop, J. “A method of assessing the fibre shedding potential of fabrics.” *Journal of the Forensic Science Society.* 32(2), 151-158, 1992.

Critchlow, Donald T. “Book review of Coping with Sickness: Medicine, Law, and Human Rights—Historical Perspectives.” *Isis.* June, 2002.

Curran, J. M., C. M. Triggs, and J. S. Buckleton. “Sampling in forensic comparison problems.” *Science & Justice.* 38(2), 101-107, 1998.

Dalrymple, Brian. “Serendipitous Sleuthing.” *Canadian Chemical News.* October, 2001.

Dubowski, Kurt. “Sidney Kaye: Internationally Renowned Forensic Toxicologist.” *American Journal of Forensic Medicine and Pathology.* June, 1985.

Evett, I. "Expert evidence and forensic misconceptions of the nature of exact science." *Journal of the Forensic Science Society.* 23, 35, 1983.

Evett, I. "What is the probability that this blood came from that person? A meaningful question?" *Nature.* 22, 605, 1880.

Fish, Raymond. “Effects of Stun Guns and Tazers.” *The Lancet.* September 1, 2001.

Fletcher, Martin.“ Dead Men Do Tell Tales.” *The Times (London).* January 27, 1992.

Fregeau C. J., K. L. Bowen, and R. M. Fourney. “Validation of Highly Polymorphic Fluorescent Multiplex Short Tandem Repeat Systems Using Two Generations of DNA Sequencers.” *Journal of Forensic Science.* 44(1), 133, 1999.

Fregeau, C. J., and R. M. Fourney. “DNA typing with fluorescently tagged short tandem repeats: a sensitive and accurate approach to human identification.” *Biotechniques.* 15 (1) 1993.

Furton, K. G., Y. L. Hsu, and M. D. Cole. “What educational background do crime laboratory directors require from applicants?” *Journal of Forensic Science.* 44(1): 128-132, 1999.

Galton, F. “Personal Identification and Description II.” *Nature.* 38, 201-202, 1888.

Gaudette, B. D. “A supplementary discussion of probabilities and human hair comparisons.” *Journal of Forensic Science.* 27 (2) 279-289, 1982.

———. “Some further thoughts on probabilities and human hair comparisons.” *Journal of Forensic Science.* 23, 758, 1978.

Gerchman, Liddy. “Shrouded in Mystery: The Turin Debate.” *Odyssey.* December, 2000.

Green, Sara Jean. “Mason’s Blood Was in Car, DNA Expert Testifies in Kirkland.” *Seattle Times.* May 21, 2003.

Grice, Gordon. “Crime Seen.” *Popular Science.* 2004.

Grieve, M. C., T. W. Biermann. “The population of coloured textile fibres on outdoor surfaces.” *Science & Justice.* 37(4), 231-239, 1997.

Gross, A. M., K. A. Harris, and G. L. Kaldun. “The effect of luminol on presumptive tests and DNA analysis using the polymerase chain reaction.” *Journal of Forensic Science.* 44(4), 837, 1999.

Hanlon, Michael. “The Finger of Fate.” *Daily Mail (London).* January 14, 2002.

Hesman, Tina. “Forensic Sleuths Swap Tips and Tales of Crime Solving.” *St. Louis Post-Dispatch.* August 26, 2004.

Hoang, Son. “Forensic Scientist Uses Blood to Solve Crime.” *America’s Intelligence Wire.* February 1, 2005.

Hollon, T. “Reforming Criminal Law, Exposing Junk Forensic Science.” *The Scientist.* no.15 (2001).

Holohan, Meghan. “For the People: Bruce Dixon.” *University of Pittsburgh Alumni Magazine.* February, 2004.

Home, J. M., and R. J. Dudley. “A summary of data obtained from a collection of fibres from casework materials.” *Journal of the Forensic Science Society.* 20, 253-261, 1980.

Horrocks, M., S. A. Coulson, and K. A. J. Walsh. “Forensic Palynology: Variation in the Pollen Content of Soil On Shoes and in Shoeprints in Soil.” *Journal of Forensic Science.* 44 (1) 119-122, 1999.

Huffine, E., B. Crews, K. Bomberger, A. D. Sinbo. “Mass identification of persons missing from the break-up of the former Yugoslavia: Structure, Function, and Role of the International commission on missing persons.” *Croatian Medical Journal.* 42(3):271-275, 2001.

Inbau, Fred E. “Firearms Identification—Ballistics.” *Journal of Criminal Law and Criminology.* Summer, 1999.

Israel National Police. “International Symposium on Fingerprint Detection and Identification.” *Journal of Forensic Identification.* 45, 578-84, 1995.

Jeffreys, A. J., V. Wilson, and S. L. Thein. “Individual-specific ‘fingerprints’ of human DNA.” *Nature.* 316(4), 76, 1985.

Judis, John B. “Loathing in Las Vegas.” *The New Republic.* July 15, 1996.

Kahler, K., J. Haber, H. P. Seidel. “Reanimating the dead: Reconstruction of expressive faces from skull data.” *ACM TOG (SIGGRAPH conference proceedings).* no. 3: 554-561, 2003.

Kalia, R. K., et al. “Role of ultrafine microstructures in dynamic fracture in nanophase silicon nitride.” *Physical Review Letters.* 78, 2144-2147, 1997.

Kaplan, Allison. “His Old-Fashioned Microscope Helps Him See Who’s Guilty.” *Daily Herald.* June 25, 1998.

Kaye, Sidney. “The Rebirth and Blooming of Forensic Medicine.” *American Journal of Forensic Medicine and Pathology.* December, 1992.

Kidd, C. B. M., and J. Robertson. "The transfer of textile fibers during simulated contacts." *Journal of the Forensic Science Society.* 22(3), 301-308, 1982.

———. "The persistence of textile fibers transferred during simulated contacts." *Journal of the Forensic Science Society* 22(4), 353-360, 1982.

Kingston, C. R., and P. L. Kirk. "Historical development and evaluation of the 12 point rule." *International Criminal Police Review.* 186, 62-69, 1965.

Kirk, P. L. "The ontogeny of criminalistics." *Journal of Criminal Law, Criminology, and Police Science.* 54, 235-238, 1963.

Koehler, A. "Techniques used in tracing of the Lindbergh kidnapping ladder." *Police Science.* 27(5), 1937.

Lewis, Mark. "Author Undertakes Cold Case Sleuthing." *Tampa Tribune.* February 27, 2005.

Lewis, Paul. "Walter McCrone, Debunker of Legends, Is Dead at 86." *New York Times.* July 26, 2002.

Locard, E. "Dust and its analysis." *Police.* J. 1, 177, 1928.

Locard, E. "The analysis of dust traces, Part I-III." *The American Journal of Police Science.* 1, 276, 401, 496, 1930.

May, L. S. "The identification of knives, tools and instruments, a positive science." *American Police Journal.* 1, 246, 1930.

Metinko, Chris. "Richmond, Va., Lab's DNA Work Vital." *Contra Costa Times.* August 13, 2000.

Mladek, Klaus. "Radical Play." *Germanic Review.* Summer 2003.

Moore, Evan. "How Do You Determine Identity When a Victim's Body Is Decomposed or Damaged Beyond Recognition?" *Houston Chronicle.* May 2, 2004.

Mullis, K. B., et al. "Specific enzymatic amplification of DNA in vitro: The polymerase chain reaction." *Cold Spring Harbor Symposium on Quantitative Biology.* 51, 263-273, 1986.

Naess, A. "Book review." *New Scientist.* August, 1998.

Neyman, J., and E. S. Pearson. "On the use and interpretation of certain test criteria for purposes of statistical inference." *Biometrika.* 20, 174-240, 263-294, 1928.

R .G. Nichols. "Firearm and toolmark identification criteria: a review of the literature." *Journal of Forensic Science.* 42(3), 466-474, 1997.

Nickell, Joe. "Pollens on the 'Shroud'." *Skeptical Inquirer.* Summer, 1994.

