Chapter 1
Introduction to Forensic Science

Chapter Outline

Mini Glossary

Behavioral forensic sciences: Applications of psychology and psychiatry to criminal matters including competency, interrogation, and crime scene reconstruction.

Computer forensics: Applications of computer science to criminal and civil offenses including the use of computers to commit crimes and the use of computers to help solve crimes.

Criminalistics: Analysis of physical evidence generated by a crime scene. Also, the pattern science areas of forensic evidence including fingerprints, firearms, and questioned documents.

Forensic anthropology: Analysis of skeletal remains recovered from crime scenes for the purposes of developing a biological profile and identification of the remains.
Forensic engineering: Application of engineering principles in forensic cases including failure analysis and traffic accident reconstruction.
Forensic entomology: Study of insect activity and cadavers assist in the determination of time of death (postmortem interval) and for other forensic purposes.
Forensic odontology: Synonymous with forensic dentistry. Analysis of dentition for the purposes of human identification and injuries. Also, analysis of bite marks.
Forensic pathology: Determination of the cause and manner of death in cases of unattended or suspicious death.
Forensic science: Application of science to matters involving the public or applications of science to legal matters.
Forensic scientist: A scientist who analyzes evidence generated by criminal or civil offenses and who can offer expert testimony concerning the evidence in court of law.
Lay witness: A witness to a crime who testifies what she saw or heard. Lay witnesses do not normally give opinions. They are contrasted with expert witnesses who do have to render opinions at times.

Acronyms

AAFS: American Academy of Forensic Sciences
ATF: Bureau of Alcohol, Tobacco, Firearms and Explosives
CSI: Crime scene investigation or investigator
DEA: Drug Enforcement Administration
FBI: Federal Bureau of Investigation
FEPAC: Forensic Science Education Program Accreditation Commission
FSS: Forensic Science Service (United Kingdom)
FWS: U.S. Fish and Wildlife Service
IRS: Internal Revenue Service
NAS: National Academy of Sciences
USPS: U.S. Postal Service
USSS: United States Secret Service

Introduction

Forensic science, forensic computing, forensic art, forensic accounting, forensic psychology. Forensic is the buzzword of the twenty-first century. It seems like there is forensic everything. More than 150 colleges and universities in the United States and more than 300 in the United Kingdom now offer some type of forensic science degree program. Movies, books, and TV shows that are about forensic science abound. Everyone is familiar with the site of a white robed scientist peering into a microscope or staring at a computer screen and uttering some dramatic statement about evidence from a crime; the hair came from the victim, the DNA matches the suspect, the white powder is cocaine. At this writing, the TV show *CSI* is still

going strong. Why the sudden popularity? After all, forensic science has been practiced in one form or another for over 5000 years. An important reason is that recent serious cases have occurred in the United States and elsewhere where forensic science has played a major role. Jon Benet Ramsey, OJ Simpson, Theodore Bundy, and the Green River Killer have all exploded onto the headlines in recent years and forensic science has played an important part of all of them. People all over the world are fascinated by crime, its investigation, and its solution. People enjoy using clues to solve puzzles and problems. They are concerned with violent crime and want to do something about it. All of this feeds into the popularity of forensic science. The major impact of this field seems to have been on women. Today, more than 80% of all students in forensic science education programs in the United Sates are women, and this trend seems to be the same in other countries such as Australia and England. In some ways, the booming interest in forensic science is not a new phenomenon. For more than a century, people have been fascinated by the exploits of Sherlock Holmes, the clever detective penned by Arthur Conan Doyle. In just the past few years, there have been several movies and TV series about the great detective. As far back as the early days of TV and the movies, there have been shows about crime, policing, lawyers, and criminals. In recent years, the focus has shifted to forensic science. Although some people decry CSI and the other shows about forensic science, the fact is that they have raised the public conscience about science and its role in crime solving. Forensic science provides a unique way of teaching students the principles of science as well as problem solving, critical thinking, oral and written skills, and the role of bias in the practice of science.

Is the portrayal of forensic science and scientists in the media accurate? What do forensic scientists really do? How is forensic science presented in court and what effect does it have on juries as they deliberate the fate of the accused? This is what this book is all about. You will learn about the various branches of forensic science, how crime labs are organized, how evidence is collected and analyzed, and how scientific testimony is presented in court.

What Is Forensic Science?

In the ancient Roman Empire, the Senate used to conduct its meetings in a public place called the *forum*. Anyone who wanted to could listen to the great debates of the day and watch government in action. The key here is that the forum was a place where everyone could come and observe. The term forum is Latin for public and forensic is derived from that term. "Forensic science" implies, then, something about science and public. In the broadest sense then, forensic science can be defined as the methods of science applied to public matters. By this definition, forensic science does not necessarily have to do with crime; however, the term has evolved in modern times to mean the application of science to court or criminal matters. Most forensic scientists work in the criminal area of the justice system, although civil cases are an important component of forensic science. In this book, focus will be on the applications of science to criminal matters.

