Chapter 1

Role of forensic science in criminal investigations

Forensic Science is no longer on the fringes of criminal investigations. Science is solving cases that otherwise remain unsolved. Science is identifying the guilty with a certainty that protects the innocent at the same time.

The Honorable John Ashcroft, former Attorney General of the United States[1]

Overview

Before an in-depth discussion of forensic entomology can really begin, there is a need to define the relationship between this discipline and the broader field of forensic science. As the name implies, science is the core of forensic analyses. It is only fitting, then, that Chapter 1 begins with an exploration of the application of science to legal matters, which also serves as a simple working definition of **forensic science**. Throughout the chapter, emphasis will be placed on the use of the scientific method in all forms of forensic analyses, from the process of analyzing physical evidence to understanding the types of outcomes associated with forensic analyses. The different specialty areas of forensic science will be discussed to allow a perspective of the broad impact of science on criminal and civil investigations.

The big picture

- What is forensic science?
- Application of science to criminal investigations.
- Recognized specialty disciplines in forensic science.

1.1 What is forensic science?

Science is used to solve crimes. In fact, it is instrumental in resolving cases involving both civil and criminal issues, particularly those of a violent nature. Not surprisingly, crime too has become more sophisticated, with today's criminals relying on aspects of science to threaten individual and national security. One has to look no further than bioterrorism to see a clear linkage between scientific understanding and violent criminal activity. This chapter is devoted to understanding the relationship between science and criminal investigations. Particular attention is given to understanding the **scientific method**, a defined way of doing science, as it serves as the core principle for studying natural phenomena and in forensic analyses.

Forensic science has become a broad term, departing somewhat from the simple definition given earlier in which it was stated to be the application of science to law. The term "forensic" is defined as pertaining to or connected with the law, while "science" is the study of the physical and natural world through

The Science of Forensic Entomology, First Edition. David B. Rivers and Gregory A. Dahlem.

Companion website: www.wiley.com/go/rivers/forensicentomology

Table 1.1 Specialized areas of forensic science recognized by the American Academy of Forensic Sciences (AAFS).

Section	Membership totals*
Criminalistics	2571
Digital + Multimedia Sciences	90
Engineering Sciences	157
General	702
Jurisprudence	189
Odontology	429
Pathology/Biology	878
Physical Anthropology	423
Psychiatry/Behavioral Science	135
Questioned Documents	198
Toxicology	516

*Membership data as of July 8, 2011 at http://www.aafs.org/sections. Forensic entomologists typically belong to the Pathology/Biology section of AAFS.

systematically arranged facts and principles that are rigorously tested by experimentation. When used together the two terms yield a discipline that addresses issues pertaining to or connected to the law through the application of tested facts and principles and by use of rigorous experimentation. As mentioned previously, the definition of forensic science has become more encompassing, now representing a vast array of medical, scientific (natural and applied) and social scientific disciplines (Table 1.1). So now we may revise our definition of forensic science to reflect modern, broader approaches: "the use of scientific knowledge and technologies in civil and criminal matters, including case resolution, enforcement of laws and national security." The term **criminalistics** is commonly used to narrow this broader definition into the specific activities of a crime or forensic laboratory (Gaensslen *et al*., 2007). Most aspects of applying science to the law, including those associated with forensic entomology, fall under the umbrella of criminalistics.

Use of the term "forensics" as a substitute for "forensic" has confused the terminology to some degree. The former term originally meant the study or art of debate or argumentation. Hence, a school debate team practices forensics or debating. Though "debate" between attorneys has a defined role in the courtroom, it does mean pertaining to the law. However, within the court of public or popular opinion, "forensics" has come to imply forensic science. In fact, a word search on the internet or in some dictionaries yields results which indicate that "forensics" can also be defined as referring to the law. In today's society, practice tends to set policy or norms and, as such, "forensics" is quickly becoming an accepted term for forensic science. No doubt this expanding definition has its origins with the popular television crime shows.

Figure 1.1 A knife found at a crime scene is an example of physical evidence. Photo by Ricce. Image available in public domain at http://commons.wikimedia.org/wiki/File:Knife_Fox.jpg