Nickell, Joe. "Scandals and Follies of the 'Holy Shroud'." *Skeptical Inquirer.* September, 2001.

Nordby, J. J. "Can we believe what we see, if we see what we believe?—Expert disagreement." *Journal of Forensic Science.* 37(4) 1115-1124, 1992.

O'Brien, Sue. "Speculation not a Journalistic Tool." *Denver Post.* January 12, 1997.

Palmer, R., and V. Chinherende. "A target fiber study using cinema and car seats as recipient items." *Journal of Forensic Science.* 41, 802-803, 1996.

Parybyk, A. E., and R. J. Lokan. "A study of the numerical distribution of fibers transferred from blended fabrics." *Journal of the Forensic Science Society.* 26(1), 61-68, 1986.

Porter, Dorothy. "Book review of The Trials of Masculinity: Policing Sexual Boundaries 1870-1930." *Canadian Journal of History.* December, 1999.

Primorac, D., et al. "Identification of war victims from mass graves in Croatia, Bosnia, and Herzegovina by use of standard forensic methods and DNA testing." *Journal of Forensic Science.* (41) 1996.

Riley, Michael. "Tales from the Crypt." *Time.* September 14, 1992.

Robertson, J., and A. K. Lloyd. "Observations on redistribution of textile fibers." *Journal of the Forensic Science Society.* 24(1), 3-7, 1984.

Roux, C., and P. Margot. "An attempt to assess the relevance of textile fibres recovered from car seats." *Science & Justice.* 37(4), 225-230, 1997.

Saiki, R. K., et al. "Enzymatic amplification of beta-globin genomic sequences and restriction site analysis for diagnosis of sickle cell anemia." *Science.* 230, 1350, 1985.

Sampson, William. "How to Get Latent Prints from Human Skin." *Evidence Technology.* May/June 2004.

Scanlon, Lisa. "Fingerprinting's Finger-Pointing Past." *Technology Review.* June, 2003.

Schlatter, Katherine. "Identifying Tsunami Vicitms." *The Scientist Daily News.* January 7, 2005.

Shannon, C. E. "A mathematical theory of communication." *Bell System Technical Journal.* 27, 379-423, 623-656, 1948.

Siegel, J. A. "The appropriate educational background for entry level forensic scientists: a survey of practitioners." *Journal of Forensic Science.* 33:1065-8, 1988.

Smith, W. C., R. Kinney, and D. Departee. "Latent Fingerprints—A Forensic Approach." *Journal of Forensic Identification.* 43(6) 563-570, 1993.

Specter, Michael. "Do Fingerpints Lie?" *New Yorker.* May 27, 2002.

Stoney, D. A. "A medical model for criminalistics education." *Journal of Forensic Science.* 33 (4), 1086-94, 1988.

———. "Criminalistics in the new millennium." *The CACNews.* 1st Quarter, 2000.

———. "Evaluation of associative evidence: choosing the relevant question." *Journal of the Forensic Science Society.* 24, 472-482, 1984.

———. "What made us ever think we could individualize using statistics?" *Journal of the Forensic Science Society* 3(2), 197-199, 1991.

Stoney, D. A., and J. I. Thornton. "A Critical analysis of quantitative fingerprint individuality models."*Journal of Forensic Science.* 31(4), 1187-1216, 1986a.

———. "A method for the description of minutia pairs in epidermal ridge patterns." *Journal of Forensic Science.* 31(4), 1217-1234, 1986b.

———. "A systematic study of epidermal ridge minutiae." *Journal of Forensic Science.* 32(5), 1182-1203, 1987.

Takatori, T. "Investigations on the mechanism of adipocere formation and its relation to other biochemical reactions." *Journal of Forensic Sciences.* 2001.

Taroni, F. "Probalistic reasoning in the law. Part 2: assessment of probabilities and explanation of the value of trace evidence other than DNA." *Science & Justice.* 38, 179-188.

Taroni, F., C. Champod, and P. Margot. "Forerunners of Bayesianism in early forensic science." *Jurimetrics.* 38; 183-200.

Technical Working Group on DNA Analysis Methods. "Guidelines for a Quality Assurance Program for DNA Analysis." *Crime Laboratory Digest* 22 (2), 21-43.

Thompson, W. C., and E. L. Schumann. "Interpretation of statistical evidence in criminal trials: The prosecutor's fallacy and the defense attorney's fallacy." *Law and Human Behavior.* 11, 167-187, 1987.

Thornton, J. I. "The DNA statistical paradigm vs. everything else." *Journal of Forensic Science.* 42(4) 758, 1997.

———. "Ensembles of class characteristics in physical evidence examination." *Journal of Forensic Science.* 31 (2) 501-503, 1986.

———. "The snowflake paradigm." *Journal of Forensic Science.* 31 (2) 399-406, 1986.

Toupin, Laurie. "It's Elementary, My Dear Watson. . .If You Have a Microscope." *Odyssey.* January, 2004.

Watling, R. J. "Laser ablation ICP-MS as an investigational tool for insurance fraud, forensic science and forensic archaeology." *Winter Conference on Plasma Spectrochemistry.* Pau, France, 49-50 (1999).

———. "Novel applications of Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) in the field of Forensic Science and Forensic Archaeology." *Spectroscopy.* (1999) 14(6), 16-34.

Watling, R. J., B. F. Lynch, and D. Herring. "Use of Laser Ablation Inductively Coupled Plasma Mass Spectrometry for Fingerprinting Scene of Crime Evidence." *Journal of Analytical Atomic Spectrometry.* February 1997, Vol. 12 (195-203).

Other

A&E Interactive Television Networks. "Cold Case Files." http://www.aetv.com/tv/shows/coldcasefiles/ (accessed February 18, 2005.)

Abramowitz, Mortimer, et al. "Polarized Light Microscopy." http://www.olympusmicro.com/primer/lightand color/polarization.html (accessed March 3, 2005.)

American Academy of Family Physicians. "Injuries Can Offer Clues." April 1998. http://www.aafp.org/fpr/980400fr/2.html (accessed March 31, 2005.)

American Board of Criminalistics (ABC). "GKE Examination Philosophy." http://www.criminalistics.com/ABC/abc002.htm (accessed April 1, 2005.)

American Board of Medicolegal Death Investigators, Inc. "American Board of Medicolegal Death Investigators, Inc." GKE Examination Philosophy. (accessed March 24, 2005.)

Associated Press. "The Unabomber Case." January 22, 1998. http://www.unabombertrial.com/archive/1998/012298.07.html (accessed March 13, 2005.)

Australian Broadcasting Corporation. " Bali bombing website." http://abc.net.au/news/indepth/default.htm (accessed March 11, 2005.)

Australian Museum Online. "Decomposition—Body Changes." 2003. http://www.deathonline.net/decomposition/body_changes/grave_wax.htm (accessed January 18, 2005.)

Australian Museum Online. "When the heart stops beating." 2003. http://www.deathonline.net/decomposition/decomposition/index.htm (accessed January 18, 2005.)

Bahrke, Michael S., and Charles E. Yesalis. "The Future of Performance-Enhancing Substances in Sport." http://www.physsportsmed.com/issues/2002/11_02/guested.htm (accessed March 5, 2005.)

Bartel, Nick. "Medieval Medicine, Health and Hygiene." November 2003. http://www.sfusd.k12.ca.us/schwww/sch618/Medicine/Medicine_and_Health.html (accessed March 13, 2005.)

BBCNews. "Agony goes on for Beslan relatives." http://bbcnews.co.uk/1/hi/world/europe/3636304.stm.htm (accessed March 13, 2005.)

———. "Beslan searches for its missing." http://newswww.bbc.net.uk/1/hi/world/europe/3635520.stm.htm (accessed March 03, 2005.)

———. "The forensics of investigating war crimes." http://news.bbc.co.uk/1/hi/world/europe/259995.stm.htm (accessed March 03, 2005.)

Bieber, Frederick R. "Science and Technology of Forensic DNA Profiling: Current Use and Future Directions." http://www.ksg.harvard.edu/dnabook/bieber.doc (accessed February 10, 2005.)