Depth and Breadth of Forensic Science

If forensic science means science applied to criminal and civil law, one may wonder which of the sciences are forensic sciences? The answer may surprise you. Any science can be a forensic science if it has some application to justice. Think about

how many different areas of science could potentially be brought to bear on solving crimes. Many medical, physical, and biological sciences have forensic applications, as do math, business practices, sociology, and psychology. The list is nearly endless. The most common areas of science that have forensic applications are described later. This will give you an idea of the "big tent" that is forensic science.

Forensic Science v. Crime Scene Investigation

There is a good deal of confusion about the relationship between forensic science and crime scene investigation/investigators (CSI). Part of this may be due to TV shows such as *CSI*, which blur the distinctions between them by depicting the same people who collect evidence from a crime scene as the ones who analyze the evidence in the crime lab. In reality, these are different functions, but with some overlap. CSIs are usually, but not always, police officers who are trained and then assigned to the crime scene unit. They learn how to recognize evidence, protect it from contamination, collect it properly, thoroughly document its location and condition, and maintain a chain of custody to help authenticate the evidence when it gets to court. Some CSIs have a science background but many do not. Some CSIs are also trained in some procedures that could be considered forensic science because they involve preliminary (or complete) analysis of some types of evidence. Examples include preliminary analysis of suspected illicit drugs (so-called "field tests"), collection and analysis of fingerprints, and documentation and analysis of bloodstain patterns. To the extent that they analyze this evidence and reach scientific conclusions and then testify in court as experts, these investigators would be considered to be forensic scientists and this part of their job would be forensic science. This type of activity among CSIs is relatively rare but still common enough to bear mention. Under normal circumstances, the job of CSIs stops when the evidence is delivered to the laboratory where the actual work of the forensic scientist begins. Most people in the forensic science field do not consider crime scene investigation activities to be part of forensic science in spite of the fact that many crime scene units are administratively within the crime lab structure and that increasingly forensic scientists are going to some crime scenes to help with investigations.

Criminalistics

The term criminalistics was first coined by Paul Kirk, considered by many to be the father of forensic science in the United States. In some quarters, criminalistics is synonymous with forensic science and the two terms are often used interchangeably. In California, forensic scientists are often officially called criminalists. The term can be used to describe the comparative forensic sciences such as fingerprints, questioned documents, firearms, and tool marks. Most commonly, however, criminalistics refers to the myriad of types of physical evidence generated by crime scenes. This includes illicit drugs, blood and DNA, fire and explosive residues, hairs and fibers, glass and soil particles, paints and plastics, fingerprints, bullets, and much more.

A Bit of History: Paul Kirk

Paul Leland Kirk was a chemist and forensic scientist. He held a PhD in biochemistry from the University of California at Berkeley. He started his career at Berkeley in the biochemistry department and became interested in forensic

science when authorities asked him to examine evidence from a rape case. Because of his interest and experience in microscopy, he was asked to head up the new Berkeley criminology program in 1937. He subsequently worked as a microscopist on the Manhattan Project where he helped isolate fissionable material for making bombs. In 1946, he returned to Berkeley and headed up the technical criminology major and served as head of the criminalistics department. Kirk is best known professionally for his work in the Sam Sheppard murder case. In this case, Dr. Sam Sheppard was falsely accused of murdering his wife. He escaped from custody and helped the police find the "one armed" man who committed the crime. This case was the basis for *The Fugitive* book, TV show, and movie. Kirk examined bloodstain patterns from the scene and his subsequent report and testimony at the second trial helped free Sheppard. Today, Kirk's legacy lives on in the Paul Kirk award, the highest award given by the "Criminalistics" section of the American Academy of Forensic Sciences.

Pathology

When some people think of forensic science, they envision dead bodies and autopsies. Some people got this idea originally from watching the TV show *Quincy*. The part of forensic science that is concerned with determining how and why people die is called forensic pathology. The forensic pathologist is a medical doctor who first specialized in pathology and then in forensic pathology. Forensic pathologists determine the cause and manner of death in cases where someone dies under suspicious or other circumstances as prescribed by state law. Many forensic pathologists work for state or local medical examiners or coroners. These are appointed or elected officials who must decide when a medicolegal autopsy (an autopsy in a case of suspicious death or homicide) is needed and they must sign death certificates that indicate the cause and manner of death. Medical examiners and coroners do not usually perform the autopsies themselves. They employ forensic pathologists to do this. Forensic pathology is discussed in detail in Chapter 13. If you would like to learn more about medicolegal autopsies, check out http://www.nlm.nih.gov/exhibition/visibleproofs/education/medical/index.html.