Yet another impact of the rising popularity of forensic science through television programming is the phenomenon known as the **CSI effect** (Saferstein, 2011). The name is derived from the very popular television series *CSI: Crime Scene Investigation* (airing on the CBS network). In general terms, the increased public attention to forensic science is usually linked to this TV series. However, there are numerous other influences that have contributed to the soaring popularity. Regardless of the source of influence, the public's perception of what science can do for a criminal investigation has become distorted. Many individuals, including those who potentially serve as jurors, have become convinced from TV shows that when the experts (i.e., forensic scientists) are called in to investigate a crime, they will always find **physical evidence** and that detailed analyses in the crime lab, using real and imaginary technologies[2], will ultimately solve the crime by identifying the perpetrator (Figure 1.1). When delays occur during an investigation or when there is simply little or no evidence to go on, the victim(s), families and even jurors become frustrated and believe the problem is the incompetence of the investigative team. After all, it only takes 1 hour for the CSI team to examine the crime scene, find evidence, analyze it, identify suspects, interview the suspects, and seal a full confession! This impressive effort is usually achieved by only one or two people, who perform all the functions that in real life would normally require a team of individuals. Of course, in reality the process is much more time-consuming, requiring many individuals working together, and often a crime goes unsolved. When television fantasy is not separated from reality, the result is that unrealistic expectations are placed on law enforcement officials based on the public's belief that television reflects the real world of forensic science and criminal investigations.

The reality is that the application of science to legal matters can profoundly influence the resolution of a crime. However, there are limitations to what can and cannot be done, some of which will be addressed later in this chapter. The real value of science in legal matters is that it relies on validation via scientific inquiry using the scientific method. The scientific method is the key, as its use requires adherence to defined unbiased approaches to designing, conducting, and interpreting experiments. Human emotions or desires, as well as error, are minimized so that the facts, or truths in the case of law, can come to light. A more detailed discussion of the scientific method can be found in section 1.2.3.

1.2 Application of science to criminal investigations

What can forensic science do to help in civil and criminal cases? Or more to the point, what do forensic scientists do? Forensic investigation is used to address numerous issues associated with criminal, civil and administrative matters. Indeed, most forensic scientists actually work on cases of a civil or administrative nature, or deal with issues related to national security such as those under the umbrella of the Department of Homeland Security in the United States (Gaensslen *et al.*, 2007). The focus of this book is **medicocriminal entomology**, so the emphasis in this chapter is placed on criminal matters.

So how do forensic scientists contribute to criminal investigations? In section 1.1 we spent some time discussing what they cannot do: solve crimes as on CSI. In real cases, forensic scientists spend the majority of their time applying the principles and methodologies of their discipline to the elements of the crime. In other words, a great deal of time is devoted to using the scientific method. Interestingly, training in scientific inquiry is not a universal feature of the curricular pedagogy of all the disciplines contributing to forensic science. Graduates in traditional science subjects such as biology, chemistry and physics (collectively referred to as the natural sciences), and even geology, are trained in rigorous use of the scientific method. Other disciplines may incorporate aspects of scientific inquiry into their curricula but the approaches are not the *core* of the training as is common in the natural sciences. Thus, our attention will be directed to what forensic scientists do when trained in the natural sciences.

The major functions performed by a forensic scientist include analysis of physical evidence, providing expert testimony to the court and, in some cases, collection of evidence at a crime scene. Details of evidence collection go beyond the scope of this textbook and the reader should consult such excellent works as Saferstein (2011) and Swanson *et al.* (2008) for a general discussion of crime scene techniques, and Haskell and Williams (2008) and Byrd and Castner (2010) for information specific to the collection of insect and arthropod evidence. The majority of this section will focus on analyses of physical evidence. However, before discussing the means of forensic analyses, we need to spend some time determining what is physical evidence.

1.2.1 Physical evidence

Physical evidence is any part or all of a material object used to establish a fact in a criminal case. Items as diverse as bullet casings, bone fragments, a dental crown, matches, or fly maggots can serve as physical evidence. Each is a physical object that may be directly related to a violent act that has been committed or that results from a criminal deed. It is this physical evidence that a prosecutor must use to "prove" the elements of a case, or **corpus delicti**, to a jury beyond a reasonable doubt. Proving something true is contrary to the training of a scientist well versed in the scientific method, and thus a forensic scientist faces an ethical challenge to stay focused on facts or data and not to make absolute statements more inclined to come from an attorney. Some of the work of the forensic scientist is to help establish the elements of the case. For example, in a scenario in which a police officer confiscates a brown powder from a suspect or alleged criminal, it is the job of a forensic chemist or toxicologist to determine whether the powder is a narcotic like heroin, in which case a crime has been committed, or whether it is some other substance. In most instances, however, forensic analyses are performed on an object or material collected from what has already been determined to be a crime scene.

