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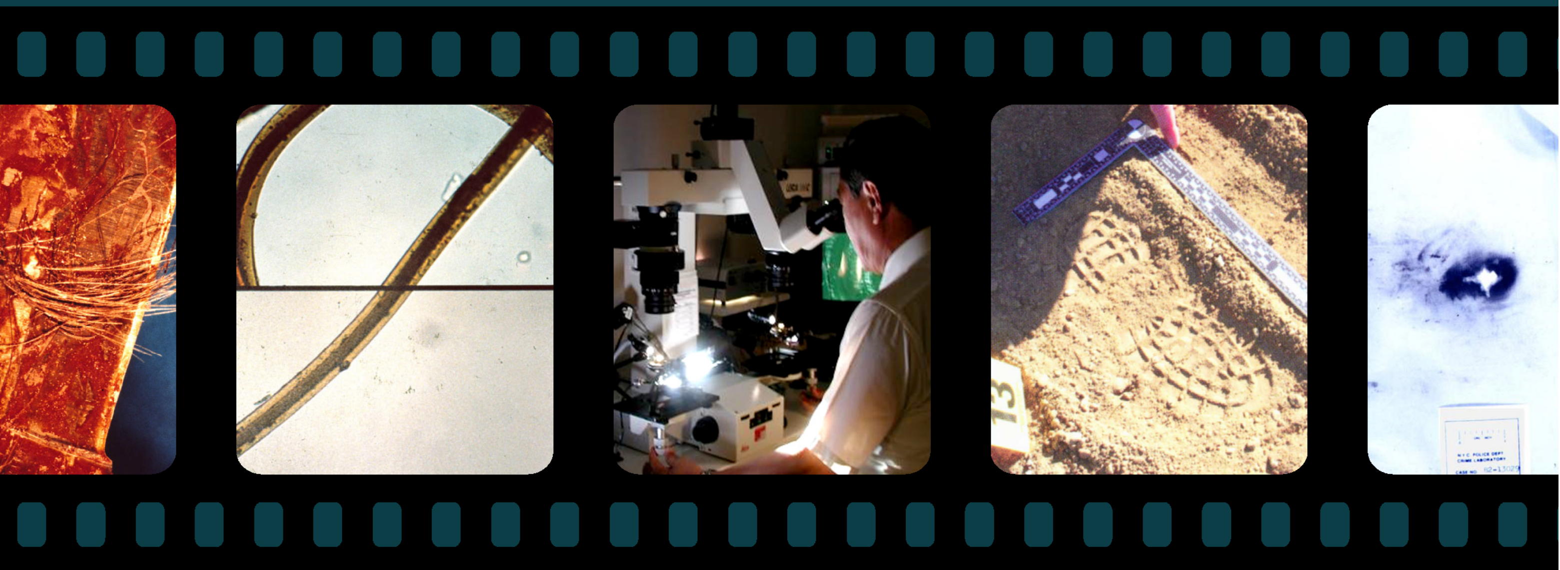

Introduction to Forensic Science and Criminalistics

Howard A. Harris
Henry C. Lee

CRC Press
Taylor & Francis Group

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Dedication

In Memory of Margaret Lee

This book is dedicated to Margaret, wife of Dr. Henry Lee. Her devotion, dedication, love, and kindness will be remembered forever by the authors and by her many friends around the globe.

This book is also dedicated to all the highly committed professionals who labor in forensic science and law enforcement throughout the world.

Contents

Preface to Second Edition

In this second edition, we have tried to update the material to include many of the improvements in the rapidly growing field of forensic science. Forensic science has become something of a household word in the past decade or so. Forensic DNA analysis, perhaps the most important development in forensic science ever, regularly makes the news. This trend probably began with cable television's interest in covering high-profile criminal cases and the O.J. Simpson trial, in particular. In recent years, network television has featured prime-time programming that has forensic science as its focus; the *CSI, Trace Evidence,* and *Law and Order* series are no doubt the most widely recognized.

The mass exposure to forensic science through media creates a danger of incorrect or misleading impressions and information through sensationalism and "artistic license." Under these circumstances, there is a need to provide good, reliable sources of information on the subject. Many college and university students, throughout the country and the world, take introductory forensic science courses. The majority of students want to learn something about the subject, and, perhaps, how investigators, police, and attorneys make use of the information forensic science can provide, even if they themselves do not intend to become forensic scientists. There has never been a forensic science textbook directly aimed at these students, who as citizens will be our future jurors, police officers, investigators, lawyers, and judges. This is that book. It has a structure reflecting the underlying philosophy that forensic science is a science and profession. Appropriate pedagogic features have been incorporated to aid the student in learning, and the authors have vast and varied experience as forensic scientists and teachers.

The book was written for students to use in an undergraduate college or university course for forensic science majors just starting out in their studies, and as an elective for criminal justice majors and others interested in our justice system who will also find it a valuable body of knowledge. It comfortably fits into a one-semester schedule and is an introduction to what is often called "criminalistics." Think of criminalistics as comprising the activities and specialty areas found in a modern, full-service forensic science laboratory.

ORGANIZATION

The whole book is organized along the lines of the criminalistics concepts of identification, individualization, and reconstruction. After introductory material and orientation to the subject, we move from crime scene investigation, reconstruction, and pattern analysis to categories of evidence for which individualization is the goal. Finally, types of evidence having identification and comparison as the primary goal of laboratory analysis are addressed.

The book begins by establishing the subject order and organization, moving on to crime scene analysis and reconstruction patterns. Generally, the book moves on to various forms of pattern evidence, then covers biological evidence analysis and forensic DNA typing. Although biological evidence fits into the category of "evidence for individualization," the subject has become so important that it warrants separate treatment. A chapter new to this edition is the digital forensics chapter. Digital evidence has become a vital tool in numerous cases these days. The book closes with identification, comparison, and sometimes quantitative analysis of chemical and trace evidence, and the vital role that laboratories are required to play.

The chapters on particular types of evidence (such as blood, drugs, etc.) all have a consistent internal organization. The subject matter and background are introduced and explained, strategies and methods for collecting and packaging that type of evidence are enumerated and explained, the forensic methods used for examination and comparison are described, and finally the results that can be expected are explained and the strengths and limitations of the tests are discussed.

FOR THE INSTRUCTOR

An Instructor's Guide with Chapter PowerPoint™ slide presentations, additional readings, and a test question bank, are available online for professors and instructors (www.crcpress.com/9781498757966).

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Raymond J. Hsieh
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California, Pennsylvania

We also thank the colleagues at the Connecticut Forensic Science Laboratory, Connecticut State Police, and the University of New Haven.

About the Book and Pedagogy

Even though the book was written for students who have a limited science or chemistry background, some basic concepts in scientific measurement and methods are necessary to fully understand all the material. Understanding the basic concepts will help students understand the science underpinning forensic science. To aid with this, Scientific Sidebars have been included. The authors collectively have spent over 80 years practicing and teaching forensic science, and we do hope that the book conveys some of the sense of excitement and commitment that we still feel about forensic science!

Each chapter contains the following features.

Learning Objectives: Learning objectives provide students with the chapter learning goals and key knowledge points they should understand upon reading the chapter.

A Lead Case: A Lead case is presented at the beginning of each chapter to offer a real-world forensic case, from both the author's collective experience, as well as famous cases that point out unique aspects of the evidence that helped solve a crime or convict a perpetrator. Each case contains many of the topics covered in the chapter, so that the student can experience how concepts apply to real-world forensic investigation.

Case Study Boxes: Case Study boxes provide brief case descriptions occurring throughout each chapter to illustrate specific points and identify the potential utility of the evidence.

Each chapter contains Science Sidebar boxes, which take the students further into the methods and techniques that are mentioned in the text.

Photographs and Figures: Each chapter is fully illustrated with photographs, diagrams, and figures—many from the case files of the authors. Students can actually see how to dust for fingerprints and understand what the different types of bloodstain patterns look like.

End of Chapter Elements: Each chapter closes with a list of key terms, review questions, and further references.