Anthropology

A Bit of History: An Early Case in Forensic Anthropology

In 1849, a Boston physician, Dr. George Parkman was murdered. The suspect in the case was John Webster, a professor of chemistry at Harvard, who was in considerable debt to Dr. Parkman. The *modus operandi* of the crime was that Professor Webster incinerated Dr. Parkman. When investigators searched through the ashes, they found some remains of skull and some badly damaged remains of dentures. The prosecution retained several experts in osteology and physiology who examined the bone fragments. They determined that they belonged to a white male, about 50–60 years of age, about 6 ft tall. Dr. Parkman was 60 years old and 5 ft 11 in. tall. In addition, experts matched the dentures to Dr. Parkman (Berryman, 13 *Crime Lab Digest*, 1986).

Forensic anthropologists work with skeletal remains. They identify bones as being human or animal. If animal, they determine the species. If human, they determine from what part of the body the bone originated. If they have the right bones, gender can be determined. Sometimes, age can be approximated and racial characteristics

determined, and even socio-economic status may be estimated. If there is an injury to a skeleton or major bones, the anthropologist can help determine the cause of the injury or even death. Forensic anthropologists do other things besides identifying bones. They also work closely with skulls. It is possible to literally build a face onto a skull using clay and wooden or plastic pegs of various sizes. Using charts that give average tissue depth figures for various parts of a face, an anthropologist constructs a face and then makes judgments as to eye, nose, and mouth characteristics. Facial reconstruction can be useful in helping to identify a missing person from the face built up on the recovered skull. It is also possible for a forensic anthropologist to superimpose a skull onto a picture of a face to see if they are one and the same person. This is not usually definitive but can be quite helpful in establishing the identity of a skull. The process of building a face on a skull and the process of superimposition of skulls and faces is now done nearly exclusively by computer, a much faster and more accurate process. Forensic anthropology is discussed in detail in Chapter 14.

Odontology

Odontology is a synonym for dentistry. You may be curious about how a dentist could be a forensic scientist. Actually, there are several applications of dentistry to forensic science. A few years ago in Pennsylvania, a burglar broke into a house and ransacked it for valuables while the owners were on vacation. During his foray, he got hungry and rooted through the refrigerator for something to eat. He found a hunk of Swiss cheese and took a bite. Later he was arrested, trying to fence (sell on the black market) the stolen merchandise. When the police investigated the home looking for clues that would tie him to the scene, they found the cheese. A forensic dentist made a cast of the bite mark in the cheese and matched it to an impression of the burglar's teeth.

The most famous case where bite marks were crucial evidence involved Theodore Bundy. He was suspected of killing more than 30 young women in his career as a serial killer. He operated first in Washington, Utah, and Colorado, and then moved to Florida. During his last homicide, he bit his victim on her buttock after strangling her. A forensic dentist was able to match Bundy's teeth to this bite mark. He was executed in Florida for this murder in 1993.

Key Figures in Forensic Science: Ted Bundy

Ted Bundy was born in 1946 in Vermont in a home for unwed mothers. His father's identity was not conclusively determined. He was raised by his grandparents. He later moved to Washington State where he went to high school. Before he graduated from high school, he was a thief and shoplifter. In high school and early in college, he was quite introverted and had poor social skills. After graduation from high school, he went to the University of Washington and ultimately earned a degree in psychology. By all accounts, he was an honors student and well liked by his teachers. He subsequently began law school there but dropped out.

Some experts including those who knew Bundy believe that he started his killing spree during his early teens. At one point, he told is attorney that he attempted his first kidnapping when he was in college. The earliest murders that could conclusively be attributed to him occurred when he was 27. He started a string of brutal killings of young, white women in Washington and Oregon, and then Utah and Colorado. He was caught in Colorado but escaped twice from jail and fled to Florida where he resumed his rampage after more than 2 years. His last murders

took place in Tallahassee at a sorority house. It was these murders for which he was tried and ultimately executed. Some of the crucial evidence in these murders was a bite mark that he left on the buttock of one of his victims. At his trial, a forensic odontologist testified that he matched the bite mark to a cast made of Bundy's teeth. Several jurors told the media after the trial that this was the crucial piece of evidence against Bundy. This was the first instance in the United States where bite marks had been used as evidence in this fashion. It should be noted that, as Bundy's execution date neared, he tried to buy time or get his sentence commuted to life in prison by offering to tell families where the bodies of some of his victims were in exchange for their writing letters to the judge asking for clemency. Not one family agreed to this, and he was electrocuted in January of 1989.

Forensic odontologists can also be very helpful in identifying the remains of victims of mass disasters such as airplane crashes. Sometimes, bodies are so badly burned or dismembered the only way to identify the remains is by using dental records. Postmortem dental records are taken and matched to x-rays taken before death.

Finally, forensic dentists may play a role in child or other abuse cases. A forensic dentist can often tell if facial injuries received by a person were the result of falling down a flight of stairs or if they were due to blunt force injury such as striking the person with a fist or other object. Forensic odontology is covered in more detail in Chapter 14.

