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CHAPTER 2

Investigating and Processing Physical Evidence

OBJECTIVES

In this chapter you should gain an understanding of:

- Common objects found at a crime scene that qualify as physical evidence
- Different types of crime labs and their organization
- The functions performed by a forensic scientist
- Class and individual characteristics of physical evidence
- Reconstruction of a crime scene
- The admissibility of physical evidence and the role of an expert in court

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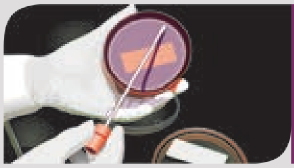


YOU ARE THE FORENSIC SCIENTIST

The smallest objects found as evidence are referred to as trace evidence. These objects (i.e., fibers, glass fragments, gunshot residue) are so easily transferred from one individual to another that they may provide evidence of association between a suspect and the victim. Because they are so readily transferred, investigators must take great care to avoid losing or cross-contaminating this evidence.

Usually trace evidence is transferred from one object to another in a process referred to as direct transfer. On other occasions, trace evidence is transferred from one object to another by way of an intermediate object, in a process known as secondary transfer. It also is possible that two or more intermediate objects may be involved in secondary transfer. It is important that investigators consider the possibility of secondary transfer whenever they examine trace evidence.

Consider the following trace evidence, which was found at the scene of a murder. In the victim's room, where the murder occurred, there is a fabric-covered chair. The suspect's jacket and sweater are seized from his apartment and examined for fiber evidence. The chair has fibers on it that match fibers from the jacket and the sweater. The jacket has fibers from the chair. The sweater does not have fibers from the chair on it.

1. Explain how the fibers might have been transferred.
2. Does this evidence prove that the suspect was in the victim's room more than once?

Introduction

Physical evidence is merely one piece of the puzzle when investigators are trying to solve a case. In some types of crimes (e.g., homicide, sexual assault), it may be the most important factor in proving the link between the suspect and the victim. Physical evidence may also be essential to prove that the same suspect is linked to a series of incidents. In other cases, the implications of the physical evidence must be confirmed by the testimony of witnesses and/or the confession of the suspect to warrant a conviction. This chapter describes how physical evidence is identified, classified, and then presented to a court of law.

Types of Evidence

Four types of **evidence** are distinguished: testimony, physical, documentary, and demonstrative (TABLE 2-1). The most common types of physical evidence are listed in TABLE 2-2. Because a crime scene tends to include so many physical items, it is impractical to treat each and every object that is encountered as evidence. Nevertheless, it is extremely important to identify those items that might provide significant probative information related to the crime. To do so, experienced investigators who are familiar with the circumstances of the crime scenes they examine must make logical decisions about precisely which items will be examined in more detail. In making this decision, an investigator does not rely on a list of what to take and what to leave

TABLE 2-1

Types of Evidence

Type	Definition	Example
Physical evidence	Tangible objects—that is, items that are real, direct, and not circumstantial	A weapon used to commit a crime; trace evidence found at the crime scene (e.g., blood, hair, fibers)
		Property recovered after a crime is committed; fingerprints shoeprints, tire tracks, handwriting
Documentary evidence	Any kind of writing, sound, or video recording; its validity is usually authenticated by expert testimony	A transcript of a recorded telephone conversation
Demonstrative evidence	Real evidence used to illustrate, demonstrate, or recreate a prior event	A cardboard model of the crime scene
Testimony	Evidence in the form of witnesses speaking under oath in court	Eyewitnesses, hearsay witnesses, character witnesses