Biohazard News. "John G. Bartlett: Infectious Disease Expert on U.S. Bioterrorism Preparedness." April 30, 2001. http://www.biohazardnews.net/int_bartlett.shtml (accessed February 13, 2005.)

Bonsor, Kevin. "How Facial Recognition Systems Work." 1998-2005. http://people.howstuffworks.com/facial-recognition.htm/printable (accessed March 13, 2005.)

Bowen, Richard. "Salivary Glands and Saliva." http://arbl.cvmbs.colostate.edu/hbooks/pathphys/digestion/pregastric/salivary.html (accessed March 6, 2005.)

Bureau of Alcohol, Tobacco, Firearms and Explosives, U.S. Department of the Treasury. "National Integrated Ballistics Information Network." http://www.atf.gov/nibin/ (accessed February 23, 2005.)

———. "The Missing Link: Ballistics Technology That Helps Solve Crimes." http://www.atf.gov/nibin/missing/index.htm (accessed February 23, 2005.)

Capital Defense Network. "Successful Cases: Supreme Court (Incompetency to Stand Trial)." http://www.capdefnet.org/hat/contents/constitutional_issues/incompetencys_to_stand_trial/incompetency_to_stand_trial_rightframe.htm (accessed March 23, 2005.)

CBSNews. "Investigators: Forensic Animation." http://cbsnews.com/stories/2002/10/25/48hours/main526999.shtml (accessed January 28, 2005.)

Center for Forensic Studies. "Fluorescence in Criminalistics: Fingerprints and Other Trace Evidence." http://www.phys.ttu.edu/~menzel/workshop_info.html (accessed March 12, 2005.)

CNN trial transcripts. "United States of America v. Terry Nichols." 1997. http://europe.cnn.com/US/9703/okc.trial/transcripts/ (accessed March 23, 2005.)

———. "People v. Simpson." http://www.cnn.com/US/OJ/trial/ (accessed March 1, 2005.)

CNN.com. "DNA bid to solve Columbus riddle." http://archives.cnn.com/2002/WORLD/europe/06/11/columbus (accessed March 12 2005.)

CODIS. "Standards for Forensic DNA Testing Laboratories." http://fbi.gov/hq/lab/codis/forensic.htm (accessed March 12, 2005.)

Columbia University. "Henry Pelouze DeForest." http://library.cpmc.columbia.edu/hsl/arch/psdbrecord.cfm?RecordNum=3547 (accessed March 30, 2005.)

Computer Crime Research Center. ""Combating Computer Crime." January 10, 2005. http://www.crimeresearch.org/articles/trenton1 (accessed February 28 2005.)

Council of Europe. "The European Convention on Human Rights." http://www.hri.org/docs/ECHR50.html (accessed February 23, 2005.)

Court TV. The Crime Library. "DNA in Court." http://www.crimelibrary.com/criminal_mind/forensics/dna/6.html?sect=21 (accessed February 28, 2005.)

———. "Forensic Voiceprints." http://www.crimelibrary.com/criminal_mind/forensics/voiceprints/1.html?sect=21 (accessed March 20, 2005.)

———. "The Horror Ends." http://www.crimelibrary.com/ (accessed March 7, 2005.)

———. "The Pressure is On." http://www.crimelibrary.com/ (accessed April 7, 2005.)

———. "The Professor-Explorer." http://www.crimelibrary.com/ (accessed April 4, 2005.)

———. "The Science of Lies: From the Polygraph to Brain Fingerprinting and Beyond." http://www.courttv.com/ (accessed March 7, 2005.)

Crime Library. "Age Progression." http://www.crimelibrary.com/criminal_mind/fornensics/art/6.html?sect=21 (accessed April 2, 2005.)

———. "Professional Opinions." http://www.crimelibrary.com/notorius_murders/famous/bimion/opinion (accessed February 20, 2005.)

———. "Serology." http://www.crimelibrary.com/criminal_mind/forensics/serology/3.html?sect=21 (accessed May 5, 2005.)

———. "The Reconstruction of a Face." http://www.crimelibrary.com?criminal_mind/forensics/art/5.html?sect=21 (accessed April 1, 2005.)

Dartmouth College Chance Team, J. Laurie Snell, Peter Doyle, Joan Garfield, Tom Moore, Bill Peterson, and Ngambal Shah. *Chance News.* "Toward a Firm Foundation for Statistical Interpretation." http://www.dartmouth.edu/~chance/teaching_aids/books_articles/DNAtyping/node6.html (accessed March 7, 2005.)

Deedrick, Douglas W. "Hairs, Fibers, Crime and Evidence." http://www.fbi.gov/hq/lab/fsc/backissu/july2000/deedric3.htm (accessed March 28, 2005.)

Doyle, Jeffrey Scott. "Gunshot Residue." http://www.firearmsid.com/A_distanceGSR.htm (accessed March 29, 2005.)

Duquesne University School of Law. "Solving the Great American Murder Mystery." http://www.jfk.duq.edu/biostarrs.html (accessed April 4, 2005.)

The Family Violence and Sexual Assault Institute "Family Violence and Sexual Assault." http://www.fvsai.org/ (accessed March 24, 2005.)

Federal Bureau of Investigation, U.S. Department of Justice. "Integrated Automated Fingerprint Identification System of IAFIS: What is it?" http://www.fbi.gov/hq/cjisd/iafis.htm (accessed February 19, 2005.)

———. "Biography of J. Edgar Hoover." http://www.fbi.gov/ (accessed March 29, 2005.)

———. "CODIS: Combined DNA Index System." http://www.fbi.gov/hq/lab/codis/index1.htm (accessed February 18, 2005.)

———. "FBI Laboratory: Latent Print Unit." October 2000. http://www.fbi.gov/hq/lab/org/lpu.htm (accessed February 24, 2005.)

———. "Integrated Automated Fingerprint Identification System." August 20, 2004. http://www.fbi.gov/hq/cjisd/iafis.htm (accessed January 16, 2005.)

———. "National DNA Index System." http://www.fbi.gov/hq/lab/codis/national.htm (accessed February 18, 2005.)

———. "Violent Crimes and Major Offenders Section." http://www.iir.com/nygc/youthGangDoc/7_justice3.htm (accessed March 30, 2005.)

Federal Bureau of Investigation, Forensic Science Research Unit. "Firearms and Toolmarks in the FBI Laboratory." *Forensic Science Communications.* http://www.fbi.gov/hq/lab/fsc/backissu/april2000/schehl2.htm (accessed February 23, 2005.)

Federal Bureau of Investigation's Criminal Justice Information Section. "NCIC: National Crime Information Center." http://www.fbi.gov/hq/cjisd/ncic.htm (accessed March 21, 2005.)

Fiatal, Robert A. "DNA Testing and the Frye Standard." http://www.totse.com/en/law/justice_for_all/dnatest.html (accessed March 30, 2005.)

The Fingerprint Society. http://www.fpsociety.org.uk/ (accessed February 24, 2005.)

Firearms Tactical Institute. "Wound Ballistics." http://www.firearmstactical.com/wound.htm (accessed January 28, 2005.)

Fong, Jason. “Erythropoietin Abuse and Detection in Athletes.” http//www.sportsmed.info/articles/epo.html (accessed March 5, 2005.)

Forensic Art Service. “Composite Drawing.” http://www.forensicartist.com/composite.html (accessed February 27 2005.)

Forensic Artist. “Composite Art and Police Drawing.” http://www.forartist.com/forensic/composite (accessed February 27 2005.)

Forensic Geology. “Overview of Services; Raymond C. Murray resume.” http://www.forensicgeology.net/ (accessed March 29, 2005.)

Forensic Handbooks Online. “Biography of David Ashbaugh, Overview of Quantitative-Qualitative Friction Ridge Analysis.” http://www.forensicnetbase.com/ (accessed April 8, 2005.)

Forensic Science. “What is a Forensic Scientist?” http://www.forensic-science.com (accessed February 28, 2005.)