Authors

Dr. Howard A. Harris is currently a professor emeritus at the University of New Haven, where he teaches and conducts research. From the fall 1996 until the fall of 2003, he was director of the Forensic Science Program. He was promoted to full professor in 2006 and awarded the rank of professor emeritus in 2015. He received his bachelor's degree in chemistry from Western Reserve University, his master's degree and PhD, both in chemistry, from Yale University, and holds a J.D. from St. Louis University. He was admitted to and has maintained his membership in the Missouri Bar. Dr. Harris was a research chemist for seven years for the Shell Oil Company before entering the forensic field as director of the New York City Police Department Police Laboratory in January of 1974. He held that position for just under twelve years. During that time, he was active in the field both locally and nationally. He was one of the founding members of the Northeastern Association of Forensic Scientists. He held offices in the American Society of Crime Laboratory Directors (ASCLD) culminating in the presidency. He was active in the American Academy of Forensic Sciences (AAFS), having presented many papers and an invited Plenary Lecture, and was elected a fellow. In addition to his scientific activities, he was also active in the Business of Criminalistics section of the AAFS and held a number of positions culminating in the section chairmanship. He was awarded the Mary Cowan Award for distinguished service to the Criminalistics Section in 1997.

Dr. Henry C. Lee is an internationally revered forensic scientist and investigator. He began his law enforcement career in Taiwan. After graduating from the Taiwan Central Police College, he joined the Taipei Police Department and quickly reached the rank of police captain. After coming to the United States, he earned a second bachelor's degree from John Jay College in New York City and a PhD in biochemistry from New York University. He has been a professor at the University of New Haven for 44 years and is largely responsible for building the forensic science academic program there. In 1978, Dr. Lee was appointed the forensic laboratory director and chief criminalist for the State of Connecticut, a position he held for 20 years. He served for two terms as commissioner of Connecticut State Police and Department of Public Safety of the State of Connecticut. Prior to retiring from government, he served as chief emeritus for the Division of Scientific Services. He is now a distinguished chair professor and founder of the Henry C. Lee Institute of Forensic Sciences at the University of New Haven.

Dr. Lee is an internationally recognized authority in forensic science and has played a prominent role in many of the most challenging cases of the last 58 years. Dr. Lee has worked with law enforcement agencies from 47 countries and has helped to solve more than 8000 cases. In recent years, his lectures and consultations have taken him to England, Bosnia, China, Germany, Singapore, Croatia, Brunei, Thailand, the Middle East, South America, Africa, and other locations around the world. Dr. Lee's testimony figured prominently in the O. J. Simpson, Jason Williams, Peterson, and Kennedy Smith trials and in convictions of the "Woodchipper" murderer, as well as thousands of other murder cases. Dr. Lee has assisted local and state police in their investigations of other famous crimes, such as the murder of Jon Benet Ramsey in Boulder, Colorado, the 1993 suicide of White House Counsel Vincent Foster, the kidnapping of Elizabeth Smart, the death of Chandra Levy, and the reinvestigation of the Kennedy assassination.

Dr. Lee has testified at thousands of trials in his career and is a frequent guest on television shows around the global. His TV series of *Trace Evidence—Dr. Henry Lee File* was well received. He has written hundreds of scientific papers and author/co-authored 40 books on forensic science and criminal investigation. In addition, he has 30 honorary doctoral degrees and has lectured widely for colleges, universities, and criminal justice and law enforcement organizations. He has also received numerous awards, medals, and honors from professional organizations and law enforcement agencies, as well as from government agencies worldwide.

Contributors

Raymond J. Hsieh is a full professor in Cyber Forensics/Forensic Science at California University of Pennsylvania; Dr. Hsieh earned his PhD in communication technology from the School of Informatics, at the State University of New York at Buffalo. His undergraduate major was forensic science from the Central Police University, Taiwan, and his graduate study was information technology from the Rochester Institute of Technology. Dr. Hsieh's research focuses on Big Data Analysis and Digital Multimedia Evidence. In addition to scholarly essays and book chapters, he has written *Cognitive Mapping & Comparison* (VDM Verlag, 2009). —*An Example* of *Online Legal Polices*, and *Intelligence and Security Informatics*. Dr. Hsieh is certified as a computer forensic examiner.

Richard Li earned his MS in forensic science from the University of New Haven and his PhD in molecular biology from the University of Wisconsin-Madison. After completing his PhD, Dr. Li was awarded a postdoctoral fellowship at Weill Medical College of Cornell University and subsequently worked as a research faculty member at the School of Medicine at Yale University. Dr. Li has served as a criminalist in the Department of Forensic Biology, the Office of Chief Medical Examiner of New York City. For the past decade, he has held faculty positions in forensic science programs at several universities before joining John Jay College. Dr. Li is an associate professor of forensic biology at John Jay College of Criminal Justice. Additionally, he serves as a faculty member for the PhD Program in forensic science for the College. Dr. Li's current research interests include the identification and analysis of biological specimens that are potentially useful for forensic investigations.

Elaine Pagliaro is a member of the Henry Lee Institute of Forensic Science and an adjunct faculty member at several colleges and universities, where she teaches science, forensic science, and law. Her educational background is in biology and chemistry (BA, University of St. Joseph), forensic science (MS, University of New Haven) and law (JD, Quinnipiac University). She was admitted to the bar in Connecticut and New Hampshire, where she maintains membership. Ms. Pagliaro had a 27-year career at the Connecticut Forensic Science Laboratory where she worked in criminalistics and forensic biology and was assistant director and director. She has been active in the Northeastern Association of Forensic Scientists, where she was president and was awarded a Life Membership. She has publications in forensic journals and is co-author of two books. During her time at the Forensic Laboratory, Ms. Pagliaro was involved in major forensic investigations in Connecticut and in cases of national prominence.

Chapter 1

Introduction

Lead Case: State v. Richard Crafts

This case is popularly known as the "Wood Chipper Case." In November of 1986, a flight attendant for Pan American World Airways named Helle Crafts returned to New York's John F. Kennedy International Airport from a routine international flight. She and another flight attendant, both of whom lived in Newtown, Connecticut, and were friends, took a limousine to their homes. The limousine dropped Mrs. Crafts off at her home, and there she and her flight attendant friend agreed to call one another later. Helle Crafts was never seen or heard from again.

Later, after the limousine ride and into early December, the flight attendant friend continued trying to contact Helle without success. Independent of this, a private investigator named Oliver Mayo, who had been hired by Mrs. Crafts to investigate possible extramarital activities of her husband, Richard, was also trying to find Helle. Mr. Mayo had gathered unequivocal, incriminating evidence against Richard of an extramarital affair. He wanted to inform his client, Mrs. Crafts, and collect his fee.

The local police did not show much interest in the case, after Helle's colleague's initial inquiries, stating that Mrs. Crafts was an adult, she hadn't been missing that long, and that she would probably turn up. Ultimately, the state's attorney's office was contacted and an investigation by the state police was initiated.

Richard Crafts was a pilot for Eastern Airlines and flew a regular New York to Miami run. He was also a part-time officer in the local police department. The couple had three children, and, because they were in the airline industry and needed to travel so much, they had a live-in nanny.

The investigation by the state police showed that the morning after Helle returned from the international trip, Richard had risen early and told the nanny to take the children to their grandparents' home. Further investigation revealed that he had rented a large, diesel powered wood chipper from a dealership a week earlier. This large model wood chipper was one of only two in the state, and the only one in the southwestern area of Connecticut. The agent at the dealership remembered Richard because he had come to rent the machine driving a small passenger vehicle. The agent had told him the car was not powerful enough to pull the wood chipper, so Richard had then gone out and rented a U-Haul truck to use to pull the wood chipper. The agent also remembered that the wood chipper had been returned in the cleanest condition that he could ever remember. Richard did own a wooded lot in Newtown. It was not, therefore, illogical for him to go and rent the chipper, except that all this activity was taking place during a major snowstorm in that part of the state. The storm had most people off the roads and at home, and many institutions were temporarily closed. A state highway snow plow driver reported seeing a U-Haul truck towing a large wood chipper headed toward Lake Zoar, a man-made lake (reservoir)—but he could not see who was driving. This activity took place the next night after Helle Crafts had returned home and gone missing.