TABLE 2-2

Common Types of Physical Evidence

Drugs: Any drugs, either licit prescription drugs or illicit substances.
Blood, semen, or saliva: Either dried or liquid blood, semen, or saliva that may be useful in identifying unknown persons or in establishing a connection between objects or persons.
Fibers: Any synthetic or natural fibers that may be useful in establishing a connection between objects or persons.
Fingerprints: Both visible and latent (invisible) fingerprints.
Firearms or ammunition: Any firearm, ammunition, shell casing, or bullet.
Glass: Holes in glass, glass fragments, cracks in glass.
Hair: Any human or animal hair.
Impressions: Impressions left by a wide variety of objects, such as shoeprints, tire treads, palm prints, and bite marks.
Organs or body fluids: Organs and body fluids undergo toxicological analysis for drugs, alcohol, and poisons.
Explosives: Objects containing explosive chemicals or objects covered with residues from an explosion.
Paint: Dried or liquid paint.
Petroleum products: Grease or oil stains, gasoline, paint thinner, or kerosene.
Plastic bags: Common household garbage bags.
Plastic, rubber, or other polymers: Common plastics found in the home.
Powder residue: Residue from the discharge of a firearm.
Serial numbers: Firearm identification numbers, vehicle identification numbers, serial numbers of computers and electronic devices.
Documents: Handwriting samples, typewritten (printer or typewriter) samples, paper, ink, erasures, and heat treatment.
Soils or minerals: Soil, gravel, or sand from various locations.
Tool marks: Objects that leave an impression, such as crowbars, screwdrivers, and hammers.
Parts from vehicles: Objects broken from an automobile.

TABLE 2-3

U.S. Federal Rules of Evidence

Article I
General Provisions
Rule 104(b): Relevancy Conditioned on Fact
When the relevance of evidence depends on the fulfillment of a condition of fact, the court shall admit it upon, or subject to, the introduction of evidence to support a finding of the fulfillment of the condition.
Article IV
Relevancy and Its Limits
Rule 401: Definition of Relevant Evidence
"Relevant evidence" means evidence having any tendency to make the existence of any fact that is of consequence to the determination of the action more probable or less probable than it would be without the evidence.
Rule 402: Relevant Evidence Generally Admissible; Irrelevant Evidence Inadmissible
All relevant evidence is admissible except as otherwise provided by the Constitution of the United States, by act of Congress, by these rules, or by other rules prescribed by the Supreme Court pursuant to statutory authority. Evidence which is not relevant is not admissible.
Rule 403: Exclusion of Relevant Evidence on Grounds of Prejudice, Confusion, or Waste of Time
Although relevant, evidence may be excluded if its probative value is substantially outweighed by the danger of unfair prejudice, confusion of the issues, or misleading the jury, or by considerations of undue delay, waste of time, or needless presentation of cumulative evidence.

behind. Instead, the investigator learns to focus on those objects whose scientific analysis is likely to yield important clues and that have provided useful forensic evidence in the past.

Once an object is collected at a crime scene, it is analyzed in the forensic laboratory. Based on the results of the scientific investigation, the prosecutor then decides whether the item will be presented to the court. Whether this object is considered evidence or not is solely determined by its relevance to the crime being investigated and the legality of its collection. In the United States, evidence is defined by the U.S. **Federal Rules of Evidence (FRE)** (TABLE 2-3). In court proceedings, the judge is responsible for determining what is relevant and what is not. Relevant evidence is deemed admissible; irrelevant evidence is deemed inadmissible.

The Modern Crime Lab

In the mid-1960s, there were roughly 100 crime labs in the United States. Today, there are roughly 390 publicly funded crime laboratories in this country, more than 80% of which are affiliated with police agencies. Clearly, the number of crime labs in the United States has increased dramatically in recent times, for two major reasons.

First, there has been an incredible increase in the crime rate in the United States. As the crime rate has increased, so has the percentage of crime that is drug related—and, in conjunction, the number of drug samples sent to crime labs. That is because all drugs that are seized by law enforcement authorities must be sent to a forensic lab for chemical analysis (to prove they are actually illicit drugs) before they can be used as evidence in court.

The second reason the number of crime labs has increased is the 1966 Supreme Court decision

on the CRIME SCENE: Physical Evidence and the Innocence Project

On November 16, 1983, as a 28-year-old woman was walking from work to home in Lowell, Massachusetts, an unknown man came up to her and tried to engage her in casual conversation. The woman didn't take up her end of the conversation, but the man forced her into a nearby yard and sexually assaulted her.

The following evening, within 100 yards of the first attack, a 23-year-old woman, who also was walking home from work, was pushed to the ground by a man wielding a knife. After struggling with her assailant, the second victim escaped her attacker and called the police. She described the assailant as a man wearing a red, hooded sweatshirt and a khaki-colored military-style jacket.