Forensic Science Associates. “Edward Blake Curriculum Vitae.” http://www.fsalab.com (accessed February 7, 2005.)

Forensic Science Service. “Welcome to the Forensic Science Service.” http://www.forensic.gov.uk/forensic_t/index.htm (accessed March 21, 2005.)

Forensic Technology, Inc. “Home Webpage of Forensic Technology, Inc.” http://www.fti-ibis.com/en/index.asp (accessed February 23, 2005.)

The Franklin Institute. “Lifeblood.” http://sln.fi.edu/biosci/blood/blood.html (accessed January 26, 2005.)

Freudenrich, Craig. “How Performance-Enhancing Drugs Work.” http://health.howstuffworks.com/athletic-drug-test.htm (accessed March 4, 2005.)

Frey, Regina. “Gas Laws Save Lives: The Chemistry Behind Airbags.” http://www.chemistry.wustl.edu/~edudev/LabTutorials/Airbags/airbags.html (accessed January 28, 2005.)

George Washington University. “A Short History of Forensic Sciences.”http://www.gwu.edu/~forensic/ (accessed March 29, 2005.)

———. “GW Law Profiles: James E. Starrs.” http://www.law.gwu/edu/ (accessed April 4, 2005.)

German, Ed. “The History of Fingerprints.” http://www.onin.com/fp/fphistory.html (accessed April 4, 2005.)

———. “Automated Fingerprint Identification Systems (AFIS).” December 12, 2004. http://onin.com/fp/afis/afis.html (accessed January 16, 2005.)

Goll-McGee, Barbara, et al. “Forensic Nursing Process: An Evaluation of Forensic Patients in the Clinical Environment.” *Forensic Nursing.* http://www.forensicnursemag.com/articles/371lifedeath.html (accessed March 31, 2005.)

Government of Canada. “Computer Age Progression.” http://www.ourmissingchlidren.ca/en/about/age.html (accessed April 2, 2005.)

Guillong, Marcel. “Laser Ablation Inductively Coupled Plasma Mass Spectrometry: Laser ablation system developments and investigations on elemental fractionation.” March 3, 2004. http://e-collection.ethbib.ethz.ch/ecol-pool/diss/abstracts/p15437.pdf (accessed February 24, 2005.)

Harvard University. "An Overview of Hemoglobin." http://sickle.bwh.harvard.edu/hemoglobin.html (accessed Febraury 20, 2005.)

Houck, Max M. “Statistics and Trace Evidence: The Tyranny of Numbers.” *Forensic Science Communications.* October 1999. http://www.au.af.mil/au/awc/awcgate/fbi/houck.htm (accessed March 7, 2005.)

How Stuff Works. “How Airbags Work.” http://auto.howstuffworks.com/airbag.htm (accessed January 28, 2005.)

———. “How Breathalyzers Work.” http://science.howstuffworks.com/breathlayzer.htm (accessed Febraury 22, 2005.)

Human Rights Watch. "Iraq. The Forensic Evidence." http://www.hrw.org/reports/2004/iraq1104/4.htm (accessed March 20, 2005.)

Indiana University. “Indiana University Center for Studies of Law in Action: The Borkenstein Course.” http://www.indiana.edu/~lawactn/ (accessed February 18, 2005.)

Institute for the Research into Organized and Ritual Violence. “The Forensics of Sacrifice.” *Anthropoetics.* Fall 2003/Winter 2004. http://www.anthropoetics.ucla.edu/ap0902/sacrifice.htm (accessed April 3, 2005.)

Institute of Mineralogy, University of Wrzburg. “Laser Ablation (LA-ICPMS) at the Institute of Mineralogy, University of Wrzburg.” http://www.uni-wuerzburg.de/mineralogie/icpms/icpms.html#ablation (accessed February 24, 2005.)

International Association for Identification. “Home Web Page of International Association for Identification.” February 1, 2005. http://www.theiai.org/ (accessed February 8, 2005.)

International Association for Property and Evidence. “Biography of Nancy E. Masters.” http://www.iape.org/bios/masters/ (accessed February 7, 2005.)

The International Council on Alcohol, Drugs & Traffic Safety. “ICADTS Home Page.” http://www.icadts.org/ (accessed February 18, 2005.)

Interpol. “Genocide, War Crimes, and Crimes Against Humanity.” http://www.interpol.int/public/crimesagainsthumanity/default.asp (accessed March 01, 2005.)

———. “Interpol’s Operational response to the tsunami disaster.” http://interpol.int/public/asiandisaster/synopsis20050126.htm (accessed March 03, 2005.)

Johns Hopkins Medicine. “Home Web Page of Johns Hopkins Medicine.” http://www.hopkinsmedicine.org/index.html (accessed February 8, 2005.)

KidsHealth. “What’s Spit?”. http://kidshealth.org/kid/talk/yucky/spit.html (accessed March 6, 2005.)

Kime, J. W. "Marine Casualty Report: Capsizing and sinking of the mobile offshore drilling unit Rowan Gorilla I in the Atlantic Ocean on 15 December 1988." http://www.uscg.mil/hq/g-m/moa/boards/rowangorilla.pdf (accessed January 27, 2005.)

Lang, J. S., and N. A. Beer. "Voyage data recorders in marine accident investigations." http://www.ntsb.gov/events/symp_rec/proceedings/authors/lang.htm (accessed Januray 26, 2005.)

Latent-prints.com. "Latent prints: A forensic fingerprint impression evidence discussion site." February 15, 2005. http://www.latent-prints.com/ (accessed February 24, 2005.)

Lederman, Peter H., and Gilbert Snowden. "DWI Field Sobriety Testing." http://www.nj-dwi.com/sobriety-1.htm (accessed March 8, 2005.)

Legal Information Institute, Cornell Law School. "Federal Rules of Evidence." 1999. http://www.law.cornell.edu/rules/fre/overview.html (accessed March 29, 2005.)

Materials Evaluation and Engineering, Inc. "Energy Dispersive Spectroscopy: Description of Technique." http://www.mee-inc.com/eds.html (accessed March 9, 2005.)

McCrone Research Institute. "About the Institute." http://www.mcri.org/ (accessed March 24, 2005.)

McFarland, P. "Guide to the Henry deForest Papers, 1898-1947." http://rmc.library.cornell.edu/EAD/htmldocs/RMM03214.html (accessed March 31, 2005.)

MedicineNet. "Hemoglobin." http://www.medicinenet.com/hemoglobin/article.htm (accessed February 20, 2005.)

Medline Plus (U.S. National Library of Medicine and National Institutes of Health). "Carbon Monoxide Poisoning." http://www.nlm.nih.gov/medlineplus/carbonmonoxidepoisoning.html (accessed March 24, 2005.)

Monroe County, New York, Office of the Conflict Defender. "Misdemeanor Indictment." http://www.mcacp.org/issue14.htm (accessed February 22, 2005.)

National Center on Shaken Baby Syndrome. "All about SBS: Physical Signs/Symptoms." http://www.dontshake.com/Subject.aspx?CategoryID=12 (accessed March 24, 2005.)

National Exchange Club Foundation. "Babies are fragile. Please don't shake a child (National Shaken Baby Syndrome Campaign)." http://www.preventchildabuse.com/shaken.htm (accessed March 24, 2005.)

National Forensic Science Technology Center (NFSTC). http://www.nfstc.org/ (accessed March 25, 2005.)

National Institute for Truth Verification. "The History and Evolution of Lie Detection." http://www.cvsa1.com/ (accessed March 7, 2005.)

National Institute of Justice—Publications and Products. "Using DNA to Solve Cold Cases." October 1, 2002. http://www.ojp.usdoj.gov/nij/pubs-sum/194197.htm (accessed February 18, 2005.)

National Institute of Neurological Disorders and Stroke. "NINDS Shaken Baby Syndrome Information Page." March 9, 2005. http://www.ninds.nih.gov/disorders/shakenbaby/shakenbaby.htm (accessed March 24, 2005.)