Engineering

Forensic engineers can be valuable in cases where something has gone wrong with a mechanical or structural entity or in cases of automobile crashes. A few years ago, a balcony collapsed in the lobby of a Hyatt hotel in Kansas City. Many people were on the balcony at the time watching a rock concert going on in the lobby, several stories below. Questions arose about why the balcony collapsed. Forensic engineers were called in to examine the structural remains of the balcony and the concrete that fell. They concluded that the construction of the balcony was faulty and contributed to its failure. Failure analysis is one of the major contributions that forensic engineers make to the justice system. Figure 1.1 shows the damage to the Hyatt hotel in Kansas City after the walkway collapse. When the World Trade Center buildings in New York City were destroyed by airplane crashes, forensic engineers were called in to investigate the disaster. The buildings were constructed to withstand such an impact, and the engineers were asked to determine why the structure failed.

The majority of the work of forensic engineers is in the investigation of traffic crashes. Accident reconstruction is used to determine speeds, directions of impact, and who was driving the vehicle at the time of the crash. Insurance companies and police departments use forensic engineers quite extensively in traffic incident investigation. Forensic engineering is covered in more detail in Chapter 9.

Entomology

When a person dies and the body is exposed to the elements, who gets there first? Not witnesses or detectives—it is flies, more specifically a species commonly called the blow fly. During the bombing of the Murrah Federal Building in Oklahoma City, bodies were buried in the tons of rubble from the collapsed building.

Figure 1.1 Wreckage of the collapsed Hyatt Regency Hotel in Kansas City. (Associated Press file photo. With permission.)

Investigators literally followed the flies into the rubble and were able to locate some bodies this way. Female blow flies and other insects lay their eggs in decaying flesh. Different insects do this at different times. Other insects such as beetles and wasps will attack and feed off the insects and the eggs. Depending upon temperature and other environmental factors, this parade of visitors takes place at surprisingly consistent time intervals. By inspecting the corpse, forensic entomologists can give a pretty good estimate of the time since death whether the body has been there for many hours or several days.

In addition to the postmortem interval, there is other information that can be gained from studying insects feeding on a corpse. If a person has been poisoned, the flies and other insects will ingest some of the poison. A toxicologist can capture some of these critters, chop them up, and extract the poison and identify it. There are also cases where a person took cocaine and then died. Some of the maggots became abnormally large in size owing to their ingestion of the cocaine. Forensic entomology is covered in detail in Chapter 15.

Behavioral Forensic Sciences

Forensic psychiatry and psychology have been long contributors to the forensic sciences. As long as there has been crime, people have wrestled with the concept of responsibility. Our laws and those of most other countries have long had provisions for how people are treated who commit crimes and have diminished capacity. If a person is truly insane, can she be held responsible for committing a crime? Although the definitions vary as to what constitutes responsibility, insanity, etc., it falls to forensic psychiatrists and psychologists to examine defendants and render expert opinions to courts. There are real differences between psychiatrists and psychologists. Psychiatry is a medical specialty attained by medical doctors. Psychology is a behavioral science that does not involve medical training. Both have a role to play in determining responsibility for committing crimes.

Forensic psychologists play other roles in the criminal justice system. Some crime investigations include a component of psychological crime reconstruction.

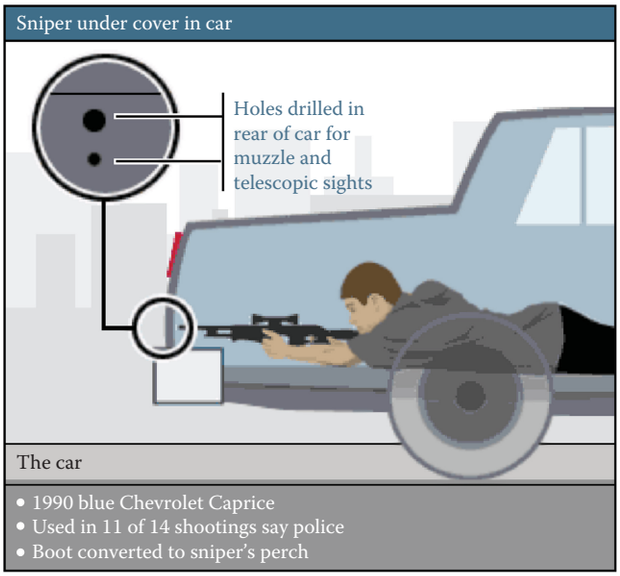

Figure 1.2 A drawing of a car outfitted so that a sniper can fire a weapon out of the back without being detected. This is similar to the setup used by the DC snipers.