On the night of the second attack, the police stopped a suspect, Dennis Maher, who was wearing clothes that matched the description given by the second victim. A search of his car turned up an army field jacket, a military-issue knife, and a rain slicker. Maher, a U.S. Army sergeant, was arrested and charged with both attacks in Lowell plus an unsolved rape case that had occurred the previous summer in Ayer, Massachusetts. All three victims identified Maher from photographic lineups, even though their original descriptions of their attackers varied. Maher, however, insisted that he was innocent.

The Lowell attacks were tried together. Relying on the identifications made by the victims and no other physical evidence, Maher was convicted of the assaults. A month later, he was convicted of the Ayer rape, where physical evidence existed but was never tested.

In 1993, the Innocence Project—part of the Benjamin N. Cardozo School of Law established by Barry C. Scheck and Peter J. Neufeld—took up Maher's case. Members of the project repeatedly tried to gain access to the physical evidence from the victims that was collected at the time of the incidents, but they were told that the evidence could not be located. In 2001, a law student scrounging around the basement of the Middlesex County Courthouse found the box of evidence containing the clothing and underwear of one of the victims. The Massachusetts State Police Crime Laboratory found seminal fluid stains on the underwear as well as possible bloodstains on the clothing. Finding biological material on these items allowed for DNA testing by Forensic Science Associates.

Although the evidence found on the clothing was deemed inconclusive, the test results on the underwear produced a genetic profile of the assailant that excluded Maher as the donor of the sample. Prosecutors soon afterward located the evidence from the Ayer case, and testing by Orchid Cellmark again revealed that Maher was not the source of the biological material found on the victim.

On April 3, 2003, after 19 years in prison proclaiming his innocence, Dennis Maher was exonerated and released from prison.

in the case *Miranda v. Arizona*. In its ruling, the Supreme Court established the need for the so-called Miranda warning, which requires arresting officers to advise criminal suspects of their constitutional rights and right to counsel. As a consequence, fewer defendant confessions are now made, which has forced prosecutors to seek more thorough police investigation and to use more physical forensic evidence as part of their cases.

A few crime labs are owned by private companies and provide a particular specialty to law enforcement. Orchard Cellmark, for example, is well known for its work on forensic DNA. Battelle Corporation has expertise in arson cases, and Sirchie Corporation is known for its work on fingerprinting and trace evidence collection.

National Laboratories

The U.S. federal government does not have a single federal forensic laboratory with unlimited jurisdiction. Instead, four federal laboratory systems have been established to deal with evidence from suspected violations of federal (rather than state or local) laws. These laboratories are operated by the following government agencies:

- Federal Bureau of Investigation (FBI; part of the Department of Justice)
- Drug Enforcement Administration (DEA; part of the Department of Justice)
- Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF; part of the Department of the Treasury)
- U.S. Postal Service (USPS; Inspection Service)

TABLE 2-4

Services Provided by the FBI and the ATF Crime Labs

FBI Crime Lab	Units: Chemistry, DNA, Explosives, Firearms and Tool Marks, Forensic Audio, Video and Image Analysis, Latent Prints, Questioned Documents, Materials Analysis, Special Photographic Analysis, Structural Design, Trace Evidence, Investigative and Prosecutive Graphics, and Hazardous Materials Response
ATF Crime Lab	Investigates crimes relating to firearms, explosives, tobacco, and alcohol

Among the federal crime laboratories, those operated by two organizations stand out above the rest—the FBI and ATF laboratories. TABLE 2-4 lists the services provided by these federal labs.

State and Municipal Laboratories

Every state has established its own crime lab; these state-based facilities serve both statewide and local law enforcement agencies (if the local jurisdiction does not have its own lab). In addition, some states (e.g., California, New York, Illinois, Michigan, Texas, Virginia, Florida) have developed a statewide system of regional laboratories whose activities are coordinated by the state government in an effort to minimize duplication of services and to maximize interlaboratory cooperation.

By contrast, local crime labs serve city and county governments. For example, some larger cities operate their own labs, which are independent of their respective state laboratories.

Divisions of the Crime Lab

A crime lab typically includes six divisions that report to the director's office.