The state police were very suspicious that Helle might have met with foul play, and that Richard might be involved, but the evidence was very sketchy. Thinking the wood chipper might somehow be involved, an extensive search of the area along Lake Zoar was conducted. Thinking the worst—that maybe Helle had been killed and the wood chipper used to dispose of her remains—the state police, with the help of criminalists from the forensic laboratory and a forensic odontologist, searched for skeletal or other remains. It was winter, and heavy snow covered the leaves that had fallen to the ground. The investigators and forensic scientists melted away the snow inch-by-inch as they searched. The leaves and debris had to be separated from things underneath them. Large quantities of leaves, debris, and anything else on the ground were placed in oil drums filled with water to float off the leaves and light plant material. The water was then emptied through narrow mesh sieves to capture any small items that might have been present on the ground.

After some days of searching, the forensic investigation team recovered:

- A human tooth
- A dental restoration
- 56 small pieces of bone and 2660 strands of human hair
- A portion of a human finger with some friction ridge skin
- A toenail painted with red nail polish

Now convinced they were handling a probable homicide case, the state police and the forensic laboratory set about to assemble a forensic team to try and establish what had happened.

A state police dive team's search in the waters of Lake Zoar resulted in the recovery of a gasoline powered chain saw. It was not very old, and its fuel tank was still half full. However, the serial number had been filed down to prevent ready identification. Serial number restoration in the laboratory revealed "E59266." Company records showed that this chain saw had been purchased by Richard Crafts a few years previous. He had used a Visa card, and the purchase record was still available. There was no question that Richard had rented the U-Haul truck and the wood chipper. Both were extensively searched for evidence. Wood chips were recovered from the back end of the U-Haul truck. The chain saw blade was carefully examined, and yielded bits of blood, tissue, fragments of head hair, and some bluish-green fibers. There was blood on some of the fibers.

The forensic issues in the case can be summarized with the following questions:

- Were the skeletal remains recovered those of Helle Crafts?
    - Could a cause and manner of death be established? Was this a homicidal death?
    - If the remains are of Helle Crafts, and if the death is homicidal, could Richard be implicated?

The forensic aspects of the investigation of this case involved many specialties: pathology, odontology, bone identification (physical anthropology), criminalistics, trace and materials evidence comparisons (such as the nail polish), wood chip comparisons, biological evidence, and comparisons of hair, fiber, toolmarks, and handwriting.

The evidence gathered is shown in Table 1.1, along with the forensic testing used for its examination and the conclusions reached. Note that some of the findings are conclusive but others are circumstantial. The tooth and restoration identity were definite, so the remains recovered on the shoreline were confirmed to be those of Helle Crafts. The pathologist ultimately ruled the death a homicide based in part on the considerable fragmentation of the body; however, there was no way to ascertain a cause of death. The bone chips and wood chips had consistent toolmarks. The wood chipper in the case had a single cutting blade, but it had been discarded before anyone knew it might be useful as evidence. The hairs were consistent with having come from the same person and with hairs from Helle's hair brush, but hair comparison is not a means of positive identification. The defense could and did argue that the hair brush was not a true "known," because its use by someone else could not be rigorously excluded. The nanny, the children, and Richard, were all excluded as sources of the questioned hairs. The fibers were consistent with a nightgown Helle had owned and worn, but no "known" was recovered or available. The polish on the recovered toenail was consistent with fingernail polish Helle owned, but it could not be proven to be the only possible source.

This is one of the most interesting cases from a forensic-science point of view, not only because of the involvement of so many different specialty areas and experts, but also because forensic scientists were directly involved in the crime scene search and in the subsequent investigation.

In 1987, the case came to trial in New London, Connecticut (the defense had asked that the venue be changed because of extensive pre-trial publicity). The trial lasted several months, and there was extensive testimony by forensic experts for

Table 1.1 Evidence table—Wood Chipper case

Item	Examination	Findings/conclusion
Tooth—Lake Zoar shoreline	Odontological and radiological: identified as Helle Crafts by comparison with ante-mortem dental X-rays	Tooth belonged to Helle Crafts
Dental crown—Lake Zoar shoreline	Odontological: identification Criminalistics: trace metal analysis	Identified as belonging to Helle Crafts by the dentist; Trace metals linked to the laboratory that made the crown
Bone chips—Lake Zoar shoreline	Anthropological and biological	human, from the head, hands and feet only; blood type O [*A match to Helle's type*?]
Sum of human remains—Lake Zoar shoreline	Pathology—Medical Examiner: cause and manner of death	Homicidal death based on the recovered bone chips; cause could not be determined
Wood chips—Lake Zoar shoreline	Toolmark: compare with U-Haul wood chips and bone chips Wood identification: link type of wood	Chips consistent with one another (as having been made by the same cutting blade); consistent with having been made by the wood chipper; Linked type of wood to the wood lot (scene)
Wood chips—U-Haul truck bed	Toolmark: compare with Lake Zoar wood chips and bone chips Wood identification: link type of wood	
Hairs—Lake Zoar shoreline	Hair comparison: compare with hairs from chain saw and hair brush	Hairs consistent with one another, and inconsistent with Richard, the nanny, or any of the children
Hairs—chain saw	Hair comparison: compare with hairs from chain saw and hair brush	
Hairs—hair brush from Helle Crafts' dressing table	Hair comparison: compare with hairs from chain saw and Lake Zoar shoreline	
Tissue—chain saw	Biological	human, blood type O, PGM 1-1
Blood—chain saw	Biological	human, blood type O
Blood—medium velocity spatter, from box spring in bedroom	Biological	human, blood type O, and yielded a PGM isoenzyme type 1-1, same as the tissue
Blue-green fibers—chain saw	Fiber analysis: classify and characterize	Consistent with fibers from a nightgown Helle is known to have owned and worn
Chain saw serial number	Restoration: render readable	Traced through manufacturer to a dealer to Richard Crafts
Chain saw credit card receipt	Questioned documents: compared signature with authentic Richard Crafts signature	Signature on credit card receipt was Richard's
Partial finger with friction ridge skin	Fingerprints: compare with known fingerprints of Helle Crafts Biology/Serology and DNA	Consistent with the known prints, but inked knowns lacked detail; Blood type O and female (X chromosome)
Partial toenail with toenail polish	Trace Evidence: Compare nail polish with known nail polished seized from Helle Crafts' dressing table	Chemical composition and color consistent with one another
Yellow paint sample from the U-Haul truck bed	Trace Evidence: instrumental analysis comparison	Similar to yellow paint from the chain saw

both the state and for the defendant. Every finding and conclusion were challenged. The jury finally received the case in early 1988, but after many days of deliberations, one of them refused to deliberate further. The judge declared a mistrial.

The state retried the case in 1989, this time in Norwalk, and that trial was much shorter. Richard was convicted by the second trial jury and sentenced to a long prison term. The conviction was ultimately upheld by the Connecticut Supreme Court.

CHAPTER ONE LEARNING OBJECTIVES

- The nature and role of forensic science
- The value of forensic science to society
- The historical development of forensic science
- Development of forensic science and laboratories in the United States
- Forensic science laboratory operations
- The importance of anthropometry and fingerprint identification to the development of forensic science
- Nature of the scientific method and how it might operate in everyday situations
- The key role that scientific method plays in all aspects of forensic science and investigation
- The main specialty areas of forensic science and the scope of each of them
- Elements of forensic analysis and the types of results forensic science can provide
- The concepts of recognition, classification (identification), individualization, and reconstruction
- Comparisons as a basis of forensic science analysis—inclusions and exclusions
- Professional responsibilities and ethics

WHAT IS FORENSIC SCIENCE AND WHAT IS ITS ROLE IN THE JUSTICE SYSTEM?

The role of forensic science

The role of forensic science in the justice system has changed enormously in the last 30 years. Before then, forensic science results were used primarily in the adjudication of cases and very little in the investigation of incidents. Forensic science generally served to confirm identifications and the nature of well-defined evidence items. However, in the last 30 years this role has greatly expanded. For a variety of reasons, the role of forensic science has greatly expanded in the last several years to be used significantly in both the investigative portion (Figure 1.1) of the of the justice system as well as in the adjudicative function.

Figure 1.1 Forensic science has become an integral part of investigation. (Courtesy of Shutterstock, New York.)