National Institute on Drug Abuse (NIDA)—Research Report Series. "MDMA Abuse (Ecstasy)." December 2004. http://www.erowid.org/psychoactives/law/law_fed_sched.shtml (accessed January 18, 2005.)

National Transportation Safety Board. http://www.ntsb.gov (accessed February 12, 2005.)

The National Women's Health Information Center (4woman.gov). "Sexual Assault." http://www.4woman.gov/faq/sexualassault.htm (accessed March 24, 2005.)

New York State Division of Criminal Justice Services. http://criminaljustice.state.ny.us/ (accessed March 10, 2005.)

Peterson, Richard N. "Setting the standard for expert witness testimony." http://www.aaos.org/wordhtml/bulletin/oct04/fline2.htm (accessed March 29, 2005.)

Physicians for Human Rights. "Medical Group Announces First Identification of Victims of Srebrenica Massacre." July 16, 1997. http://www.phrusa.org/research/forensics/bosnia/forid.html (accessed March 22, 2005.)

Piquepaille, Roland. "3D Biometric Facial Recognition Comes To UK." November 26, 2004. http://www.primidi.com/2004/11/26.html (accessed March 13, 2005.)

Pissarenko, Dimitri. "Eigenface-based facial recognition." February 13, 2003. http://openbio.sourceforge.net/resources/eigenfaces/eigenfaces-html/facesOptions.html (accessed March 13, 2005.)

Police Academy Alumni Association. January 8, 2005. http://www.cspaaa.com/ (accessed February 7, 2005.)

Protocol online. "DNA extraction and Purification." 1999–2004. http://www.protocol-online.org/prot/Molecular_Biology/DNA/DNA_Extraction___Purification/index.html (accessed March 13, 2005.)

Rensselaer Polytechnic Institute. "Chromatography." http://www.rpi.edu/dept/chem-eng/Biotech-Environ/CHROMO/chromintro.html (accessed April 3, 2005.)

Ridges and Furrows. "Early Fingerprint Pioneers." http://www.ridgesandfurrows.homestead.com (accessed February 28, 2005.)

———. "Significant Dates and Events." http://www.ridgesandfurrows.homestead.com (accessed April 8, 2005.)

Robinson, Philip C., and Michael W. Davidson. "Introduction to Polarized Light Microscopy." http://www.microscopyu.com/articles/polarized/polarizedintro.html (accessed March 3, 2005.)

Roche Diagnostics. "Innovating Health Information." February 7, 2005. http://www.roche-diagnostics.com/ (accessed February 8, 2005.)

RxMed. "Lilly Glucose Enzymatic Test Strip Diagnostic Aid." http://rxmed.com/b.main/b2.pharmaceutical/b2.1.monographs/CPS-%20Monographs/CPS%20 (accessed General%20Monographs-%20T)/TES.htm (accessed March 27, 2005.)

Scottish Criminal Record Office. "History of Fingerprints—A Time Line." http://www.scro.police.uk/fingerprint_history.htm (accessed February 28, 2005.)

Shaken Baby Syndrome Defense. "Shaken Baby Syndrome: A Tutorial and Review of the Literature." http://www.sbsdefense.com/SBS%20101.htm (accessed March 24, 2005.)

SMC Business Councils. "Southwestern PA Conference on Emergency Preparedness & Disaster Planning." http://www.smc.org/ (accessed February 21, 2005.)

Society of Forensic Ink Analysts. "Introduction." http://www.sofia-ink.org/ (accessed March 9, 2005.)

Southern California Association of Fingerprint Officers. "Effective and Cost Efficient Catalyst." March 1994. http://www.scafo.org/ (accessed February 21, 2005.)

Sponberg, Eric W. "Forensic Naval Architecture." http://www.sponbergyachtdesign.com/Forensic.htm (accessed January 26, 2005.)

Technology Review Online. "The Voice of Osama bin Laden." January 23, 2004. http://muller.lbl.gov/Tressays/24-Voice_of_Osama.htm (accessed March 20, 2005.)

The Thin Blue Line. "Forensic Serology—Bloodstain Pattern Analysis." http://www.policesw.com/info/forensic/ (accessed April 4, 2005.)

Triplett, Michele. "Fingerprint Terms." http://www.fprints.nwlean.net/sl.htm (accessed February 21, 2005.)

Trueman, C. "A history of medicine." 2002. http://www.historylearningsite.co.uk/history_of_medicine.htm (accessed March 13, 2005.)

University of California. "Obituary of Paul Kirk." http://dynaweb.oac.cdlib.org:8088/dynaweb/ (accessed March 24, 2005.)

University of Cape Town. "SDS Polyacrylamide Gel Electrophoresis (accessed SDS-PAGE)." http://www.mcb.uct.ac.za/sdspage.html (accessed April 3, 2005.)

University of Dundee, Department of Forensic Medicine. "Undergraduate Teaching Materials." http://www.dundee.ac.uk/forensicmedicine/ugmaterials.htm (accessed February 13, 2005.)

———. "Wounds." http://www.dundee.ac.uk/forensicmedicine/llb/woundsdjp.htm (accessed April 3, 2005.)

University of Pennsylvania Law School. "Uniform Rules of Evidence." 1998. http://www.law.upenn.edu/bll/ulc/fnact99/ure88.html. (accessed February 15, 2005.)

University of Pittsburgh Medical Center. "Center for Biosecurity of UPMC." http://www.upmc-biosecurity.org/ (accessed February 8, 2005.)

University of Virginia. "DNA fingerprinting using VNTRs." August 25, 1999. http://www.people.virginia.edu/~rjh9u/vntr1.html (accessed January 25, 2005.)

The University of Utah, Genetic Science Learning Center. "How to Extract DNA from Anything Living." 2005. http://gslc.genetics.utah.edu/units/activities/extraction/ (accessed March 13, 2005.)

U.S. Congress, Office of Technology Assessment. "Chapter 4: DNA as Evidence from Genetic Witness: Forensic Uses of DNA Tests." http://www.wws.princeton.edu/cgi-bin/byteserv.prl/~ota/disk2/1990/9021/902106.PDF (accessed February 28, 2005.)

U.S. Department of Justice, Drug Enforcement Administration. "Description of Federal Controlled Substances—Schedules I–V." June 2004. http://www.erowid.org/psychoactives/law/law_fed_sched.shtml (accessed January 18, 2005.)

U.S. Department of Transportation. "Introduction to Standardized Field Sobriety Test." http://www.nhtsa.dot.gov/people/injury/alcohol/SFST/introduction.htm#1%20Development%20and%20Validation (accessed March 8, 2005.)

USConstitution.net. "The U.S. Constitution Online." http://www.usconstitution.net/const.html#A1Sec9 (accessed March 23, 2005.)

WebMD. "Complete Blood Count (CBC)." http://my.webmd.com/hw/health_guide_atoz/hw4260.asp (accessed January 27, 2005.)

Weeks, Eric. "How does a confocal microscope work?" http://www.physics.emory.edu/~weeks/confocal/ (accessed January 26, 2005.)

Weintraub, Arlene. "Can Drug-Busters Beat New Steroids?". http://www.businessweek.com/magazine/content/04_24/b3887096_mz018.htm (accessed March 4, 2005.)

West Virginia University College of Law. "Competency to Stand Trial." http://myweb.wvnet.edu/~jelkins/lawpsy04/competence.html (accessed March 23, 2005.)

WhyFiles. "Virtually Framed, or Animatedly Exonerated?" http://whyfiles.org/014forensic/computer_animation.html (accessed January 28, 2005.)

Wired News. "Tsunami tests limits of forensics." http://www.wired.com/news/medtech/0,1286,66184 2,00.html?tw=wn_story_page_next1.htm (accessed March 03, 2005.)

HISTORICAL CHRONOLOGY

c.1980 B.C. Egyptian pharaoh Amenemhet I is targeted as one of the first recorded victims of political assassination.