1. Biological/Serological Division: Deals with anything pertaining to fluids.
2. Chemistry or Toxicology Division: Deals with unknown substances, drugs, or poisons.
3. Trace Evidence or Microscopy Division: Deals with anything small enough to require a microscope for viewing, such as hairs or fibers.
4. Ballistics, Firearms, and Tool Marks Division: Deals with guns or weapons.
5. Latent Fingerprints Division: Locates, photographs, processes, and compares latent fingerprints to known candidates and to fingerprints in the Automated Fingerprint Identification System.
6. Questioned Document Division: Examines documents to identify the writer and to detect a forgery or alteration.

For their findings to be widely accepted, crime labs must establish their credentials as forensic laboratories. Accreditation by professional organizations such as the American Society of Crime Laboratory Directors, the National Forensic Science Technology Center, and the College of American Pathologists serves this function. In addition, labs may perform—and be certified for—specialized services. For example, a lab that specializes in the analysis of teeth and bite marks might apply to the National Board of Forensic Odontology for accreditation in this specialty area. Individual lab workers may also enhance their own credentials by joining associations such as the American Academy of Forensic Sciences and the American Board of Criminalistics.

To warrant accreditation, a crime lab must meet minimum requirements established by the certifying authority. Among other things, it must develop the following documents and programs:

- A quality control manual. Quality control measures ensure that test results (e.g., the results of DNA analysis) meet a specified standard of quality.
- A quality assurance (QA) manual. QA serves as a check on quality control. That is, a laboratory's QA measures are intended to monitor, verify, and document the lab's performance.
- A lab testing protocol. Protocols are the procedures and processes followed by the laboratory to ensure that it performs tests correctly and accurately. For example, a lab may perform validation studies to confirm that it is performing specific types of tests properly.
- A program for proficiency testing. Proficiency testing determines whether lab workers as individuals and the laboratory as an institution are performing up to the standards established by the profession. The laboratory or worker is given a sample, for which the results of the analysis are already known; if the lab's or worker's results do not match the known results, clearly there is a problem. Proficiency tests may be either blind (the worker is unaware that he or she is being tested) or known (the worker is aware of the test and can consult any resources necessary).

Functions of a Forensic Scientist

The forensic scientist performs the following steps as he or she processes physical evidence:

1. Recognize physical evidence.
2. Document the crime scene and the evidence.
3. Collect, preserve, inventory, package, and transport physical evidence.
4. Analyze the physical evidence.
5. Interpret the results of the analysis.
6. Report the results of the analysis.
7. Present expert testimony.

The first step, recognition of physical evidence, begins at the crime scene. Because all subsequent steps involve working with evidence retrieved from the actual scene, processing the crime scene is not only one of the first events to occur following commission of a crime but also one of the most important. If the case is to proceed smoothly, the collection and processing of physical evidence must be done both thoroughly and correctly. Yet another important aspect of forensic training is learning how to choose the appropriate analysis for the evidence that has been gathered.

Additional Information

The primary goal in analyzing physical evidence is to make the facts of a case clear. Through the analysis and interpretation of physical evidence, the expert can provide additional information that ties together the facts of the case.

Information on the Corpus Delicti

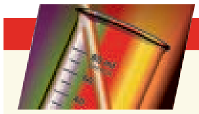
Facts dealing with the **corpus delicti** ("body of the crime") prove that a crime has actually taken place and that what happened was not an accident. Examples of such evidence for the crime of burglary might include tool marks on a broken door, which strongly indicate a forced entry, or a ransacked room from which jewelry is missing. For an assault, relevant evidence might include the blood of the victim on a suspect's clothes and a bloody knife, both of which indicate foul play.

Information on the Modus Operandi

The **modus operandi** (MO; the "method of operation") is the characteristic way in which career criminals commit a particular type of crime. In burglary cases, the types of tools used and the tool marks they leave, methods of ingress and egress, and types of items taken are all important clues. In arson cases, the type of accelerant used, its position in the building, and the technique that was used to ignite the fire often turn out to be a particular arsonist's "signature." Indeed, comparing the MO for a specific case to closed arson cases can sometimes lead to the identification of the arsonist.