In contrast, some evidence is the result of the interaction that occurs between individuals, presumably the

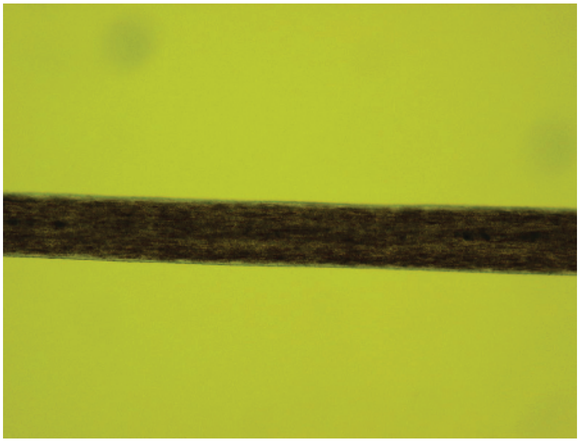

Figure 1.2 Human hair is a common form of trace evidence found at a crime scene or on a victim. Photo by Edward Dowlman. Image available in public domain at http://commons.wikimedia.org/wiki/File:Human_Hair_10x.JPG

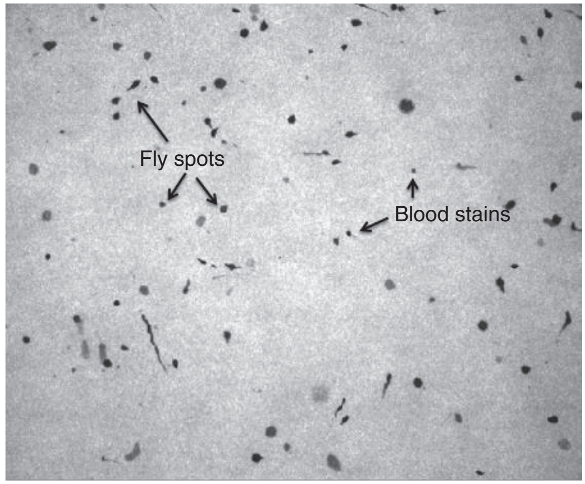

Figure 1.3 Bloodstains and fly spots or artifacts are virtually undistinguishable from each other. Photo by D.B. Rivers.

victim and assailant. According to **Locard's exchange principle**, every contact between individuals leaves a trace; that is, physical contact between two individuals will inevitably lead to transference of materials that can serve as trace amounts of physical evidence (Gaensslen *et al.*, 2007). These minute amounts of materials are referred to as **trace evidence** and can include such items as hairs, clothing or fabric fibers, gunshot residue, **bloodstains**, and other types of body fluids (Figure 1.2). Entomological trace evidence is not common but can include fly spots (regurgitate containing corpse's blood), insect artifacts (similar to fly spots), and frass on a body left by **necrophagous** insects (Figure 1.3).

1.2.2 Collection of evidence

Details of proper methods of evidence recovery will not be covered in this textbook. What is important to emphasize is that before any evidence is sent to a forensic laboratory for further analysis, the physical evidence collected at a crime scene must be properly maintained. In this respect, evidence from a crime scene must be accounted for during the entire process of investigation, from the time the physical or trace evidence is recovered at a crime scene and analyzed at a forensic laboratory until the evidence is presented in the courtroom by expert witnesses, many of whom are the forensic scientists conducting the analyses. The "accounting" is in the form of paperwork that provides a complete flowchart showing with whom and where

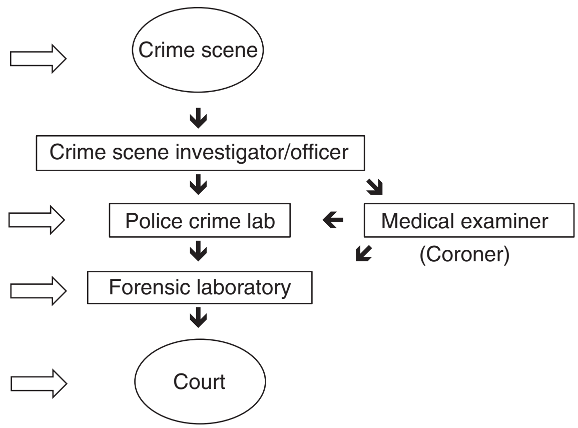

Figure 1.4 Chain of custody of physical evidence collected at a crime scene. The open arrows designate points along the chain where a forensic scientist may be involved. Modified from Jackson & Jackson (2008).

the evidential object has been at all times and is referred to as **continuity of evidence**. The group of individuals responsible for maintaining continuity of evidence during a criminal investigation is termed the **chain of custody** and a typical evidence progression is illustrated in Figure 1.4.