Perhaps the single largest factor in this change has been the development of many computerized databases. This began with the development of useful automated fingerprint identification systems. For many years, people had been using fingerprints to identify individuals and suspects. However, one needed to know to whom a particular fingerprint or set of fingerprints might belong to make an identification. Thus, in the vast majority of latent fingerprint cases—where fingerprints are recovered from a crime scene or other relevant locations—unless one had a suspect or a very limited group of suspects, the fingerprint information might not be useful. Because the number of individuals whose fingerprints were in the hardcopy fingerprint files were so large, it was practically impossible to search for an individual's fingerprints in even a somewhat limited file. In the late 1970s, computer technology improved sufficiently so that several private companies developed search systems. These systems allowed for the searching of fingerprint information recovered from a scene, or taken at the time of arrest, against large computerized databases of people who had provided fingerprints during previous arrests. Although automated fingerprint identification systems were initially private, they fairly quickly became a government sponsored activity. These automated systems developed into extremely reliable and highly useful tools in expanding the ability to make use of both 10-print fingerprint cards and latent fingerprints from crimes. Now, of course, all 50 states have access to automated fingerprint database systems, and they are interconnected through the federal system. Thus, any fingerprint information that comes into the hands of the proper authorities can be searched against, most commonly, criminal databases in the state where they are taken. If not found there, they can then be searched in the federal jurisdiction or, subsequently, in other states if no matches are found.

The success of automated fingerprint identification systems was the first major step in making forensic science much more useful in the investigative aspects of the justice system, both criminal and civil. This use of large databases has now expanded enormously, particularly with the availability of the DNA database named CODIS, which stands for Combined DNA Indexing System. Everyone recognizes that DNA evidence has been a major breakthrough, particularly, in criminal but also in many civil situations. The ability to search a DNA profile against a large database of people who have committed crimes—or against people reported as missing persons listed in variety of other databases—has moved forensic science even further into the investigative area, rather than in just adjudicative. Forensic science-based databases are now expanding in other areas, such as firearms-related databases, as well as a variety of trace evidence-based databases that have become available to the justice system.

As a result of the ever-growing availability of such forensic science-based databases, forensic science is much more commonly looked upon as an ally by police and other investigators. The availability of such databases has allowed prosecution of many both criminal and civil cases that would never have been brought to trial before their availability. With this larger role in both investigation and adjudication, and the ensuing public awareness, understanding of the value of forensic science has grown. This has been very beneficial for forensic science, because it has attracted many young and talented individuals into the field who otherwise probably would not have become forensic scientists.

This increase in public awareness has been something of a double-edged sword. The public now virtually demands the use of forensic science by the adjudicative bodies as well as by investigators. This attention has brought to light certain high-profile failures of the justice system, rare though they may be. Forensic scientists are, of course, human and can make errors or show poor professional ethics. Because of very high expectations and greater scrutiny, the role of the forensic scientist has become more difficult though certainly not unreasonably so.

Definition of forensic science

Let us start with a very simple, working definition of Forensic Science: Forensic Science is science in service of the law. *Forensic* means, "having to do with the law." Science is a way of studying questions about the natural world in a systematic way. We will discuss the "scientific method" in some detail later in the chapter.

The term *forensics* means, "debating," and, in spite of its use in popular media, it is not the same as forensic science. Forensic science is, in fact, an incredibly broad subject that people now use to cover virtually any scientific, and some technical endeavors, which have applications to the law (Figure 1.2).

This book will concentrate, primarily, on forensic science in the service of criminal law, which is science applied to criminal cases. Besides criminal matters; however, there are numerous civil and administrative matters that can sometimes benefit from scientific and technical analyses. More and more forensic scientists are now involved in

Figure 1.2 Forensic science is a significant factor helping to ensure that the justice dispensed by the justice system is true justice. (Courtesy of Shutterstock of New York.)

civil, national security, and other administrative applications. Although most governmental crime laboratories work primarily on criminal cases, there is considerable forensic science effort applied to civil matters, such as product failure liability, disputed paternity resolution, and so on. More "expert witnesses" actually work on civil and administrative matters than on criminal ones. Although this book emphasizes applications to criminal cases, the application of science to other types of legal concerns is largely analogous. We will briefly describe and discuss some of the non-criminalistic specialty areas of forensic science. They are complex enough to require special treatment. There are entire books written on each of them.

The value of forensic science to society

One way of thinking about the "value" of forensic science is to ask: How does it serve the community? Another is to consider whether the benefits exceed the costs. Yet another way of thinking about it is to ask: What are the uses of physical evidence and physical evidence analysis in our legal system? We will discuss a number of these uses shortly.

Most public, forensic science laboratories are supported by municipalities, counties, state governments, or the federal government. Municipal and county labs with a dozen employees can have operating budgets of $1–2 million per year. Large laboratories serving major cities and laboratories serving larger states have multi-million-dollar annual budgets. To put the costs of forensic science in some perspective, it should be understood that such costs are only a miniscule fraction of the total cost of our justice system. For governments to continue to be willing to fund forensic science laboratories, there must be a belief that society significantly benefits from their work.

Looking into the type of information one can get from physical evidence helps clarify its value in investigations and prosecutions.

INFORMATION OBTAINABLE FROM PHYSICAL EVIDENCE

- *Corpus Delicti*—Elements of a crime
- Support or disprove statements by witnesses, victims, or suspects
- Identify substances or materials
- Identify persons
- Provide investigative leads
- Establish linkages or exclusions

The following are the major contributions that forensic laboratories provide to the criminal justice system, some of which are pretty obvious, while others are not.

1. Aid in the Investigation of Incidents of Possible Legal Interest

   A considerable proportion of the work submitted to and done in forensic science laboratories is *post facto*; that is, only after a crime has been committed and after someone has been arrested. Traditionally, laboratory services and findings have not been optimally utilized during the critical investigative period before an arrest. Laboratories are typically overloaded with casework and sometimes severely backlogged, which can prevent prompt analysis. However, physical evidence analysis can help provide investigative leads, or keep an investigation from going down an unproductive path.

2. Help Establish the Basic Legal Elements of a Crime–*Corpus Delicti*

   In law, *corpus delicti* refers to the body or "elements" of the crime. The elements are the things that the prosecutor is obligated to prove "beyond a reasonable doubt" to gain a conviction. Some of the analyses done in forensic laboratories serve primarily to establish elements of a crime. For example, in a possession of an illegal drug case, the laboratory must establish that the white powder seized is cocaine, or that those funny looking cigarettes contain *Cannabis sativa* (marijuana) (Figure 1.3). In a potential "drunk driving" case, the laboratory has to show that the person charged had a blood alcohol content above the legally allowed limit. Identifying that semen is present on a vaginal swab, from an alleged sexual assault victim, corroborates a crucial element of a sexual assault or rape charge; namely, penetration. Proving these elements of any such crime is required for successful prosecution, and one cannot convict someone without proving **all** the required elements of the crime.

3. Support or Disprove Statements by Witnesses, Victims, or Suspects

   The outcome of many investigations relies heavily on things people say about the case. In many instances, these things can become formal statements. Eyewitness testimony, for a host of reasons, is often known to be unreliable. Witnesses can often be influenced by their perspectives, prejudices, memory flaws, and other such factors. Suspects, and sometimes even victims, may have reasons not to be completely truthful in their statements.

   Physical evidence and its analysis can play an important role as an "objective" reporter in a case, against which statements can be evaluated. Nothing is more important in gaining a proper result in our system of justice than judging the credibility of witnesses. The entire trial process depends on the trier of fact (judge, jury, or administrative officer) being able to accurately evaluate what they hear. Forensic science can play an important role in this regard. If the physical evidence and its analysis objectively demonstrate something that contradicts

Figure 1.3 Chemical identification of the drug in seized drug evidence is a critical element in controlled substances cases. (Courtesy of Shutterstock, New York.)

a statement by someone in a case, it means that the statement is incorrect. Similarly, physical evidence can support a statement by a witness, victim, or suspect.

4. Identify Substances or Materials

   In many cases, the scientific examination of physical evidence provides an identification of a substance or material. Two obvious examples are a controlled substance possession case and a counterfeiting case. Further, identifying probable accelerant material in debris from an arson case, for example a flammable liquid (accelerant), such as gasoline, which can be used to start a fire. Perhaps finding gunshot residue on the hands of an individual suspected of firing a weapon in a shooting case, is another example.

5. Identify Persons

   Reliable identification of individuals is critical to the proper operation of our justice system. Biological evidence and fingerprints (Chapter 6) are routinely used to identify persons in criminal cases. Fingerprints have served the justice system well for over 100 years. As we will also see in Chapter 6, the identification of human remains is an important activity in cases of individual death and of mass disasters.