Linking a Suspect and a Victim

Identifying a link between a suspect and a victim is extremely important, particularly in cases of violent crime. Blood, hairs, fibers, and cosmetics can all be transferred between victim and perpetrator, which are examples of **Locard's exchange principle**. This principle states that whenever two objects come into contact with one each other, there is an



BACK AT THE CRIME LAB

A forensic scientist must be a "jack-of-all-trades" when it comes to the sciences. In particular, the forensic scientist needs basic knowledge in the following areas:

- Physics: Ballistics, explosion dynamics, fluid viscosity, and dust impression lifting
- Chemistry: Arson investigation, chemical decomposition of matter, and soil analysis
- Biology: Genetic fingerprinting, biological decomposition, and DNA analysis
- Geology: Soil samples
- Statistics: Statistical relevance of comparison tests that can stand up to cross-examination in court

Although many of these tasks will be carried out by trained specialists, having a basic understanding of each discipline ensures that the forensic investigator will not make mistakes in handling, preparing, and analyzing evidence.

exchange of materials between them. For this reason, every victim and every suspect must be thoroughly searched for trace evidence. As can be seen in **FIGURE 2-1**, every crime scene should be connected to a criminal and victim and every criminal and victim should be connected to the crime scene.

Linking a Person to a Crime Scene

Perpetrators as well as victims often leave fingerprints, shoeprints, footprints, tire tracks, blood, semen, fibers, hair, bullets, cartridge cases, or tool marks at the scene of a crime—another example of the Locard exchange principle. Conversely, victims, perpetrators, and even witnesses may carry glass, soil, stolen property, blood, and fibers away from the scene of the crime, and this evidence can be used to prove their presence at the scene.

Disproving or Supporting a Suspect's or Witness's Testimony

Suppose a person is accused of a hit-and-run accident. Examination of the undercarriage of the car reveals blood and tissue, but the vehicle's owner claims he ran over a dog. A species test on the blood would reveal whether it came from a human source, thereby supporting or disproving the investigator's hypothesis of the crime.

Identification of a Specific Suspect

Fingerprints and DNA left at the scene of a crime are the most conclusive ways of identifying a suspect. The probability of finding a fingerprint at a crime scene is more likely than the likelihood of finding a DNA sample.