1500 B.C. In Babylon, fingerprints are pressed onto clay tablets of business contracts.

c.480 B.C. Demaratus of Sparta uses an early form of secret writing, concealing a message on a wooden tablet covered with wax, to warn his countrymen of invasion by the Persian empire.

c.300 B.C. *Arthasastra*, an ancient Indian manual on politics, discusses mining, metallurgy, medicine, pyrotechnics, poisons, and fermented liquors.

c.618 In China during the T'ang dynasty (618–906 A.D.) fingerprints mark divorce decrees and business documents.

c.1600 Chemists invent invisible inks, and the rebirth of complex mathematics revives encryption and code methods long dormant since Antiquity. Later, during the Scientific Revolution and the Enlightenment, telescopes and magnifying glasses are developed.

1609 In France, François Demelle publishes a book on the techniques of document analysis.

1679 The *Habeas Corpus* Act is formally passed by English Parliament.

1681 Publication of Jean Mabillon's *De Re Diplomatica*, which outlines the science of diplomatics, a precursor of questioned document examination.

c.1684 British physician Nehimiah Grew describes the shapes of ridges on the ends of the fingers in a treatise.

c.1686 As part of a general study of human skin, Italian anatomist Marcello Malpighi, an anatomy professor at the University of Bologna, describes the patterns of the ridges on the fingertips. Malpighi does not suggest that fingerprints can be used for unique identification of individuals.

1703 Although concepts of disease are primitive, in an act of biological warfare, Sir Jeffrey Amherst, commander-in-chief of British forces in North America, suggests grinding the scabs of smallpox pustules into blankets intended for Native American tribes known to trade with the French.

1789 Congress passes the Judiciary Act, which establishes the federal justice system and creates the Office of the Attorney General, as well as the U.S. Marshal Service.

1790 France introduces the metric system.

1802 John Dalton introduces modern atomic theory into the science of chemistry.

1817 German pharmacist Frederick Serturner announces the extraction of morphine from opium.

1818 Augustin Jean Fresnel (1788–1827), French physicist, publishes his *Mémoire sur la diffraction de la lumière* in which he demonstrates the ability of a transverse wave theory of light to account for such phenomena as reflection, refraction, polarization, interference, and diffraction patterns.

1828 Friedrich Wöhler synthesizes urea. This is generally regarded as the first organic chemical produced in the laboratory, and an important step in disproving the idea that only living organisms can produce organic compounds. Work by Wöhler and others establishes the foundations of organic chemistry and biochemistry.

1828 Luigi Rolando (1773–1831), Italian anatomist, achieves the first synthetic electrical stimulation of the brain.

1836 Toxicological evidence (related to arsenic poisoning) is first used in a trial (in the U.K.).

1839 Semen and sperm characteristics are defined by microscopic examination.

1839 Theodore Schwann extends the theory of cells to include animals and helps establish the basic unity of the two great kingdoms of life. He publishes *Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants*, in which he asserts that all living things are made up of cells, and that each cell contains certain essential components. He also coins the term "metabolism" to describe the overall chemical changes that take place in living tissues.

1840 Friedrich Gustav Jacob Henle publishes the first histology textbook, *General Anatomy*. This work includes the first modern discussion of the germ theory of communicable diseases.

1843 Charles-Frédéric Gerhardt (1816–1856), French chemist, simplifies chemical formula-writing, so that water becomes H_20 instead of the previous H_40_2.

1857 Louis Pasteur demonstrates that lactic acid fermentation is caused by a living organism. Between 1857 and 1880, he performs a series of experiments that refute the doctrine of spontaneous generation. He also introduces vaccines for fowl cholera, anthrax, and rabies, based on attenuated strains of viruses and bacteria.

1858 Rudolf Ludwig Karl Virchow publishes his landmark paper "Cellular Pathology" and establishes the field of cellular pathology. Virchow asserts that all cells arise from preexisting cells (*Omnis cellula e cellula*). He argues that the cell is the ultimate locus of all disease.

1862 Dutch scientist J. Van Deen develops a presumptive blood test.

1862 Department of Agriculture establishes the Bureau of Chemistry, the organizational forerunner of the Food and Drug Administration.

1864 First photographic plates made for the purpose of identification of criminals and questioned documents.

1865 The United States Secret Service is established to interdict counterfeit currency and its manufacturers.

1867 Secret Service responsibilities broadened to include "detecting persons perpetrating frauds against the government."

1870 Lambert Adolphe Jacques Quetelet shows the importance of statistical analysis for biologists and provides the foundations of biometry.

1872 Ferdinand Julius Cohn publishes the first of four papers entitled "Research on Bacteria," which establishes the foundation of bacteriology as a distinct field. He systematically divides bacteria into genera and species.

1876 Robert Koch publishes a paper on anthrax that implicates a bacterium as the cause of the disease, validating the germ theory of disease.

1877 Microscopic delineation of palm prints.

1877 Congress passes legislation prohibiting the counterfeiting of any coin, gold, or silver bar.

1878 Charles–Emanuel Sedillot introduces the term "microbe." The term becomes widely used as a term for a pathogenic bacterium.

1879 German pathologist Rudolf Ludwig Karl Virchow studies and characterizes hair.

c.1880 Two Englishmen working abroad notice that fingerprints are unique to individuals. Sir William Herschel, a British Magistrate working in India, uses the impressions of fingers of local businessmen to validate contracts. As Herschel collects these fingerprints, he notices that no two are alike. In Japan, British physician Henry Faulds studies fingerprints he finds on ancient pottery. He documents their individual patterns and develops a method for categorizing them. His work is published in the journal *Nature*.

1880 Louis Pasteur develops a method of weakening a microbial pathogen of chicken, and uses the term "attenuated" to describe the weakened microbe.

1882 Sir Francis Galton publishes a book titled *Fingerprints*, that proves that fingerprints do not change during a person's lifetime. He also develops a set of characteristics called minutia that can be used to identify fingerprints. These characteristics, also called Galton's Details, are still used in modern forensics.

1882 The German bacteriologist Robert Koch (1843–1910) discovers the tubercle bacillus and enunciates "Koch's postulates," which define the classic method of preserving, documenting, and studying bacteria.

1883 French police worker Alphonse Bertillon links criminal behavior to body measurement (anthropometry).

1887 Arthur Conan Doyle publishes first Sherlock Holmes story.

1889 In 1899 and 1900, Sir Edward Richard Henry improves on Galton's classification system, allowing forensics experts to handle larger numbers of fingerprints in their filing systems. Henry's system remains one of the most common systems used.

1892 Argentinean police worker Juan Vucetich advances the fingerprint classification system. Vucetich identifies a woman who murdered her own sons by finding her bloody print on the doorpost.

1898 In Germany, Paul Jesrich compares bullets using photomicrographs.

1900 Friedrich Ernst Dorn (1848-1916), a German physicist, demonstrates that the newly discovered radium gives off a gas as well as producing radioactive radiation. This proves to be the first demonstrable evidence that in the radioactive process, one element is actually transmuted into another.

1900 Karl Landsteiner discovers the blood-agglutination phenomenon and the four major blood types in humans.

1901 In England and Wales, fingerprints are incorporated into the criminal investigation system.

1903 The New York State Prison system begins systematically fingerprinting criminals.

1904 The St. Louis Police department uses fingerprint identification during the World's Fair.

1904 Oskar and Rudolf Adler develop a benzidine-based presumptive test for blood.

1908 Formal beginning of the Bureau of Investigation (BOI) that became the FBI in 1935.

1911 Fritz Pregl (1869–1930), an Austrian chemist, first introduces organic microanalysis. He invents analytic methods that make it possible to determine the empirical formula of an organic compound from just a few milligrams of the substance.

1912 Joseph Thomson develops a forerunner of mass spectrometry and separation of isotopes.

1913 In Paris, Victor Balthazard identifies bullet marking classifications and techniques.

1915 The International Association for Criminal Identification, a precursor of the International Association for Identification (IAI), is founded, with founder Harry H. Caldwell as its presiding officer.