Serial killers and others who commit multiple crimes develop habits and traits that show up time after time as they commit crimes. Discovering and understanding these patterns can help lead investigators to the right suspect. Specially trained forensic psychologists can examine a series of crime scenes and develop some theories about the type of person who committed the crimes. It must be noted that this is much more art than science and can be fraught with uncertainties. A case in point is the Washington, DC, snipers case of October 2002. Forensic psychologists and criminal investigators initially determined that the killer was a young, white male. As it turned out, the killers were two black males. Such attempts to determine a profile of a serial killer can be very difficult even if there are many incidents to draw upon for data. Figure 1.2 is a drawing of the car that the killers used when killing their victims.

Psychological profiling has also been used in other criminal and civil areas. For example, the Transportation Security Administration (TSA) uses forensic psychologists to create profiles of what a likely airplane hijacker might look like or behave like so security checkpoint officials can subject people who meet the profile to additional screening. This has been going on for many years in one form or another. The Department of Homeland Security has a similar program for border guards to help spot potential terrorists.

There are other types of behavioral forensic scientists. Some study interrogation and investigation techniques such as polygraph instruments to determine their accuracy and usefulness in criminal and civil investigations. Others do research in developing new areas of interrogation and deception detection.

Digital Evidence

This area is sometimes called digital forensics as well as by other descriptors. Computers and other electronic devices such as cell phones have become very important in crime today, both as instruments of crime and in helping to solve crime. Many criminals and criminal enterprises conduct much of their business and keep

their business records on computers. Sometimes, these records are highly encrypted. When caught, criminals often try to erase or physically destroy the data to avoid it being used against them. Computer forensic scientists and engineers study ways to recover data even from smashed hard disk drives. They also learn how to handle a computer found at a crime scene, especially one that is turned on. Computers are also used to steal identities from people as well as merchandize from companies. They can be used to disrupt entire networks and hack into otherwise secure, private websites. Computers can also be used to help solve crimes. They can track people, store incriminating data that can be used against criminals, and help test and improve computer security. Digital forensics is one of the fastest growing areas of forensic science and will continue to grow in the future. Digital evidence is covered in more detail in Chapter 8.

History and Development of Forensic Science

When did people actually start doing forensic science? When was science first applied to answering questions about crimes or civil issues? Some baby boomers remember the *Quincy* TV show as the first time they saw forensic science in action. Twenty- and thirty-somethings think of the OJ Simpson case as the beginning of the use of science to solve real crimes. Today, many people think of *CSI* as the birth of forensic science. In reality, some aspects of forensic science have been at least recognized for centuries. An excellent outline of the history of forensic science in the form of a timeline has been published by Norah Rudin and Keith Inman and can be found on the web at http://www.forensicdna.com/Timeline020702.pdf. This organizes the history of forensic science by time. The earliest milestones in all areas are covered first and then gradually brought up to date. In this chapter, data from the timeline referenced earlier will be used to illustrate the history of forensic science highlighting three important examples: fingerprints, crime laboratories, and blood analysis.

As in many other fields of knowledge, the Chinese were the first to discover the value of forensic science in identification. They were the first to use fingerprints to identify the owner of objects such as pottery, but, of course, had no formal classification process. In later centuries, a number of scientists, such as Marcello Malphighi, noted the presence of fingerprints and that they had interesting characteristics, but did not make any connection to personal identification. The first person to recognize that fingerprints could be classified into types (nine major kinds) was John Purkinji, a professor of anatomy. In 1880, a Scottish physician, Henry Faulds published an article in the journal *Nature* that suggested that the uniqueness of fingerprints could be used to identify someone. This was quickly followed in the 1890s by Frances Galton, who published the first book on fingerprints, Juan Vucetich, who developed a fingerprint classification system that is still used today in South America and Sir Edward Henry, who developed the fingerprint classification system that has been adopted in the United States and Europe.

The development of a forensic science infrastructure including crime labs is much more recent but quite interesting. For example, the first detective force was developed in France, *The Sûreté of Paris* in 1810 by Eugene Vidocq. In 1905, President Teddy Roosevelt established the Federal Bureau of Investigation (FBI), but the FBI lab was not established until 1932. The first crime laboratory was established in France in 1910 by Edmund Locard, a professor of forensic medicine. He later espoused his famous *Locard Exchange Principle*, which will be discussed in Chapter 3.

In the United States, the first crime laboratory was established by August Vollmer, chief of police in Los Angeles. The first journal devoted to forensic science was begun by Calvin Goddard and his staff in 1930 at the newly formed Scientific Crime Detection Laboratory on the campus of Northwestern University. The journal was called *American Journal of Police Science*. It was later changed to the *Journal of Criminal Law, Criminology and Police Science*. In 1937, Paul Kirk established the first university-based forensic science program at the University of California at Berkeley. It was called *Technical Criminology*. Dr. Kirk is generally considered to be the father of modern forensic science in the United States. In 1950, the American Academy of Forensic Science was founded in Chicago. The American Academy of Forensic Sciences (AAFS) is the largest forensic science society in the world and has members from many different countries. The Academy began publication of the *Journal of Forensic Sciences*, the professional journal of forensic science, shortly after AAFS was founded.