1.2.3 The scientific method is the key to forensic analyses

Scientific inquiry using the scientific method is the foundation for the natural sciences as well as forensic science. More generally, science is a process of asking questions about natural phenomena and then seeking the answers to those questions. Scientists as a whole are inquisitive in nature and it is this core make-up that leads individuals to study a particular scientific discipline. Asking questions is one feature of scientific inquiry. Asking the right questions in the right way and then designing means (experiments) to test those questions is what scientists do (Barnard *et al*., 1993). Anyone can ask questions and try to find the answers. However, testing questions using an approach centered on formulating hypotheses, making observations from carefully designed experiments, refining questions, and narrowing possible explanations is a skill that is learned or acquired from rigorous training. The process outlined is referred to as the scientific method, a systematic approach or procedure for investigating natural phenomena. Simply stated, it is a defined way of doing science. Not everyone is trained in the scientific method, including many who engage in forensic analyses. Such training is typically associated with education in the natural sciences. The inherent value of the scientific method to scientists is that it provides a roadmap for conducting scientific investigations and also serves as a means for peers in the scientific community to scrutinize research in their respective fields. It can be viewed, then, as a means of validation of results (observations), methodology, and explanations. In the applied world of forensic science, the scientific method provides not only validation but also a systematic approach for distinguishing between alternate hypotheses for elements of a crime.

The scientific method is our way to really understand cause-and-effect relationships in the world around us. Carefully crafted, controlled experiments allow scientists to move beyond observed correlations between one variable and another to a real understanding of the underlying causal relationships (or a realization that two events, while correlated, are not intimately linked to each other).

Research, especially published research, provides the background for quality scientific testimony in the courtroom. The landmark ruling by the United States Supreme Court in *Daubert v. Merrell Dow Pharmaceuticals, Inc*. provides a framework for judges to assess the scientific opinion. The decision provides guidance by establishing four criteria to assess scientific testimony (Faigman, 2002):

1. Is the information testable and has it been tested?
2. What is the error rate and is that error rate acceptable?
3. Has the information been peer reviewed and published?
4. What is its general acceptance by other scientists in the same field?

Figure 1.5 Tire treads pressed into mud, dirt or sand can represent a scene impression found at a crime scene. Photo by D.B. Rivers.

The process of scientific inquiry is straightforward and use of the scientific method is not meant to be intimidating. That said, asking the right questions in the right way generally requires a fundamental understanding of the phenomena or organisms to be observed as well as practice in developing the skill of scientific inquiry. If you are not convinced that scientific investigation is a skill that is developed, read through any research journal and compare the "quality" of the experiments detailed.

The scientific method can be broken down into specific steps that can be followed much like a flowchart (Figure 1.5):

1. *Make observations that lead to lead to questions*. Observing a natural phenomenon generally leads to formulation of questions: Why did this happen? How did this happen? Will it happen again? The latter two questions can lead to the development of explanations that can be tested by the scientific method, but not necessarily the former. "Why" questions imply evolutionary meaning and, while fun for speculation, often cannot be framed, at least not simply, in a manner that allows experimental testing.
2. *Formulation of hypotheses*. The "right" or "good" question is one that lends itself to being tested. What is tested is not the question directly, rather

the explanation that has been formulated to account for the initial observation. In other words, an educated guess or explanation of the initial observation or phenomenon, which is called a **hypothesis**. Scientists are trained to develop multiple hypotheses to explain a phenomenon and then design experiments that can test each of these explanations. Formulation of good hypotheses is often based not only on the researcher's observations but also on a comprehensive knowledge of information that has been published on similar situations in the past. Science builds on the work of past scientists. Here lies the key to hypothesis formation: a good hypothesis is one that is testable by experimentation. If after conducting a well-designed experiment the investigator cannot support or refute the hypothesis, it was not a good one to begin with. Conversely, the results of an experiment can falsify a hypothesis, meaning that the data generated do not support the explanation for the original observation, but a hypothesis can never be proven true (Morgan & Carter, 2011). As should be obvious, a conflict potentially exists between the outcomes available to a scientist using the scientific method and those desired by officials working in a judicial system.

3. *Testing hypotheses*. Hypotheses are tested through carefully controlled experiments. In this case, controlled means that all possible variables or factors that could influence the outcome of the experiment must be taken into consideration so that only one of them – the one being tested in the hypothesis – is allowed to vary during the study. The others are held as constant or static as possible for the experimental conditions. For example, in a study interested in testing the influence of temperature on the rate of development of necrophagous fly larvae, the hypothesis will be based on the idea that temperature is the most important factor influencing development. In this example, temperature is the **independent variable**. Aspects of fly development that can be measured as impacted by temperature are called **dependent variables**, and might include overall length of development or the duration of each stage of larval development. Other factors (e.g., food, humidity, species of fly, size of maggot mass) which could potentially be independent variables that influence fly development must be maintained at a constant value (as much as is possible) and are referred to as **control variables**. Only carefully controlled experiments allow an investigator to examine the impact of one variable alone on the condition being examined.
4. *Evaluating observations or data*. Once the observations have been made, it is imperative that the scientist or investigator thoroughly interprets the data collected. In many cases this involves a series of comparative evaluations (addressed in more detail in section 1.2.4) with other data in the scientific literature, databanks, test or **voucher specimens** (a specimen archived in a permanent collection serving as a reference for a taxon), or other resources. The data are also evaluated by statistical analyses to determine if what has been observed differs significantly from what was predicted or from other treatments. Statistical analyses require that the investigator understand the type of data to be collected prior to initiating the tests so that the experimental deign is appropriate for the data and statistical test to be used.
5. *Refining hypotheses*. After careful evaluation of the data, the original hypotheses are reevaluated or refined so that they can be retested, repeatedly, by the original researchers or by others. The process of experimental testing, if done well, should lead to new, more narrowly focused explanations of the original phenomenon that can be retested over and over. The idea is that with each subsequent round of experimentation, the scientist is moving closer and closer to the real explanation, or in the case of criminal investigation, a step closer to the truth.