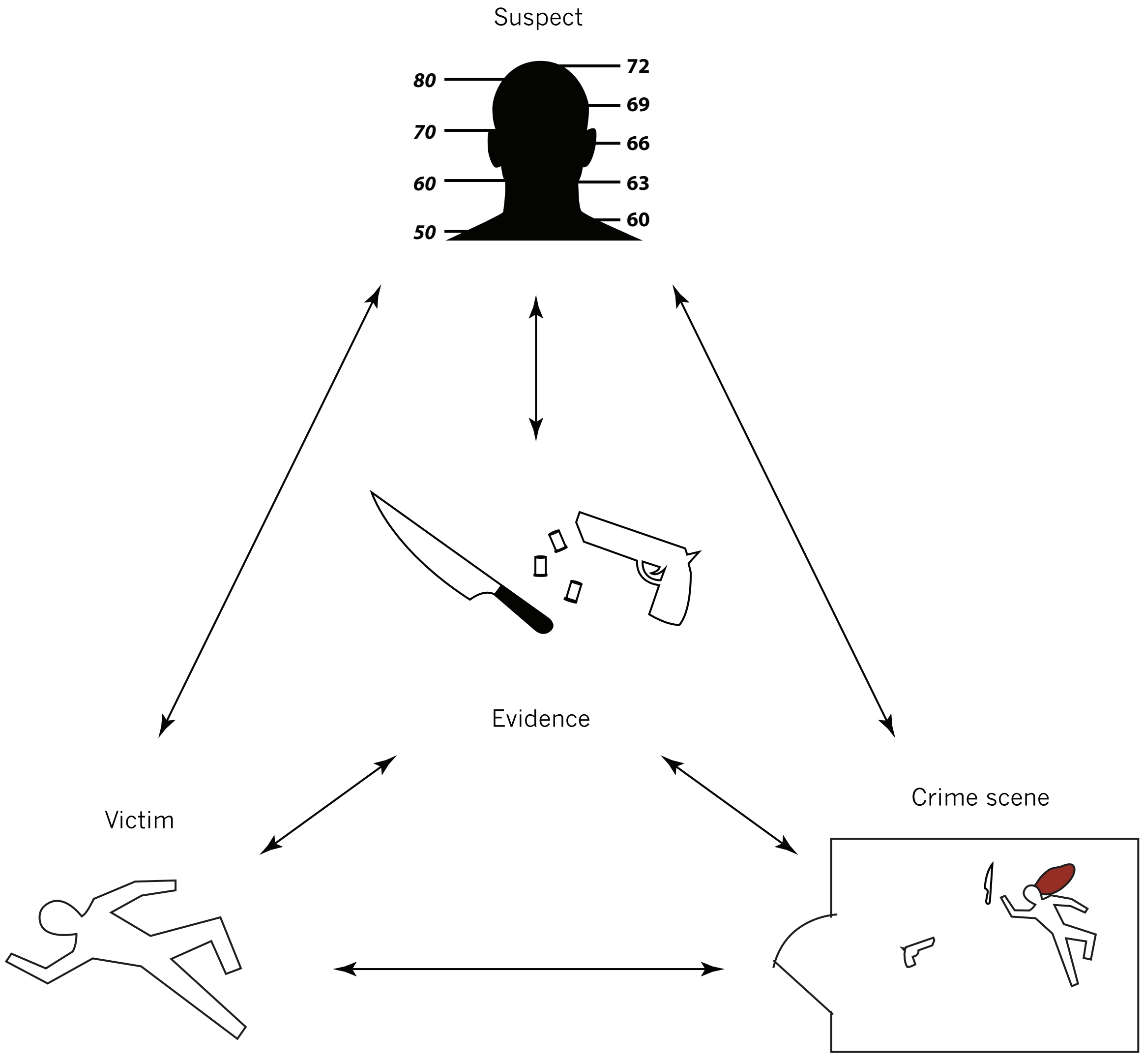


FIGURE 2-1 Every criminal, vicitm, and crime scene are connected by the transfer of physical evidence.

Providing Investigative Leads

Physical evidence can be used to direct the course of an investigation. For example, a paint chip left at the scene of a hit-and-run accident can be analyzed and used to narrow the search for the type of car that might have been involved in the accident.

Eliminating a Suspect

Physical evidence has exonerated many more suspects than it has convicted.

State of the Evidence

The crime scene and all of the evidence in it are subject to the effects of time. For example, sunlight or other environmental factors such as rain, snow, or wind may all alter the crime scene and destroy evidence. The moment an object is considered to be physical evidence, it becomes a mute witness to the crime. Investigators must move quickly to identify and protect evidence before environmental effects begin to alter its appearance and composition.

Biological evidence is most susceptible to change. A bloodstain found on the wall of a crime scene shortly after a shooting initially will be wet and red. As it is exposed to air, it will clot, dry, and eventually turn brown. If the crime scene is outside, blood also may be exposed to direct sunlight, which can change it from a red drop to a black dry spot in a relatively short period of time. In addition, rain can quickly wash it away.

Other physical evidence also may undergo changes due to time and physical influences. For example, a bullet may pass through a body of a suspect, picking up blood that could later be used to identify this person. But if the bullet then smashes through a wall, where the blood is scraped off its surface, its shape will likely be altered. The blood evidence on the bullet is scattered as it passes through the wall and might even be totally lost.

Likewise, part of a torn document left at a crime scene may be altered by exposure to the sun or water. The rays of the sun might bleach out the color, and water might change its texture. If a forensic scientist was trying to match the exposed piece to an unexposed piece of the same document, the two pieces might appear to be quite different.

Objects of evidence whose appearance changes with time can test the wits of crime scene investigators. These changes in appearance also challenge the forensic scientist, who must try to compare the evidence from the crime scene to a reference material, known as an **exemplar**. The forensic scientist must be able to show that the evidence (questioned sample) and the known sample (exemplar) have a common source. This leads the forensic scientist to use one of the most basic tenets of forensic science: **explainable differences**. That is, to show a common source for the two samples, the forensic expert must have a sound scientific explanation for any differences between the evidence (questioned sample) and the reference material (exemplar).

Why Examine Physical Evidence?

A forensic scientist examines physical evidence for one of two purposes: identification or comparison. **Identification** is the process of elucidating the physical or chemical identity of a substance with as much certainty as possible. Comparison is the process of subjecting both the evidence (questioned sample) and the reference material (exemplar) to the same tests to prove whether they share a common origin.