1915 Germany uses poison gas at the Battle of Ypres.

1916 Vacuums are used to collect trace evidence.

1918 Edmond Locard advances 12 point fingerprint matching scheme.

Oct 28, 1919 Congress passes the National Motor Vehicle Theft Act, also known as the Dyer Act. This act authorizes the Bureau of Investigation to investigate auto thefts that cross state lines.

1921 William Marston develops first modern polygraph.

1921 Twenty-six year old J. Edgar Hoover named Assistant Director of BOI.

1922 White House police force created at request of President Warren G. Harding. Ultimately this will become the uniformed division of the United States Secret Service.

1924 United States consolidates fingerprint files in the Identification Division of the Federal Bureau of Investigation. By 1946, there are more than 100 million fingerprint cards in their files. Eventually this collection of cards becomes the Automated Fingerprint Identification System, or AFIS, and in 1999 it becomes IAFIS.

1924 Los Angeles Police Chief Vollmer establishes the first U.S. police crime laboratory.

1924 J. Edgar Hoover designated Director of the BOI.

1924 BOI establishes an Identification Division after Congress authorized "the exchange of identification records with officers of the cities, counties, and states."

1925 Johannes Hans Berger (1873–1941), German neurologist, records the first human electroencephalogram (EEG).

1925 Special Agent Edwin C. Shanahan becomes the first BOI agent killed in the line of duty.

1930 *American Journal of Police Science* begins publication.

1930 United States Food, Drug, and Insecticide Administration is renamed Food and Drug Administration (FDA).

1930 U.S. Treasury Department creates Bureau of Narcotics, which will remain the principal anti-drug agency of the federal government until the late 1960s.

1930 Primitive anthrax vaccine developed.

1932 Federal Bureau of Investigation (FBI) crime laboratory established.

1932 The Bureau of Investigation starts the international exchange of fingerprint data with friendly foreign governments. Halted as war approaches, the program is not re-instituted until after World War II.

1932 In response to the Lindbergh kidnapping case and other high profile cases, the Federal Kidnapping Act is passed to authorize BOI to investigate kidnappings perpetrated across state borders.

1934 U.S. Congress passes National Firearms Act.

1935 The Federal Bureau of Narcotics, forerunner of the modern Drug Enforcement Administration (DEA), began a campaign that portrayed marijuana as a drug that led users to drug addiction, violence, and insanity. The government produced films such as *Marihuana* (1935), *Reefer Madness* (1936), and *Assassin of Youth* (1937).

Jul 1, 1935 The BOI officially becomes the Federal Bureau of Investigation (FBI).

1941 Researchers publish studies of voiceprint identification.

1941 Arnold O. Beckman, American physicist and inventor, invents the spectrophotometer. This instrument measures light at the electron level and can be used for many kinds of chemical analysis.

1942 Formation of the American Society of Questioned Document Examiners

1942 Alcohol Tax Unit (ATU) formed and given responsibility for enforcing the Firearms Act.

1946 R. R. Race advances Kell blood group system.

1950 Duffy blood group system advanced.

1950 American Academy of Forensic Science (AAFS) established.

1950 Puerto Rican nationalists attempt to assassinate President Harry S Truman. As a result of this incident, in which a United States Secret Service (USSS) agent is killed, Congress greatly expands the duties of USSS.

1950 The FBI initiates the Ten Most Wanted Fugitives Program in May in order to draw national attention to dangerous criminals who have avoided capture.

1951 Kidd blood grouping system advanced.

1953 James D. Watson and Francis H. C. Crick publish two landmark papers in the journal *Nature*. The papers are entitled "Molecular structure of nucleic acids: a structure for deoxyribose nucleic acid" and "Genetic implications of the structure of deoxyribonucleic acid." Watson and Crick propose a double helical model for DNA and call attention to the genetic implications of their model. Their model is based, in part, on the x-ray crystallographic work of Rosalind Franklin and the biochemical work of Erwin Chargaff. Their model explains how the genetic material is transmitted.

1954 Indiana State Police Captain R. F. Borkenstein invents Breathalyzer®.

1958 International Association for Identification establishes the John A. Dondero Memorial Award, first awarded to FBI Director J. Edgar Hoover.

1959 The microchip, forerunner of the microprocessor, is invented.

Nov 22, 1963 Lee Harvey Oswald assassinates President John F. Kennedy in Dallas, Texas.

1966 The Naval Investigative Service, predecessor of the Naval Criminal Investigative Service, formed as an office within the Office of Naval Intelligence.

1967 National Crime Information Center created by U.S. Federal Bureau of Investigation.

1968 U.S. anti-drug agencies in the Treasury and Health, Education, and Welfare departments merge to form the Bureau of Narcotics and Dangerous Drugs under the Justice Department.

1968 The National Institute of Justice established under the authority of the Omnibus Crime Control and Safe Streets Act to provide independent, evidence-based tools to assist state and local law enforcement.

Apr 4, 1968 James Earl Ray assassinates Dr. Martin Luther King, Jr. in Memphis, Tennessee. The FBI opens a special investigation based on the violation of Dr. King's civil rights so that federal jurisdiction in the matter could be established.

Jun 5, 1968 Senator Robert F. Kennedy is assassinated by Sirhan B. Sirhan.

1968 As a result of Senator Robert F. Kennedy's assassination, Congress authorizes protection of major Presidential and Vice Presidential candidates and nominees.

1969 Microprocessor developed.

1969 Defense Department Advanced Research Projects Agency (ARPA) establishes ARPANET, a forerunner to the Internet.

1970 Forensic odontology division of the American Academy of Forensic Sciences created.

1970 United States Congress passes Controlled Substance Act (CSA).

1970 The Consolidated Federal Law Enforcement Training Center, a bureau of the Department of the Treasury, is established as an organization to provide training for all federal law-enforcement personnel. Today known as the Federal Law Enforcement Training Center, it is now part of the Department for Homeland Security.

1970 Congress approves the Organized Crime Control Act of 1970 in October. This law contains a section known as the Racketeer Influenced and Corrupt Organization Act or RICO. RICO becomes an effective tool in convicting members of organized criminal enterprises.

1971 B. J. Culliford publishes *The Examination and Typing of Bloodstains in the Crime Laboratory.*

1972 Recombinant technology emerges as one of the most powerful techniques of molecular biology. Scientists are able to splice together pieces of DNA to form recombinant genes. As the potential uses, therapeutic and industrial, become increasingly clear, scientists and venture capitalists establish biotechnology companies.

1972 The ATF Division of IRS becomes a separate Treasury bureau, the Bureau of Alcohol, Tobacco, and Firearms.

1974 Scanning electron microscopy with electron dispersive x rays (SEMEDX) used to identify gunshot residue.

1975 The Federal Rules of Evidence enacted.

1977 Forensic scientists begin to use Fourier transform infrared spectrophotometer.

1977 FBI advances Automated Fingerprint Identification System (AFIS).

1981 First corpse donated for study received at the Body Farm.

1982 In January, federal law enforcement reorganization gives Drug Enforcement Administration (DEA) and Federal Bureau of Investigation (FBI) concurrent jurisdiction in drug-related criminal matters.

1982 The FDA issues regulations for tamper-resistant packaging after seven people die in Chicago from ingesting Tylenol capsules laced with cyanide. The following year, the federal Anti-Tampering Act was passed, making it a crime to tamper with packaged consumer products.

1984 Crime-fighting efforts bolstered by the Sentencing Reform Act, which stiffens prison sentences, requiring mandatory terms for certain crimes and abolishing federal parole; and by the Victims of Crime Act. Throughout the 1980s, numerous national and community-based organizations are formed to provide support to victims of rape, spousal abuse, drunk driving, and other crimes.

1984 Congress enacts legislation making the fraudulent use of credit and debit cards a federal violation.

1984 The United States Department of Energy (DOE), Office of Health and Environmental Research, U.S. Department of Energy (OHER, now Office of Biological and Environmental Research), and the International Commission for Protection Against Environmental Mutagens and Carcinogens (ICPEMC) cosponsor the Alta, Utah, conference, which highlights the growing role of recombinant DNA technologies. OTA incorporates the proceedings of the meeting into a report acknowledging the value of deciphering the human genome.