It is important to understand that the scientific method is not simply a cookbook approach to scientific inquiry, meaning that once the final step is complete, the answer is known. Rather, doing science is a process whereby each observation leads to new questions with new hypotheses. The journey may seem endless, and in the sense of new observations stimulating new ideas and new questions, it is. However, this systematic approach to addressing questions also guides us closer to the real answers and away from incorrect or false explanations.

It is also important to understand that the scientific method is not the sole source of information used by forensic entomologists and other scientists. Much of our understanding of the relationships between insects and decomposing carrion has come from publications relying on careful systematic observations rather than controlled experiments where a single variable is manipulated to establish cause and effect. For example, we might be interested in knowing what insects are associated with the early decay process of several species of wildlife (Watson & Carlton, 2005) or what species are attracted to human remains in a geographical area (Carvalho *et al.*, 2000). These studies generate new data for forensic inquiry through systematic observations rather than by testing a clearly stated hypothesis. The basic research that we compare against to establish postmortem interval (PMI) is based on detailed observations of a species life stage and size at different times and temperatures (Byrd & Butler, 1998).

1.2.4 Analysis of physical evidence

Physical or trace evidence collected from a crime scene is typically delivered to a crime laboratory or sent directly to a forensic expert for further analyses. The initial characterization may be simply a quantitative or qualitative assessment of the evidence (Jackson & Jackson, 2008). In other words, the analyses may be needed to determine the identity of the evidential sample (**qualitative analysis**) in order to determine if a crime has even been committed, such as drug identification. In other instances, **quantitative analysis** is performed to determine the amount of a particular substance that has been discovered in order to affirm whether legal limits have been exceeded. Both forms of analysis are relevant to entomological evidence.

In the majority of cases, the forensic scientist evaluates physical evidence through comparison testing: the evidential object may be compared to known objects in databases or validated reference collections such as voucher specimens, or compared with the outcomes of controlled experiments. There are several ways in which comparison testing is utilized in forensic science and the most common are discussed briefly here.

1.2.4.1 Recognition of evidence

Recognizing whether a physical object is actually evidence is the first step in forensic analysis (Gaensslen *et al.*, 2007). Such determinations often rely on the experience of the forensic investigator or scientist, whereby the object has been previously observed during training, prior cases or experimentation.

When entomological evidence is present at a crime scene, care must be taken to collect as much material as possible, even if much of the material will never be used. In general, entomological evidence needs to be collected at the time the crime is discovered; we cannot go back a month later to get additional specimens to use as evidence. Empty puparia associated with a shallow grave at the time of a body's discovery are much more relevant than empty puparia collected 2 months later at the old crime scene. In order to estimate PMI on a fairly fresh corpse, the entomologist needs to see the biggest maggots of as many different species as possible to make the determination. Just collecting a few maggots from the first larval mass encountered could seriously compromise the ability of an entomologist to accurately estimate the time of death.

1.2.4.2 Classification

Once an item has been recognized as physical evidence, the object is processed in an attempt to identify it. Broadly, this means classifying the evidential object into groups or categories. Hairs, bloodstains, and other body fluids must be identified to determine if in fact they are human and, if not, to classify what animal or organism the samples may have been derived from. For example, fly spots created by adult flies regurgitating undigested food (such as blood) onto a surface appear almost indistinguishable from some types of blood spatter at a crime scene (Parker *et al.*, 2010). So an initial analysis of the spots is needed to classify them as either a bloodstain or some other object like an insect artifact. Likewise, paint chips, powders, and other materials must be identified so that objects can be grouped with similar items. Comparisons are generally performed between the object of interest and known databases, reference collections or other validated resources. In the case of insects, voucher specimens are used to confirm relationships with an insect group (usually a family or genus).

The process of classification can also lead to the exclusion of objects from a grouping. Such is the case with material such as paint chips, fibers or glass fragments, which may be broadly classified or grouped but determined to be not the same as those found on a victim, perpetrator and/or at some other location of interest. The object would be excluded or considered dissociated from the crime scene since it does not belong to the same class or group of interest.