The realization that blood and body fluids had the potential for being important evidence in criminal investigation is an old idea. Bloody palm prints were used as evidence more than 1000 years ago in Rome. In 1853, Ludwig Teichmann developed the first of a number of crystalline tests still used today in the characterization of blood. His test detected the presence of hemoglobin. The German scientist, Schőnbein, developed the first presumptive test for blood. It takes advantage of the ability of hydrogen peroxide to react with hemoglobin. This was in 1863. In 1900, Karl Landsteiner made the major breakthroughs in the analysis of blood when he determined that there are actually four types of human blood. This became the basis for the ABO blood typing system and set the stage for all further work in serology. Landsteiner won the Nobel Prize for his work in 1930. Max Richter took Landsteiner's results and adapted them to blood stains, such as those found in crime scenes. Fifteen years later, Leone Lattes, a professor in Italy, developed a test to determine blood type in the ABO system and wrote a book about how to type dried stains. There were a number of advances over the next 30 years, culminating in the work of Sir Alec Jeffries of the University of Leicester. In 1984, Jeffries used a technique called *DNA Fingerprinting* to solve a double murder case in England, the first case solved by DNA analysis. The year before, Kary Mullis developed the *polymerase chain reaction* (PCR), which is the basis for all DNA typing in forensic cases today. He also won the Nobel Prize for his work.

What Is a Forensic Scientist?

Since practically any science can be a forensic science at times, many scientists can be forensic scientists. It is partially a matter of what they do in their jobs but also a matter of training and education. Forensic pathologists, for example, are educated as physicians and then trained as pathologists. After that, they can get specialized training in the forensic aspects of pathology and become certified as a forensic pathologist. This assures that they will have the proper education, training, and licensure to practice their pathology on medicolegal cases. There is, however, a critical shortage of certified forensic pathologists in the United States and many medicolegal autopsies are performed by pathologists who have no forensic training. Are they forensic pathologists by virtue of their performing forensic autopsies? Most pathologists would agree that they are not. The situation is somewhat different for forensic anthropologists, odontologists, and entomologists. There are a few forensic

anthropology degrees but essentially none in odontology or entomology. There are certifications for all three that result in a designation as forensic anthropologist, odontologist, or entomologist. The fact is, however, that most of what would be considered forensic cases in these areas are performed by noncertified but professional scientists. With increased attention being paid to these forensic sciences, questions of who should be performing forensic analysis becomes more important.

The majority of forensic scientists work in crime laboratories on the local, state, or national level. Most forensic science laboratories are associated with law enforcement agencies; for example, Detroit Police Department Crime Lab, Indiana State Police Forensic Lab, FBI Lab. Although early in their history most of these laboratories were staffed by enlisted officers, special agents, and the like, today, increasing numbers are civilians and have no police duties. One of the reasons for this is that, as forensic science has become more sophisticated and rigorous, it has been harder to find scientifically trained police officers. The other reason for this is that police departments want to put more officers on the street and are transferring analysts out of the lab to law enforcement duty.

In a crime laboratory, forensic scientists have two major duties; to analyze evidence and to testify in court. Forensic science laboratories behave in a reactive role. When a crime is committed, the crime scene unit collects the evidence and turns it over to the police investigators (sometimes detectives) who then bring it to the crime lab. In some cases, the crime scene investigation unit may turn it directly over to the lab. The lab scientists then analyze the evidence. They generally do not have much input into what evidence is collected, although there may be occasions where a forensic scientist asks the police to collect additional items of evidence for comparison or further analysis. In recent years, there has been an increasing trend toward having forensic scientists attend at least some crime scenes. For example, the Michigan State Police Forensic Science Division forms teams of forensic scientists that are called upon to help process serious crime scenes such as those in which there is a dead body. These scientists work along with the police CSI team to help process the scene and collect evidence.

The other major duty of forensic scientists is to testify in court. In the U.S. criminal justice system, there are basically two types of witnesses that testify in court, lay and expert witnesses. A lay witness is someone who is not an expert but has something to contribute to help the judge or jury determine the guilt or innocence of the accused. This person may have been an eyewitness to a crime, a victim or someone who knows something about the suspect or the crime. Such witnesses are supposed to testify only to what they have perceived with their five senses; touch, taste, smell, sight, or hearing. They are not to give their opinions. It is the jury's job to make conclusions about the evidence presented to them, not the witness. For example, if a witness offers testimony that the driver of a car involved in a traffic accident was drunk, that conclusion would not be permitted in court. Being "drunk" in the motor vehicle code sense requires an expert finding of sufficient alcohol in the driver's body exceeding the legal limit.