   As discussed previously, the development of national databases has made forensic science much more helpful during an investigation. We will discuss these databases in detail in the appropriate chapters. CODIS contains DNA profiles of convicted offenders and unidentified suspects in unsolved cases. Automated Fingerprint Identification System (AFIS) contains many known fingerprints and evidentiary fingerprints not yet identified. National Integrated Ballistic Identification Network (NIBIN) contains image data from bullets and cartridge cases from known weapons seized in cases and from evidence collected in unsolved cases.

CASE ILLUSTRATION 1.1

We have two middle-aged gentlemen who perhaps look much older because they drink much too much. They have been soused for years living off odd jobs and public assistance. Whenever the check comes, they go out and buy their bottles of wine and get drunk. In between checks, they live a classic homeless existence. So, while they are not exactly what one would call model citizens, they are not really dangerous criminals either. One night these two gentlemen are sitting in a vacant cabin out in the woods. They are old friends; sort of friends and enemies. They do not trust anybody else, and so they support each other. They are sitting in this cabin rapidly approaching oblivion when, all of a sudden, a shot rings out. The window in the cabin breaks and a bullet zips by the head of one of them, misses him, and buries itself in the wall. Both of them are startled to attention, and, about a minute later, someone smashes in the door with their foot, comes in, shoots one of the two gentlemen in the head, and then runs out the door. Now, those of you who are law enforcement officers, do you believe this story, or does it seem a little self-serving? We have a likely homicide, and one of only two witnesses is dead. The survivor doesn't want to be in the position of facing a murder charge. Did he make up this nice story after he and his buddy argued, and he shot him in a drunken rage? That's the question a jury must ultimately decide. If you are his defense lawyer, you are going to clean him up a little bit and keep him off the sauce for a while so that he makes a decent appearance. But no matter what you do, when he gets up on the stand, he is not going to be one of the world's most believable witnesses. He may be a perfectly honest individual; however, once his history comes out, he is not going to play well in front of the jury.

How can one assist the jury in making the correct decision? If we want to decide whether he is telling the truth, or whether he has made up this story to cover the fact that he murdered his friend, then how can one tell? Well, physical evidence for starters. If it's collected properly, and the scene is carefully processed, it can tell us a lot about what might have actually happened. Here are a few examples. The first thing the defendant said, in his description of the events, was that a shot rang out, the window broke, and the bullet just missed his buddy. What can one look for? First of all, one can look at the glass that's lying on the floor. In Chapter 4, on pattern evidence, we will discuss the fact that it is often possible to tell from which direction a window was broken. Did the bullet come from the outside in, or did it go from the inside out. Because, obviously, anyone who has watched crime shows on television, is aware of this common scenario. An investigator would often say; "Aha, this was staged. They really didn't break in through the French door because the glass is on the wrong side." When one looks at the physical evidence, one can probably tell that the window was broken from the outside in. Does that prove the defendant is telling the truth? It really does not, but it doesn't hurt.

(*Continued*)

CASE ILLUSTRATION 1.1 (Continued)

Secondly, one should look for a bullet or bullets. If our defendant is telling the truth, one should find two bullets or a bullet in the body and a second bullet or hole in the cabin. When one determines where they are, one should be able to do a little bit of trajectory reconstruction, as will be discussed in Chapter 4. An investigator should be able to tell whether one of those bullets at least came through that window. This also provides possible corroboration for the defendant's story. Thirdly, one can look at the door. Forensic labs get a lot of interesting things from doors all the time. What is on the door? One might find a dust print from somebody's foot having kicked in that door. Now, if that somebody was wearing a shoe with any kind of a patterned sole, it might leave an image of its pattern on the door. Taking a cross section of our society today, you will find a high percentage of individuals wearing pattern shoes. There are hiking boots, waffle stompers, lots of sneakers, and a variety of other patterned soles. Even some shoes, that look like dress shoes, can have patterned bottoms. The point being, one can look at the defendant and reason that he is likely to have no more than one or two pair of shoes. You can examine them to see if they are patterned shoes, and if one matches the pattern on the door. If there is no match, then he probably isn't the one who kicked in the door. None of the evidence mentioned so far can actually determine much about who committed the crime, nor much about what might have occurred.

The physical evidence **does** tell us; however, that if all these things collectively check out, it may be that the defendant is telling the truth. He probably is not knowledgeable enough to fool the experts who look at these things. The net result is that his credibility is enormously improved. This is a key role that forensic science can play in making the justice system work better. It is a fairly subtle role, because it does not scream "guilty or not guilty," but this type of evidence can play a significant role in helping the jury come to the correct decision. Those processing a crime scene should not concern themselves with who is going to turn out to be a creditable witness or who is going to turn out to be an abysmal witness. Nor, should any of these factors determine what evidence they ought to collect based on anything like this. This is why it's particularly important to examine each scene carefully, even when the case seems simple and straightforward. The investigators may not be able to see any obvious probative value in collecting all the available physical evidence. However, in a particular case, non-probative evidence may say a lot about when, in fact, someone is or is not telling the truth.

A BRIEF HISTORY OF FORENSIC SCIENCE

Early applications of forensic science

To understand forensic science as it is today, it is helpful to take a brief look at its origins and how it has evolved over time. Some very early work on forensic medicine was published in China in AD 1250. Although many of the concepts that we think of as belonging to forensic science have been around much longer, one can argue that the formal beginnings of modern forensic science in the western world began in the period between 1800 and 1850.

Medicine has become less experience-based and more scientifically based on understanding of disease process developed from experiment and careful observation. Doctors were carefully dissecting bodies, and the microscope became available to help develop a better understanding of detailed anatomy and body functions. In ancient and medieval times, there are accounts of alleged homicidal poisonings. The Medicis are thought to have poisoned people in the 1600s. Socrates was killed by being forced to drink hemlock (which has nothing to do with hemlock trees, but contained a toxic substance later identified as coniine). Many of the forensic science specialties we recognize today can be traced back to early medico-legal institutes in Europe. Although these institutes concentrated on investigating death cases, some of the early medico-legalists also did work on the identification of blood and semen stains. Proper identification of body fluid stains has long been important to the investigation and prosecution of crimes. Common questions to ask in the identification of blood stains include:

1. Is the sample blood?
2. Is the sample animal blood?
3. If animal blood, from what species?
4. If human blood, what type?
5. Can the sex, age, and race of the source of the blood be determined?

During the middle 1800s the natural sciences chemistry, biology and physics were developing and scientific method was being refined. The recognition of the potential value of the non-medical forensic sciences, particularly criminalistics, took a giant stride with the writings of Hans Gross. In 1893, he published a book entitled *Handbuch für Untersuchungsrichter, Polizeibeamte, Gendarmen* (*Handbook for Coroners, Police Officials, Military Policemen*), which was very influential on the practice of criminal investigation. Gross was not a scientist, but rather a magistrate and law professor in Austria. Him championing the utility of the developing discipline of forensic science was very important to its acceptance by many rather skeptical police agencies. Gross is responsible for the word "criminalistics," and was one of the first people to carefully consider the value of physical evidence in investigations. In European justice systems, the magistrate had a role both as judge and as the primary investigator in a case. In that primary investigator role, he could call on the services of forensic experts, and that is what prompted Gross's interest in what we now call forensic science.

Concurrent and overlapping with this period, continuing until about 1900, was the major period of development of more systematic methods for human identification. In the 1890s, Alphonse Bertillon developed a method for criminal identification for the metropolitan police agency in Paris based on a series of body measurements (Figure 1.4).

The measurements of people arrested or incarcerated were classified and kept on file. Since many people misrepresented their identities to the police, this proved a valuable method to see if an arrested individual might be a person wanted by the police for another crime, perhaps under a different name. After a time, it became clear that these files had significant limitations, such as measurement errors and not enough independent measurements to truly distinguish each individual, as the files became large.

At about the same time, Galton, Herschel, and Henry, and others in England were studying and trying to apply fingerprints to medical diagnosis and identification (Figure 1.5). This resulted in the newly developing science of fingerprints becoming the method of choice for routinely identifying people, and this is still true today. These developments are described more fully in Chapter 6.