1.2.4.3 Individualization

The process of classification leads to the identification of the object so that it can be grouped or classified. Classification is not intended to identify specifically

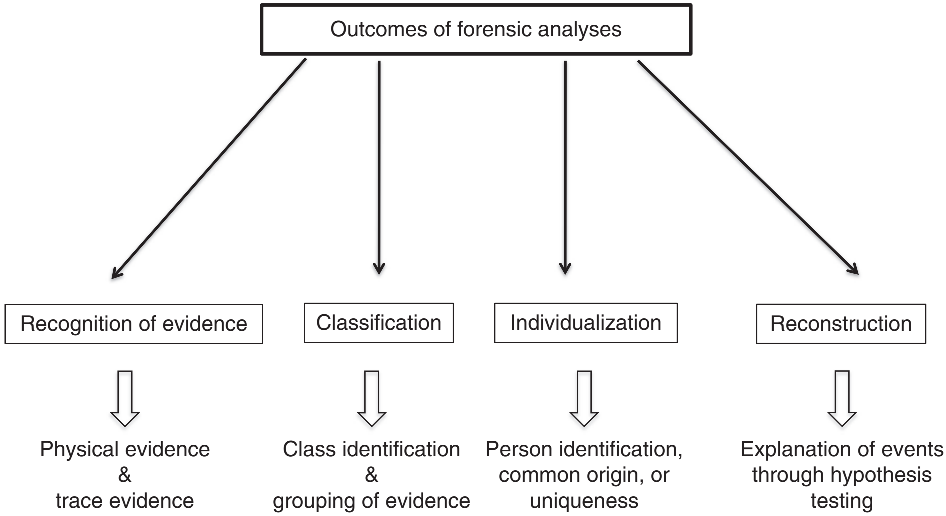

Figure 1.6 Types of comparison testing used in forensic analyses and the possible outcomes that can result.

say the individual or, in the case of insects, the species of fly or beetle found on a corpse. Individualization is a further level of identification, or narrowing of classification, that involves comparison testing to distinguish an object as being unlike or unique from others in a grouping, or to determine that the physical evidence has the same source or origin when compared with another item in the same class (Gaensslen *et al*., 2007). The latter is commonly done when impressions of shoe prints or tire tread marks from a crime scene (**scene impressions**) are compared with **test impressions** (Figure 1.6). The impressions can then be identified further by making comparisons with specific brand characteristics using databases supplied with information from the manufacturers.

The identity of a victim or an attacker like a rapist can be determined or individualized through the use of DNA profiling on blood, semen or other body fluid evidence, or from fingerprint analyses. In the case of an individual with a prior criminal record, the DNA sequences or fingerprints can then be compared in databases like CODIS. Insect evidence can be identified in a similar fashion by using a series of dichotomous identification keys, voucher specimens, and even DNA analysis to determine which species was collected from a crime scene. These testing procedures can lead to **positive identification** of a victim, criminal and/or specimen. As with classification, individualization comparisons can also yield negative identifications or exclusions, for example an alleged suspect may be exonerated because the fingerprints or DNA do not match those found at the crime scene or on the victim.

1.2.4.4 Reconstruction

The investigative efforts of a forensic scientist that perhaps most closely showcases use of the scientific method is reconstruction. Because the process of reconstruction involves using the physical evidence and results from analyzing evidential objects to try to piece together the events of the crime, it can be thought of as analogous to hypothesis testing. Crime scene reconstruction requires formulation of explanations to account for the evidence collected, testing the explanations and then, based on the test results, refining the initial hypotheses so that further testing can be performed. The results of reconstruction can shed light on the events that occurred before, during, or immediately after the crime was committed. This information is useful in corroborating or refuting statements made by a victim, suspect or eyewitness. As with scientific inquiry, this form of forensic analysis yields information that is mostly speculative theory based predominantly on physical evidence. Reconstruction does not “prove” anything is true (Figure 1.7).

1.2.4.5 Intelligence information

Ordinarily, gathering of intelligence information related to the activities of criminals falls outside the realm of the natural sciences, and is more consistent

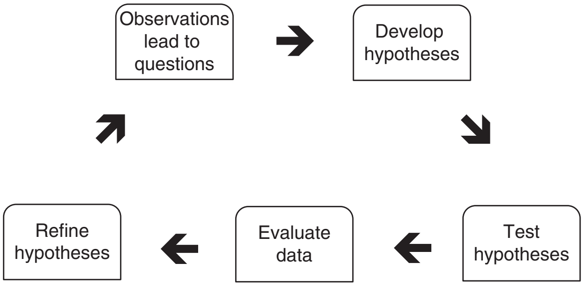

Figure 1.7 Schematic depiction of how the scientific method is used in the process of scientific inquiry.

with disciplines focused on profiling. However, changes in the global interactions between different groups of people, namely the widespread acts of terrorism, have broadened the scope of forensic science. Terrorist acts have become very sophisticated as has the "war on terror" employed by some nations. In the United States, several forensic scientists work to gather information on terrorist groups or cells by analyzing the weapons or components used to make the devices so that material suppliers or locations can be determined. Even insects have been used, as necrophagous fly larvae can be tested for bomb or other explosives residues in the hope that those responsible can be identified and/or the location of explosives assembly, and hence the terrorist group, can be identified. This approach relies on the assumption that a terrorist cell or group has an established **modus operandi**, i.e., that they use characteristic explosive materials.