The other type of witness in a court is an *expert witness*. This is a person who has knowledge and/or skills, derived from education and/or experience, that qualifies him or her to take a set of facts and reach conclusions not attainable by the average person (the judge or jury). Most people think of experts as being PhD scientists or doctors and although many of them are, other experts may derive their expertise from experience rather than formal education. For example, suppose that a man is driving down a mountainous road when his car's brakes fail. He crashes his car and dies. The police investigator would want to know why the brakes failed. Were they old and in

need of repair? Were they installed improperly by a mechanic? Were they tampered with so that they would fail purposefully? Each of these explanations would call for a different response by the justice system. If someone were put on trial for killing the driver, it would not be prudent to have the jury go to the garage where the wrecked car was stored and have the jurors inspect the brakes to see what caused them to fail. Most jurors would not have the knowledge to inspect the brakes (the facts) and draw conclusions (the opinions) about how they failed. An expert brake mechanic should be called upon to inspect the brakes and determine the cause of their failure. This individual can give testimony as an expert about the failure of the brakes.

Whether a trial is by jury or judge, it is the judge's responsibility to decide if expert testimony is needed and who is qualified to offer it. Even if a forensic scientist has testified hundreds of times, he or she must be requalified as an expert for every trial. It is important that the expert explain complex scientific or technical principles in a language that a jury can understand. Forensic scientists must be equally competent in the trial part and the scientific part of their jobs. The legal aspects of forensic science are covered in more detail in Chapter 24.

So You Want to be a Forensic Scientist

So now you know what forensic scientists do and where they work, but what does it take to be one? This depends upon what type of forensic scientist you want to be and what type of work you want to do. Becoming a forensic scientist requires both education and training. We shall discuss a few of the more common areas of forensic study. Table 1.1 is a chart that summarizes selected forensic science careers, optimal education, and job markets.

Crime laboratory forensic scientist—The entry-level requirements for forensic scientists who work in the traditional areas of forensic science in a forensic science laboratory vary with the particular discipline. Forensic chemists analyze chemical evidence such as drugs, fibers, paints, explosives, fire residues, etc. They would be expected to have a strong background in chemistry and related sciences as well as microscopy. Forensic biologists are responsible for the analysis of blood, other body fluids and, particularly, DNA. They should have a strong background in the biological sciences including molecular biology, genetics, and population statistics, as well as chemistry and biochemistry. For those forensic scientists who analyze pattern evidence such as fingerprints, firearms, and tool marks and questioned documents, educational requirements are somewhat less specific. Methods of analysis of these types of evidence have evolved over the years to include chemical, microscopic, and even biological tests, and it is advisable that those who specialize in pattern evidence have some background in the natural and physical sciences and statistics.

Until the middle of the twentieth century, most people who would work in the natural or physical science areas of a forensic science laboratory pursued a bachelors of science degree in one of the chemical or biological sciences. Starting in the 1940s, some institutions began to offer forensic science classes of a general nature that students could take as electives. Later, some classes in specific areas such as questioned documents or firearms began to show up. Then, a few universities began to offer entire degrees in forensic science. These started as largely criminal justice programs with science, forensic science, and law classes included. Often, an internship in a forensic science laboratory was also available. As the twentieth century wore on, forensic science became ever more popular, fueled by the rise of movies, books, and TV shows that glamorized the field. Many universities and colleges offered forensic science degrees that ranged from very rigorous curricula

TABLE 1.1
Types of Careers and Best Educational Preparation for Various Areas of Forensic Science

Career	Job Description	Optimal Education	Job Market
Crime lab forensic scientist	Analyze scientific evidence Testify in court	At least a BS degree in science MS degree preferred	Robust but spotty More than 1900 new forensic scientist needed
Forensic pathologist	Determine cause and manner of death in suspicious or unattended deaths	BS or BA degree +4 year-medical school degree + 3–4-year residency in pathology + 1–2-year residency in forensic pathology	Excellent. There is a nationwide, critical
Forensic anthropologist	Excavate crime scenes and analyze skeletal remains	PhD in physical or forensic anthropology	Most forensic anthropologists teach at colleges and do forensic anthropology on the side. Job market is small
Forensic odontologist	Analyze bite marks, facial injuries, and identify human remains from dental work	BS or BA degree +4 years of dental school. No residencies in forensic dentistry	Few people make a living strictly on forensic dentistry. Most have conventional dental practices and do forensic work on the side. Job market is small
Forensic engineer	Reconstruct vehicle accidents, structural failure analysis, explosion analysis, electrical systems	PhD in engineering, lots of experience	Most forensic engineers are in private practice. Need for experienced engineers is pretty large
Computer forensic scientist	Determine role of computers in crime Reconstruct media devices and computers Track down criminals who hack into sites and steal identities	Experience is most important consideration. Bachelor's degree in relevant field is desirable	Some are in private practice. Many work for colleges as teachers/researchers and do forensic work on the side

dominated by chemistry, biology, and math coursework, to those that were little more than criminal justice with an internship thrown in. Presently, there are more than 100 forensic science degree programs in the United States and more than 300 in the United Kingdom! This situation put a great burden on students who wanted to become forensic scientists and their academic advisors. With all of these forensic science degrees, how is one to decide which ones are rigorous and relevant enough to arm one with the credentials needed to work in a forensic science laboratory?