1984 President Ronald Reagan issues a directive giving the NSA responsibility of maintaining security of government computers.

1985 Alec Jeffreys develops "genetic fingerprinting," a method of using DNA polymorphisms (unique sequences of DNA) to identify individuals. The method, which is subsequently used in paternity, immigration, and murder cases, is generally referred to as "DNA fingerprinting."

1985 Kary Mullis, who was working at Cetus Corporation, develops the polymerase chain reaction (PCR), a new method of amplifying DNA. This technique quickly becomes one of the most powerful tools of molecular biology. Cetus patents PCR and sells the patent to Hoffman-LaRoche, Inc. in 1991.

1985 The Global Positioning System (GPS) becomes operational.

1986 First use of PCR-based forensic DNA analysis in the United States. Henry Erlich confirms that two autopsy samples came from the same person in the case *Pennsylvania v. Pestinikas*.

1986 DNA is first used to solve a crime as Alec Jeffreys uses DNA profiling evidence to identify Colin Pitchfork as a murderer.

1986 Computer Fraud and Abuse Act enacted, defining federal computer crimes.

1986 U.S. intelligence community establishes Intelligence Community Staff Committee on MASINT (measurement and signatures intelligence) to oversee all relevant activities.

1987 Based on RFLP analysis, DNA profiling is introduced into a U.S. criminal trial.

1987 Congress passes the Computer Security Act, which makes unclassified computing systems the responsibility of the National Institute of Standards and Technology (NIST) and not the NSA with regard to technology standards development.

1987 The idea to use patterns of the iris of the eye as an identification marker was patented, along with the algorithms necessary for iris identification.

1988 International Association for Identification establishes peer-reviewed publication: *Journal of Forensic Identification*.

1988 Loss of Pan Am Flight 103 over Lockerbie, Scotland.

1988 The Human Genome Organization (HUGO) is established by scientists in order to coordinate international efforts to sequence the human genome.

1988 The federal Polygraph Protection Act prohibits employers from using polygraphs for employment screening.

1991 Forensic Science Service (U.K.) established as an executive agency of the Home Office of the U.K. government.

1992 National Crime Information Center consolidates with the FBI's Criminal Justice Information Services division.

1992 Naval Criminal Investigative Service formed as an entity separate from the Office of Naval Intelligence.

1993 A U.S. federal court relaxes *Frye* standard for admission of scientific evidence (*Daubert et al. v. Merrell Dow*.

Feb 26, 1993 The World Trade Center in New York City is badly damaged when a car bomb planted by Islamic terrorists explodes in an underground garage. The bomb leaves six people dead and 1,000 injured. The men carrying out the attack were followers of Umar Abd al-Rahman, an Egyptian cleric who preached in the New York City area.

1993 After a 51-day siege by the Bureau of Alcohol, Tobacco, and Firearms, a federal team assaults a compound held by the Branch Davidians, a religious sect charged with hoarding illegal weapons. The Branch Davidians allegedly set the buildings on fire, killing 76 people, including cult leader David Koresh.

1994 DNA Identification Act of 1994 authorizes establishment of NDIS.

1994 The Genetic Privacy Act, the first United States Human Genome Project legislative product, proposes regulation of the collection, analysis, storage, and use of DNA samples and genetic information obtained from them. These rules were endorsed by the ELSI Working Group.

1995 Forensic Science Service (U.K.) established the world's first national criminal intelligence DNA database, the National DNA Database.

1995 A study by the Rand Corporation finds that every dollar spent in drug treatment saves society seven dollars in crime, policing, incarceration, and health services.

Apr 19, 1995 A car bomb explodes outside the Alfred P. Murrah Federal office building in Oklahoma City, Oklahoma, collapsing walls and floors, killing 169 people, including 19 children and one person who died in the rescue effort. Timothy McVeigh and Terry Nichols are later convicted in the anti-government plot to avenge the Branch Davidian standoff in Waco, Tex., exactly two years earlier.

1996 The Forensic Science Service (U.K.) merges with the Metropolitan Police Laboratory, London, England.

1996 First computerized searches of the AFIS fingerprint database.

1996 First use of mitochondrial DNA typing evidence in a U.S. trial (*Tennessee v. Ware*).

1997 The National Center for Human Genome Research (NCHGR) at the National Institutes of Health becomes the National Human Genome Research Institute (NHGRI).

Dec 8, 1997 The FBI announces its new National DNA Index System (NDIS) allowing forensic science laboratories to link serial violent crimes to each other and to known sex offenders through the electronic exchange of DNA profiles.

1998 NDIS becomes operational.

1998 FBI and ATF agree to pursue joint development of one system, using only IBIS, and create the National Integrated Ballistics Information Network.

1998 DNA analyses of semen stains on a dress worn by Monica Lewinsky were found to match DNA from a blood sample taken from President Clinton.

1998 DNA fingerprinting used to identify remains of Russian Imperial Romanov family.

1999 The FBI teams with federal, state, and local criminal investigation departments to establish IAFIS, the Integrated Automated Fingerprint Identification System. This facility electronically stores the fingerprints and criminal history information of more than 47 million individuals.

1999 Osama bin Laden is added to the FBI's "Ten Most Wanted Fugitives" list in June, in connection with the U.S. Embassy bombings in East Africa.

Jun 23, 1999 FBI personnel travel to Kosovo to assist in the collection of evidence and the examination of forensic materials in support of the prosecution of Slobodan Milosevic and others before the International Criminal Tribunal for the former Yugoslavia.

2000 Debut of the CBS television series *CSI: Crime Scene Investigation*.

Sep 11, 2001 Islamist terrorists mount a coordinated terrorist attack on New York and Washington. The World Trade Center Towers are destroyed, killing nearly 3,000 people. In Washington, a plane slams into the Pentagon, but passengers aboard another hijacked airliner, aware of the other terrorist attacks, fight back. During the struggle for the aircraft, it crashes into a Pennsylvania field, thwarting the terrorist's plans to crash the plane into either the U.S. Capital or White House, but killing all on board.

2001 The FBI dedicates 7,000 of its 11,000 Special Agents and thousands of FBI support personnel to the PENTTBOM investigation. "PENTTBOM" is short for Pentagon, Twin Towers Bombing.

2001 Letters containing a powdered form of *Bacillus anthracis*, the bacteria that causes anthrax, are mailed by an unknown terrorist or terrorist group (foreign or domestic) to government representatives, members of the news media, and others in the United States. One letter is postmarked to a U.S. senator on October 8, resulting in closure of the Hart Senate building and other government offices and postal facilities. More than 20 cases and five deaths are eventually attributed to the terrorist attack.

Oct 18, 2001 In conjunction with the U. S. Post Office, the FBI offers a reward of $1,000,000 for information leading to the arrest of the person who mailed letters contaminated with anthrax to media organizations and congressional offices.

Oct 26, 2001 President George W. Bush signs the Patriot Act into law, giving the FBI and CIA broader investigatory powers and allowing them to share with one another confidential information about suspected terrorists. Under the act, both agencies can conduct residential searches without a warrant and without the presence of the suspect. The act also allows immediate seizure of personal records. The provisions are not limited to investigating suspected terrorists, but may be used in any criminal investigation related to terrorism. The Patriot Act also grants the FBI and CIA greater latitude in using computer tracking devices to gain access to Internet and phone records. Forensic science becomes more entwined with National Security interests.

2001 Enough closed-circuit television cameras (CCTV) are installed in public places in Britain that, on an average day in any large British city, security experts calculate that a person will have over 300 opportunities to be captured on CCTV during the course of normal daily activities.

2002 Cable television network Court TV launches its Forensics in the Classroom program.

Jan 24, 2003 The Office of Homeland Security becomes the Department of Homeland Security.

2004 Total number of DNA profiles in the FBI NDIS database reaches 2,132,470; the total number of forensic profiles is 93,956, and the total number of convicted offender profiles is 2,038,470.

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