The preceding simply provides an overview of some of the activities performed by forensic scientists. A more in-depth presentation of the roles of forensic scientists in forensic science and criminalistics can be found in National Research Council Committee on Identifying the Needs of the Forensic Science Community (2009) and Daeid (2010).

1.3 Recognized specialty disciplines in forensic science

Forensic investigation is used to examine issues common to criminal, civil, and administrative matters. To address such a vast array of topics, experts from many disciplines are needed to perform forensic analyses. The remaining chapters focus exclusively on forensic entomology. Eleven major subdivisions of forensic science are recognized by the American Academy of Forensic Sciences (http://aafs.org, see Table 1.1), considered to be the largest organization of forensic scientists in the world, with as many as 31 subdisciplines contributing expert analyses in legal cases. Here we provide a brief snapshot of some of the related fields of forensic science, and forensic entomologists may collaborate with workers in these fields while working on a case.

1.3.1 Forensic pathology

Synonymous with forensic medicine, forensic pathology is the discipline concerned with determining the cause of death through examination of a corpse. A forensic pathologist determines the medical reason for the person's death and also attempts to decipher the circumstances surrounding the death. The pathologist performs an autopsy at the request of the medical examiner (a physician by training) or coroner (an elected official who may or may not be trained in medicine).

1.3.2 Forensic anthropology

Forensic anthropology uses applied principles of physical anthropology, the study of human form via the skeleton system and osteology (study of bones) to examine human remains in a legal context. Reconstructing a body from skeletal remains or making individual or gender identifications are some of the main functions of a forensic anthropologist. The "body farm" at the University of Tennessee in Knoxville is a major research facility maintained by the Department of Anthropology that essentially thrust forensic anthropology into the limelight. The facility has been instrumental in conducting basic and applied research using human corpses to shed light on factors influencing decomposition and altering remains **postmortem**.

1.3.3 Forensic dentistry (odontology)

Forensic dentistry is the area of forensic science concerned with dentition or teeth as it pertains to legal matters. The discipline can essentially be divided into activities where dental patterns or individual teeth are used for identification of an individual or to whom an individual tooth belongs, and use of bite marks to individualize a potential attacker in which a victim has been bitten. Teeth can also be used as a source of DNA for subsequent identification as well.

1.3.4 Forensic psychology and psychiatry

Forensic psychologists and forensic psychiatrists have similar roles in the judicial system. In some instances, they determine if a defendant is competent to stand trial for the accused offense. In other instances, the expertise of a psychologist or psychiatrist is needed in intelligence gathering, i.e., trying to characterize the patterns or other features of the modus operandi of a criminal in an effort to apprehend the individual before he or she commits another crime. This role is generally referred to as **forensic profiling**.

1.3.5 Forensic toxicology

Forensic toxicology primarily functions to analyze samples associated with poisoning, drug use, or death. Forensic analyses performed by a forensic toxicologist include qualitative analysis and classification to determine what the substance is, as well as quantitative analysis to determine amounts of substance. The latter can be significant in determining if a crime has been committed, such as when alcohol has been consumed, or deciphering causation of death when poisoning or an overdose is suspected.

1.3.6 Computer forensic science/ computer forensics

This discipline is considered a branch of digital forensic science and is focused on the information or data found on computer devices and other forms of digital media. As one might expect, the recent explosion of electronic data devices such as smart phones, MP3 players, readers and all forms of laptop computers has created an upsurge in training associated with digital media. Computer forensic science focuses on the identification, retrieval, preservation and storage of information found on digital media and associated devices as it pertains to civil and criminal matters.

1.3.7 Forensic botany

Forensic botany is the application of plant science to legal matters. Identification of plant species and application of plant development can be used to determine if a crime has been committed in a particular location, a body has been moved before or after death, and can help to calculate a portion of the PMI. In many ways, the roles of a forensic botanist are similar to those of a forensic entomologist.

Chapter review

What is forensic science?