In the early part of the twenty-first century, the AAFS and the American Society of Crime Laboratory Directors (ASCLD) teamed up to create an accreditation process whereby colleges and universities could qualify for accredited status for their forensic science programs. The process started with the creation of a Technical Working Group on Forensic Science Education (TWGED), made up of more than 40 scientists and practitioners. They developed a set of curricular mandates and requirements that must be met for a program to be accredited. This, in turn, led to the formation of a Forensic Science Education Accreditation Commission (FEPAC), which contained five forensic science educators, five ASCLD members, and one public member. They took the recommendations from TWGED and created an accreditation process for BS and MS degrees in forensic science. To become accredited by FEPAC, a forensic science degree program must meet rigorous curricular, infrastructure and staffing requirements. Emphasis is placed on courses in the natural, biological, physical and mathematical sciences, forensic science, law, and criminal justice. Internships or other similar experiences are required. At the graduate level, a research experience is also required. Currently, approximately 30 BS and MS degree programs are accredited. A student who attends one of these programs is assured of a rigorous, science-based degree that will qualify them for employment in virtually every forensic science laboratory in the United States.

Information about FEPAC and its accreditation program as well as the educational requirements for accreditation and a current list of accredited degree programs can be found at the website of the AAFS; www.aafs.org.

- *Forensic pathologist*: To become a forensic pathologist, you first need to graduate from college with an excellent academic record. Then, you must graduate from medical school, requiring another 4 years. After medical school, you complete a residency in pathology that takes an additional 4 years. Finally, an additional residency in forensic pathology is recommended in order to become certified. This takes another year to complete.
- *Forensic anthropologist*: Few crime labs can afford to hire a forensic anthropologist full time. If you have another area of specialization such as trace evidence or DNA typing, you could get hired by a crime lab and then do anthropology cases as they come up. Another way of getting into the field is to obtain a PhD in physical or forensic anthropology and teach and do research at a university and then local crime labs would come to you for your services as needed.
- *Forensic odontologist*: This is similar to the route for a forensic pathologist except that you would complete dental school instead of medical school. There are few (if any) residencies in forensic odontology; therefore, you would have to work with police departments on an as-needed basis.
- *Forensic engineer*: This career requires education in engineering and the more the better. Usually, PhDs are in demand for forensic engineering. Most forensic engineers have their own private companies that are hired by prosecutors or defendants.

- *Computer forensic scientist*: There are few education programs that turn out computer forensic scientists. People who work in this area invariably have a strong interest and educational background in computer science and engineering. Their designation as computer forensic scientists arises from the types of cases that they work on or the type of research and teaching that they do.
- *Related careers*: Not everyone wants to be a forensic scientist in a laboratory. Some people decide that they want to work in a career that makes use of their strong science background and perhaps a forensic science education. There are a large number of related careers that one could consider. If you decide to be a lawyer, a science background can be very handy in the field of patent law. Many patents require practice and skill in reading and digesting sometimes complicated journal articles and books. These particular skills are highly developed in a science education. Environmental forensic science is becoming a major area of environmental science. Scientists work for environmental analytical laboratories determining pollution levels in air, water, and soil and can help companies comply with environmental laws or, conversely, help government agencies track down and prosecute polluters. The pharmaceutical industry is very interested in people with a strong analytical chemistry background. Many forensic science educational programs teach the chemistry and analysis of illicit drugs; information that can be valuable in a career in pharmaceutical chemistry. The insurance industry is also interested in employing scientists including those with a forensic science background. They do investigations of fires, explosions, traffic accidents, stolen automobiles, and other property incidents to help determine if a crime was committed or a covered loss occurred.

For More Information on Careers in Forensic Science

The websites of any of the federal agencies listed in the section on the organization of Federal forensic science labs will provide information about how one joins that organization as a forensic scientist. In addition, one can check the website of the state or local law enforcement agency where crime labs are housed for information about obtaining employment.

General job and career information in forensic science can be found at the AAFS; www.aafs.org. The Academy is the major national organization for forensic scientists. There is a section on their website with job openings in the field. They also have written information on careers in forensic science.

Information about careers in particular areas of forensic science can be found on the websites of their association or society. A few of the more common ones are

- AAFS: www.aafs.org
- National Association of Medical Examiners: www.thename.org/
- Society of Forensic Toxicologists: www.soft-tox.org/
- American Society of Questioned Document Examiners: www.asqde.org/
- American Board of Forensic Anthropology: www.csuchico.edu/anth/ABFA/
- Forensic Entomology: www.forensic-entomology.com/
- Association of Firearm and Tool Mark Examiners: www.afte.org/index_forum.php
- American Society of Forensic Odontology: www.forensicdentistryonline.org/new_asfo/newasfo.htm