Development of forensic science laboratories and professional organizations

Forensic science laboratories, as we know them today, began to emerge in the early twentieth century. In Europe, they tended to grow out of the medico-legal institutes, which performed what we now think of as primarily forensic pathology functions. In 1909, a professor named Riess started a forensic photography laboratory at the University of Lausanne in Switzerland, which soon broadened its areas of expertise. In 1910, Dr. Edmond Locard (Figure 1.6) started the first forensic laboratory in Lyons, France. Dr. Locard is particularly important in the history of forensic

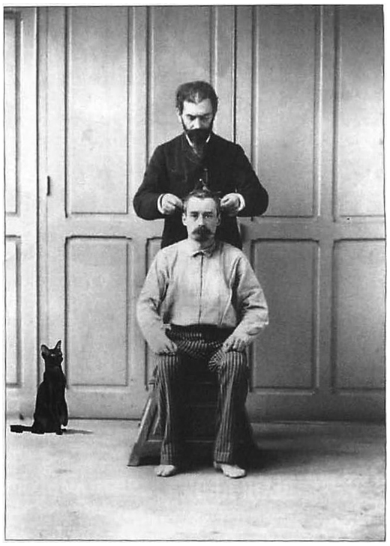
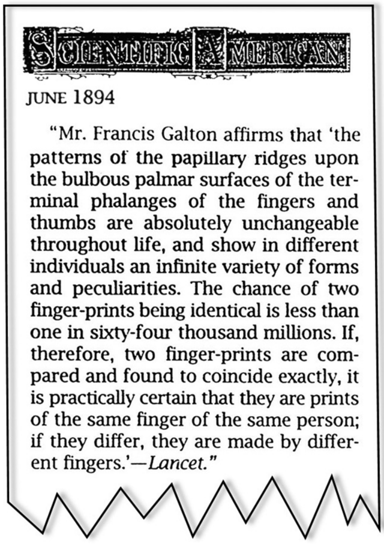


Figure 1.4 One of the first challenges faced by forensic science was establishment of a person's identity. Bertillonage was one of the first scientific methods used.



SCIENTIFIC AMERICAN

JUNE 1894

"Mr. Francis Galton affirms that 'the patterns of the papillary ridges upon the bulbous palmar surfaces of the terminal phalanges of the fingers and thumbs are absolutely unchangeable throughout life, and show in different individuals an infinite variety of forms and peculiarities. The chance of two finger-prints being identical is less than one in sixty-four thousand millions. If, therefore, two finger-prints are compared and found to coincide exactly, it is practically certain that they are prints of the same finger of the same person; if they differ, they are made by different fingers.'—*Lancet.*"

Figure 1.5 Galton's stature as a scientist helped lend credibility to the early use of fingerprints for identification.

Figure 1.6 Locard was a pioneer in use of physical evidence and the founder of one of the first forensic laboratories in Europe.

science because of the Locard Exchange Principle, which will be discussed in some detail in Chapter 14. In Europe, many forensic science laboratories were, and still are, affiliated with universities. In the United States, most forensic science laboratories initially emerged in police agencies.

The development of forensic laboratories in the U.S. came little later. August Vollmer, who was the police chief in Berkley, California in 1928, became interested in the use of scientific evidence in police investigations. He was responsible for starting the forensic laboratory of the Los Angeles Police Department when he became its Chief. It is interesting that many of the pioneers in forensic science were medical doctors. An important person in the development of firearms examination, Calvin Goddard, was a military physician. He was involved in several pioneering studies that demonstrated the value of firearms identification to a skeptical law enforcement community. Following the St. Valentine's Day massacre in Chicago, Goddard was called in as a consultant and demonstrated the usefulness of examining bullet and cartridge case evidence. That led to his starting a forensic laboratory in 1929 in Chicago. It was originally a privately funded laboratory housed at Northwestern University, but, subsequently, it became the

Chicago Police Department Laboratory. The Federal Bureau of Investigation (FBI) started their laboratory in 1932, and the New York City Police Department Police Laboratory can trace its origin to about 1934. Originally, there were two detectives assigned to the New York City Police Department forensic laboratory. In the next few years, many other crime laboratories were started.

Between 1940 and 1970, the governmental responsibility to provide crime laboratory services to law enforcement became fully recognized. Between 1970 and 1980, there was a very rapid growth in the number and scope of forensic laboratories. The Law Enforcement Assistance Administration, set up by the federal government as a result of the Safe Streets Act of 1968, provided considerable funding to state and local jurisdictions to either start new laboratories or expand and improve existing ones.

The American Academy of Forensic Sciences (AAFS) was formed by a small group of interested pathologists, psychiatrists, criminalists, and attorneys led by Dr. R.B.H. Gradwohl of St. Louis in 1948. Today, American Academy of Forensic Sciences (AAFS) has sections representing 11 different forensic disciplines and specialties. AAFS has grown to a quite substantial organization with members from many countries in addition to the United States. AAFS started its peer-review journal, the *Journal of Forensic Sciences*, which many professionals feel has become the premier journal in the field. Besides the Academy, six regional associations of forensic scientists, primarily criminalists, have grown up across the country. The International Association for Identification (IAI) was formally incorporated in 1919 and fingerprint examiners, and other pattern evidence specialists belong to the IAI. Today, there are professional organizations of firearms and toolmarks examiners as well as documents examiners. Some of them are discussed in the chapters on those topics.

In the early 1970s, the American Society of Crime Laboratory Directors (ASCLD) was formed by a sizable group of crime laboratory directors with a strong assist from the FBI. One of their first projects was to develop a system of voluntary laboratory accreditation (Figure 1.7). It took 10 years to develop a workable scheme, but they created the ASCLD Laboratory Accreditation Board and began laboratory accreditation in 1982.

This has proven to be a highly successful venture, and the majority of forensic laboratories have become accredited or are actively working toward that goal. This is generally a voluntary process sought by the laboratories themselves to validate the quality of their work. In recent years, several states through legislation have made accreditation mandatory for their laboratories, and there is some pressure to mandate accreditation of all forensic laboratories.

Starting in 1994, particular concern over the complexities of DNA analysis has made accreditation of DNA sections virtually mandatory. After a study by the National Academy of Science in 2008, there has been a sizable federal bureaucracy set up to improve and regulate almost all aspects of forensic science.

Besides **accreditation** (which applies to laboratories), there has been the development of **certification** programs (which apply to individuals). The American Board of Criminalists (ABC) has the most extensive program for criminalists. There are specialty certification boards for forensic pathologists, forensic dentists (odontologists), forensic

Figure 1.7 The American Society of Crime Laboratory Directors was instrumental to bringing uniformity to forensic laboratory practice and developing forensic laboratory accreditation in the United States.

anthropologists, forensic entomologists, forensic document examiners, forensic toxicologists, and other specialties. The IAI has certification programs for latent fingerprint examiners, forensic artists, crime scene photography, footwear and tire tread evidence, and crime scene investigators.

There are over 300 governmental forensic laboratories in the U.S. They are maintained by agencies of the federal government (such as the FBI, Bureau of Alcohol, Tobacco, Firearms and Explosives (ATFE), Secret Service, Drug Enforcement Administration (DEA), and so forth), or by units of local government (state, county, or city). Some states have multiple laboratories organized into a central laboratory and satellite laboratories around the state. Many labs are located within a law enforcement agency, but they can be found in prosecutors' offices, medical examiners' offices, and in departments of health. Some laboratories are very small, while others have hundreds of personnel. There are also a number of privately operated forensic laboratories, most of them specialize in DNA analysis, toxicology, engineering or questioned document examination, although virtually all forensic specialties are represented. Most large laboratories use a major portion of their analytical resources on controlled substance identification and DNA analysis.

THE MANY FACES OF FORENSIC SCIENCE

Human biological and medical sciences

Forensic science, in the broad sense of the term, encompasses many different scientific and technological specialty areas. All or most of them can have applications in both the civil and criminal justice systems. Some of the specialty areas will be described in the following sections, including some that are beyond the scope of the book and won't be discussed in detail in subsequent chapters. There are many others, such as forensic accounting, forensic meteorology, and forensic nursing (mentioned in Chapter 10) that are not discussed here. Today, "forensic" is used as an adjective to describe many disciplines in the context of applying the methods of that discipline to legal matters, and new forensic specialties are regularly being developed.