- Forensic science can be defined broadly as the use of scientific knowledge and technologies in civil and criminal matters, including case resolution, enforcement of laws, and national security.
- Criminalistics is a term used to describe the functions of a crime or forensic laboratory and represents a more narrow definition of forensic science.
- The real value of science in legal matters is that it relies on validation via scientific inquiry using the scientific method, an approach that requires adherence to defined unbiased approaches to designing, conducting and interpreting experiments.
- Public opinion of what forensic science is and what it can do with regard to legal matters is riddled with unrealistic expectations, termed the CSI effect from popular television crime shows like *CSI: Crime Scene Investigation*.

Application of science to criminal investigations

- Forensic science is used to investigate several issues associated with criminal, civil, and administrative matters. Most forensic scientists work on cases of a civil or administrative nature, or deal with issues related to national security such as those under the umbrella of the Department of Homeland Security in the United States.

- The major functions performed by a forensic scientist include analysis of physical evidence, providing expert testimony to the court and, in some cases, collection of evidence at a crime scene.
- Forensic scientists spend the majority of their time applying the principles and methodologies of their discipline to the elements of the crime, principally analyzing the physical evidence, which is any part or all of a material object used to establish a fact in a criminal case. Items as diverse as bullet casings, bone fragments, a dental crown, matches, or fly maggots can serve as physical evidence.
- Many aspects of forensic analyses utilize the scientific method for the examination of physical and trace evidence, as well as other elements of a crime. The scientific method is a systematic approach or procedure for investigating natural phenomena. It relies on testing questions using an approach centered on formulating hypotheses, making observations from carefully designed experiments, refining questions, and narrowing possible explanations, so that further testing and observation can occur. The method is a skill that is learned or acquired from rigorous training and extensive practice.
- Physical or trace evidence collected from a crime scene is delivered to a crime laboratory or sent directly to a forensic expert for quantitative or qualitative analyses. In the majority of cases, the forensic scientist evaluates physical evidence by comparison testing, which includes recognition of evidence, classification (classifying or grouping the object), individualization (identification of individual or determining if two similar objects have a common origin), reconstruction (hypothesis testing when reconstructing events of the crime), and intelligence information (making inferences about criminals based on modus operandi).

Recognized specialty disciplines in forensic science

- Forensic investigation is used to examine issues common to criminal, civil, and administrative matters, and requires experts from many disciplines to perform the multiple forensic analyses.
- The American Academy of Forensic Sciences recognizes 11 major subdivisions of forensic science, with as many as 31 subdisciplines contributing expert analyses in legal cases.

Test your understanding

Level 1: knowledge/comprehension

1. Define the following terms:
   (a) modus operandi
   (b) physical evidence
   (c) scientific method
   (d) hypothesis
   (e) classification
   (f) trace evidence.

2. Match the terms (i–vi) with the descriptions (a–f).

(a) Identification of a victim based on DNA profiling	(i) Scene impression
(b) Study of poisons, drugs and death	(ii) Dependent variable
(c) Shoeprints found at crime location	(iii) Individualization
(d) Validated identified insect in a museum collection	(iv) Forensic toxicology
(e) Identifying an object to class or group	(v) Qualitative analysis
(f) Factor that is measured in an experiment	(vi) Voucher specimen

3. Explain how qualitative and quantitative analyses are used generally in forensic analyses.

4. Discuss how test and scene impressions are used in criminal investigations.

Level 2: application/analysis

1. Describe the process of classification and individualization for entomological evidence such as the presence of second- and third-stage larvae of the necrophagous blow fly *Lucilia sericata* collected from a corpse discovered in a wooded area in the southeastern region of the United States.
2. In an experiment aimed at determining which odors emanating from a corpse are attractive to adult flesh flies, identify potential independent variables that must be controlled.
3. Explain why controlled experiments are an important feature of well-designed reconstruction analyses.

Level 3: synthesis/evaluation

1. Design an experiment to test the hypothesis that "skin" color in adult blow flies (Family Calliphoridae) is due to pigments located in the exoskeleton. In your answer, identify the independent, dependent and control variables.

Notes

1. From the Plenary Session of the American Academy of Forensic Sciences 2004 Annual Meeting, as reprinted in Gaensslen *et al*. (2007).
2. Several TV shows portray computer applications, databases, molecular biology techniques and other technologies that do not yet exist, but the general public is unaware of this and expects similar approaches to be used today.

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Supplemental reading

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Additional resources

American Academy of Forensic Sciences: www.aafs.org
American Board of Forensic Anthropology: www.theabfa.org
American Board of Forensic Psychology: www.abfp.com
American Board of Forensic Toxicology: http://abft.org
American Board of Odontology: www.abfo.org
American Society of Forensic Odontology: http://asfo.org
Forensic medicine for medical students: www.forensicmed.co.uk
International Association of Computer Investigative Specialists: www.iacis.com
International Society of Forensic Computer Examiners: www.isfce.com
Society of Forensic Toxicology: www.soft-tox.org