Forensic pathology is another name for forensic medicine. Forensic pathologists are Doctors of Medicine (MD) who have first specialized in pathology (the study of the nature of disease and its causes, processes, development, and consequences), then take further training in forensic pathology. Forensic pathologists are experts in determining the *cause* and *manner* of death (Figure 1.8). The *cause* of death is a medical determination—the medical explanation for why a person died. The *manner* (also called circumstances) of death is a medico-legal determination. Cause of death is a gunshot wound, asphyxiation, poisoning, and so forth. Manner can be homicide (one person kills another), suicide (a person kills himself or herself), accidental, or natural. The media routinely confuse cause and manner of death. Both the cause, or manner, of death may sometimes be *undetermined*.

Figure 1.8 Pathology was one the first truly scientific forensic specialties. Shown here, Dr. Lee conferring with a medical examiner.

There are two "systems" of death investigation in the U.S.: the coroner system and the medical examiner system. A *coroner* is an elected official and need not have any special medical knowledge or training, since he or she can call on specialists to assist in technical determinations. A coroner has the power to convene a *coroner's inquest* and take sworn testimony at a proceeding if necessary to assist in making determinations. A *medical examiner* system specifies by law that a forensic pathologist—again, someone with extensive medical training—make appropriate determinations in cases of questioned, suspicious, or unattended deaths. Many bigger cities and some states use the medical examiner system, but many jurisdictions are still under the coroner system. There are some coroners who are forensic pathologists, and other coroners who enlist the services of a medical examiner or other pathologist.

A medical examiner's determinations are based on all available information about a death, including the scene, results of the police investigation, results from the forensic science laboratory, results from the post-mortem toxicology, in addition to the findings at autopsy.

Entomology is the branch of biology devoted to the study of insect species (Figure 1.9). When an animal or human dies, houseflies and other insects are able to detect the location of the body quickly. The adult flies will lay their eggs on or in a corpse, if they have access to it. The life cycle of many insects consists of egg, larva (or maggot), pupa (or cocoon), and adult. In some insects, there can be multiple larval stages. Entomologists know the life cycles of the insects in detail, and, thus, know how long each stage of the life cycle takes. The time is governed by temperature and by the length of daylight and darkness during each day. Forensic entomologists can examine insect eggs, larvae, or pupae from a body to determine which species of insect produced them. Eggs and larvae must be collected and reared to the adult stage to identify the species. Then, using information about the number of insect cycles, temperature, length of daylight hours, and other information from the scene, they can often "back calculate" to estimate the time of death. Since determining exact time of death is often a problem, forensic entomologists can make important contributions to cases when insect evidence is found and the time since death is an issue.

Forensic odontologists are forensic dentists. They do two major types of analyses involving human dentition. One is identifying human remains that are so altered by decomposition, fire, or explosion that they cannot readily be identified by visual means. Typically, the odontologist looks at pre-mortem and post-mortem dental X-rays. The dentition, and, in most cases, the dental work done on an individual is sufficiently unique to permit personal identification in this way. The X-rays of a decedent must be compared with pre-mortem X-rays from one or more persons suspected of being the person. The use of dental identification in mass disaster situations is a component of this and discussed further in Chapter 6.

Figure 1.9 Forensic entomology is an important forensic specialty helping to discover time of death in difficult cases. (Courtesy of Shutterstock, New York.)

The second major activity in forensic odontology is bitemark comparisons. There are several different techniques for actually doing the comparisons. Bitemarks may be found on human bodies in cases of assault, sexual assault, and child abuse, and occasionally on other objects that show an impression of the teeth. If the marks are recognized, properly documented, and examined by a forensic odontologist, they can be compared with known bitemarks obtained from suspects. Often suspects who did not make the bitemark can be readily excluded. Sometimes, a suspect who did make the bitemark can be identified.

Physical anthropology is the study of the human skeleton and how it has evolved over time. Forensic anthropologists are physical anthropologists specialized in examining primarily human skeletal remains (Figure 1.10). They can quickly determine if skeletal remains are human or animal, and often can estimate approximately when they were deposited. If the remains are human, they can be "reconstructed" (laid out in proper orientation). Depending on the condition and amount of skeletal remains, forensic anthropologists can often provide estimates of the age, stature, and gender of the individual. They can also sometimes tell if the remains belong to the *Caucasoid*, *Negroid*, or *Mongoloid* race. They can spot skeletal abnormalities and skeletal trauma that may be present. Traumatic injuries can provide information about cause of death (e.g., a knife blade cut on a bone supports a stabbing death), and sometimes help in identification based on comparison with antemortem X-rays. Finding indicia of repair (plates, screws, or implants) can often provide valuable information. Thus, the anthropologist can often provide descriptive information about remains even if it is not possible to identify (individualize) the skeletal remains.

Although not a part of forensic anthropology, *per se*, we should mention that there is a sub-specialty sometimes referred to "forensic sculpture" or more technically cranio-facial reconstruction. Forensic sculptors need a skull to work with. From the skull, they attempt to reconstruct what the person's face may have looked like. The reconstruction is based on tissue thickness and other data that has been gathered from population studies. Eye color, hair color, and hairstyle are usually unknown, so it is often difficult for the sculptor to create a readily recognizable likeness of the person. Similarly, computer technology can be used to "age" a missing person's photograph. This kind of information can sometimes be helpful in determining an identity.

Forensic toxicology is the study of the effects of extraneous materials, such as poisons, toxins, and drugs, in the body. Forensic toxicologists must determine both the presence and amounts of such materials in a body and also attempt to interpret the possible effects of these materials. They must be quite knowledgeable in analytical chemistry techniques as well as biology, physiology, and pharmacology. Toxicology is discussed in Chapter 13. Forensic toxicologists who work on post-mortem specimens are often associated with medical examiners' offices. Many forensic toxicologists are also involved in testing specimens from living persons examples include: blood and breath alcohol determinations in

Figure 1.10 Forensic anthropology is an important forensic specialty in determining what happened to an individual in cases involving skeletonized remains.

the enforcement of “driving under the influence” laws, urine or hair testing to enforce “drug free workplace” rules, and checking for “date rape” drugs in sexual assault complainants.

Forensic psychiatrists and psychologists do similar work. The psychiatrists are medical doctors, while the psychologists are usually PhDs who have obtained a license to have a clinical practice. Forensic psychiatrists and psychologists evaluate offenders for civil and criminal competence and may be involved in offender treatment programs. They may also evaluate juveniles to assist courts in determining the best placement for them. A few of these specialists “profile” criminal cases. Profilers can sometimes provide useful information about the characteristics of an unidentified offender based on his *modus operandi* (MO), habits, and crime scene patterns. Profiling has concentrated primarily on serial murderers and serial rapists.

Natural sciences—chemistry, biology, and physics

Criminalistics is a term that sometimes is used to cover all the natural science approaches to evidence examination and is the primary subject of this book. An easy way to think about criminalistics is that it encompasses all, or most all, of the specialty areas found in full-service forensic science laboratories. It involves the examination, identification, and interpretation of items of physical evidence. In general, criminalistics can be divided into four major categories of examinations: biological evidence analysis; analysis of materials evidence; forensic chemistry, including but not limited to fire debris and controlled substance identification; and pattern evidence, including documents, firearms, toolmarks, fingerprints, footwear, and other patterns, including scene reconstruction patterns. Most of the rest of the chapters in the book are devoted to these subjects.

FOUR MAJOR CATEGORIES OF EXAMINATION IN CRIMINALISTICS

Biological	Material	Chemical	Pattern evidence
Blood	Objects	Drugs and toxic substances	Imprints
Body fluids	Pieces of objects	Paints, pigments	Fingerprints
Hair	Plastics (pieces)	Gunshot residue	Tire impressions
Tissues	Glass (pieces)	Accelerants, solvents, alcohols	Footwear impressions
Pollens		Rubber materials	Physical patterns
Wood materials		Resins	Firearms, bullets
Other plant derived material		Plastic materials	Cartridge cases
Feathers		Explosives residue	Toolmarks
		Fibers	Questioned documents
		Soil	
		Glass	
		Misc. trace evidence	

Criminalistics is as much an approach to evidence examination—a way of looking at it—as it is a collection of specialties. A criminalist is a person who thinks about a case and evidence in specific ways. A criminalist thinks about what information can be gleaned from a piece of evidence that can further the investigation or adjudication of the incident to which it is related. Criminalists are usually specialists in one of the analysis areas, but that alone is not what make them criminalists. It is possible to be a very skilled chemist or molecular biologist and not be a criminalist at all. To follow—and at intervals as we go through the book looking at different categories of evidence and analyses—we hope to give you an appreciation for those elements of forensic thinking and analysis that define criminalistics.

Technology and engineering

Forensic engineers are experts trained in one or more of the engineering specialties (often, but not exclusively, mechanical, electrical, or civil). Many are professional engineers; a professional licensure gained by qualifying for and then passing a challenging examination. Forensic engineers are involved in reconstructing automobile and some other transportation accidents, materials failure cases, and building or structure collapses. The majority of cases involving forensic engineers are civil rather than criminal.

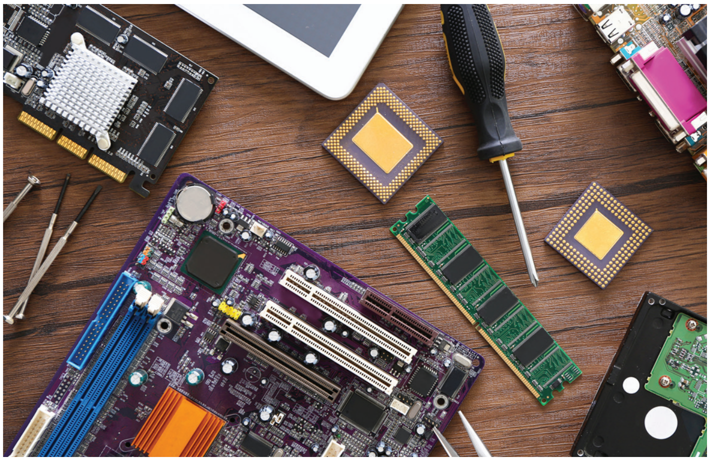


Figure 1.11 Digital forensics is one of the newest and most rapidly growing forensic specialties and can involve myriad hardware and software. (Courtesy of Shutterstock, New York.)

Digital forensic examinations; often computer or processor related

There are two aspects to what might be called digital forensic science. You may hear this specialty called "computer forensics." This is misleading terminology as we have explained previously since "forensics" is not forensic science. One aspect is the investigative use of computer technologies and electronic records, sometimes called "digital evidence." Investigators may make use of information on computer hard drives, in pagers, cell phones, handheld devices, and other such technologies to help solve cases (Figure 1.11). Another aspect is more technical, where considerable knowledge of computer science and computer engineering may be needed to find hidden or deleted information on electronic media. Such information can be used to track down those who have committed computer crimes, such as circulating pornography or unauthorized access to confidential information residing on computer networks. This work can include Internet-based child pornography investigations, tracing the origin of computer viruses, worms, and so forth, as well as elaborate "hacking" schemes.

Forensic/Investigative Technologies—Almost any kind of technology that has or could have any application to criminal or civil investigation, can loosely be called "forensic." Often, products or technologies are called "forensic" for marketing purposes. Many technologies associated with scene investigation fall into this category. Use of various types of specialized light sources and specialized scene search techniques, like ground penetrating radar, are just two examples. Many advanced photographic and video techniques, especially digital, are coming into more frequent use in appropriate cases.

NATURE OF FORENSIC SCIENCE AND THE SCIENTIFIC METHOD

Forensic science is, first and foremost, *science*. It is important, therefore, to describe briefly how science differs from other areas of human inquiry, and how the "scientific method" works. Most scientists, who use the scientific method in their work all the time, don't consciously think about using it. The scientific method is more of a way of approaching problems than a detailed recipe. It is that particular approach, the scientific approach, which distinguishes between scientists and others.

In forensic science, the scientific method is extremely valuable in many different ways. First, as noted, forensic science is science, but the importance of the scientific method in forensic science is not limited to scientific analysis tasks. It has major applications in doing investigations, reconstructions, and many other important tasks. We will illustrate as we go along that there is a distinct parallel between the scientific method and *reconstruction* (this will be discussed in more detail in Chapters 3 and 4).

The scientific method is not esoteric, and you don't have to be a professionally trained scientist to use it. In fact, many people use it every day, without even thinking about it. There are various "formulations" of the scientific method, but it can be viewed as a four-step process.

1. Careful Observation: The importance of these two words cannot be overemphasized. The first step in the scientific method is being receptive and inquisitive. Anyone can be a careful observer. Observations of events and phenomena in the natural world and curiosity about what is behind them have been the driving force behind the development of science.
2. Make Logical Suppositions to Explain the Observations: The point of scientific inquiry is to try to understand natural phenomena and the natural world. So, the second step is to take an "educated guess" as to an explanation. The educated guess is usually called a *hypothesis*. The most important thing about the hypothesis is that it has to be made up of *experimentally testable* propositions. Predictions can be made based on the truth of the hypothesis. If the hypothesis is true, certain things that follow from it must be true. Then experiments are designed to test the predictions.
3. Hypothesis Testing—Controlled Experiments: Developing ways to test the hypothesis is the heart of experimental science and scientific method. The experiments that are devised must be *controlled*, that is, designed so that only one thing varies at a time. If the experimental design is correct, it enables the experimenter to find out the effect of that variable alone.

   As an example, a scientist might want to know how adult salmon are able to find their way from the Pacific Ocean hundreds of miles up freshwater streams and tributaries to the place they were born in order to spawn. Do the fish do this visually, by smell, or some other way? A controlled experiment might be designed in which the fishes' sense of smell was disrupted to test whether the mechanism was olfactory. Suppose the fish, whose olfactory faculties were disrupted, found their way to their spawning ground just as well as the control fish (whose sense of smell was not tampered with). The hypothesis being tested was: The fish use their olfactory sense to make the journey. The experimentally testable prediction was: If the hypothesis is true, disrupting the fishes' olfactory abilities will prevent them from migrating. The prediction was found to be false, invalidating the tested hypothesis.
4. Refine the Hypothesis—Theories and Natural Laws: Hypotheses must be continually refined; that is, re-tested over and over. The reason is that while true hypotheses generate true predictions, false hypotheses can also generate true predictions in a particular test. It may take many tests, and a long time, to discover the proper tests to show that a hypothesis is false and has to be adjusted.

   The "closed loop" of hypothesis testing continues forever. Some hypotheses that have been tested extensively by many different scientists, and found to be sound, become established as *theories*. Think of a theory as a well-tested hypothesis. Occasionally, a well-tested theory may become known as a *natural law*. But, no matter how well tested a theory is, it may still be shown to be wrong at some point. All good scientists recognized that no hypothesis, theory, or natural law is absolute. Someone may come up with another experiment that shows a flaw and requires modification of the original hypothesis or theory. That is what the "scientific method" is all about: the recognition that one is never finished, that each observation must be tested in new ways to ensure that the current theory keeps being refined. The process is diagrammed in the Figure 1.12.

   Science, because it follows the scientific method, does not deal with absolutes. Scientific "truth" is the current, best, most refined hypothesis or theory. This concept is important because forensic scientists work extensively in the legal system. References to "proof" and "truth" by lawyers do not have the same meaning as they do to scientists.

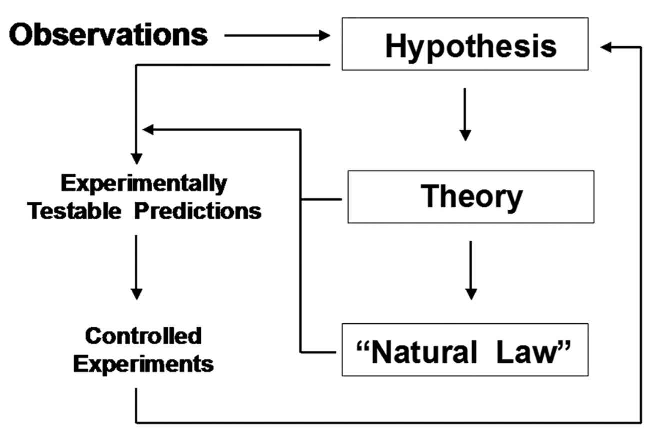


Figure 1.12 In classifying evidence comparisons, disassociation is every bit as important as association; two non-matching hairs depicted.