The comparison of evidence to reference material is an aspect of forensic science that differentiates it from all other applications of science. An object becomes evidence only when it contributes information to the case; otherwise, it is excluded from consideration. A bloodstain on the jeans of a homicide victim, for example, might appear to be an important piece of evidence until it is determined that the stain came from the victim. We already know the victim was present at the crime scene, so such a stain cannot be used to identify the perpetrator. Nevertheless, the location of the stain might provide valuable clues about the manner in which the victim was assaulted.

Characteristics of Physical Evidence

Identification

When a forensic scientist attempts to identify an object, he or she takes measurements that describe the physical and chemical properties of that object with as near-absolute certainty as scientific techniques will allow. For example, the crime laboratory might use chemical tests to determine if a white powder found at a crime scene is an illicit drug, such as cocaine or heroin, or the residue from bomb making, such as TNT. In cases involving biological material, such as blood, semen, and saliva, the crime lab might use molecular biological tests to determine the identity of the sample.

Many forensic analyses involve comparison of the questioned sample to some standard sample. A test is considered valid if it is reproducible, sensitive, and specific. To be reproducible, the test's analysis of the standard sample must always yield the same, correct results. To be sensitive, it must be able to accurately identify the unique characteristics of the substance. To be specific, the test must give a definitive result for a particular substance.

For example, if the forensic chemist is testing a white powder sample found at a crime section to determine whether it is cocaine, the test results must narrow the possibilities down so that cocaine is the only substance that would produce a positive result. That is, no other substance should give the same results as cocaine. Sometimes a battery of several different tests must be carried out to reach this conclusion with certainty.

One of the forensic scientist's most prized skills is the ability to pick the appropriate test for each questioned sample. In making this choice, the scientist must take a variety of issues into account, including the quantity and quality of the evidence (questioned sample). Some standard tests are easy to perform with large samples of material but do not have enough sensitivity to analyze trace quantities of evidence.

Once these testing procedures have been used repeatedly and shown to give reproducible, accurate results when used by several different laboratories, the test protocols are permanently recorded and become protocols that are accepted by the court. The FBI has established several scientific working groups (SWGs) that develop testing protocols in conjunction with crime laboratories as new standard tests emerge. For instance, in 2005 the Scientific Working Group for Materials Analysis issued protocols for the elemental analysis of glass to crime laboratories. Other FBI SWGs are focusing on gunshot residue, DNA analysis, the analysis of human hair, and other forensic evidence. Professional organizations, such as the American Society for Testing Materials, also establish standards for test methods that have been adopted by crime laboratories for specific analysis.

Forensic scientists must rely on their experience to know when they have performed enough tests on the questioned sample. At this point, they should have enough data to draw a conclusion about the questioned sample to a reasonable degree of scientific certainty—that is, beyond any reasonable doubt. The result is then ready to be presented to a court of law.

Associative Evidence

Physical evidence located at a crime scene can be used either to associate a suspect with a crime or to rule out that person as a suspect. Indeed, physical evidence excludes or exonerates people from suspicion more often than it implicates them.

Blood and other body fluids, fingerprints, hairs, bullets, firearms, and imprint evidence can all be **associative evidence**. These items are considered to be of uncertain origin until they are compared to a known standard (exemplar) that may be collected from suspects, victims, or witnesses. Two types of associative evidence are identified: that with **class characteristics** and that with **individual characteristics**. Associative evidence that has class characteristics can be classified only as belonging to a certain class of objects; such an item may be excluded as belonging to other classes of objects. When an object is examined and placed in a class, multiple sources remain as possibilities. By contrast, associative evidence that has individual characteristics can be associated with only a single source. When an object is individualized, the number of possible sources is reduced to just one. In some cases, it is even possible to state that a questioned object is unique.

For manufactured objects, class characteristics include, but are not limited to, the size, shape, style, and pattern of an object when it is made. These characteristics originate as a result of repetitive, mechanical steps that are repeated as copy after copy of the object is made. The distinctive tread pattern on the sole of a new shoe is a good example (FIGURE 2-2). The size, shape, style, and pattern are distinctive to the class of shoes that are produced by one manufacturer for one style. A tread pattern found at a crime scene would allow the forensic scientist to determine the size of the shoe, the manufacturer, and the style, which would allow the investigator to determine that the print was made by someone who owns a shoe from this particular class of shoes. Although such a shoeprint can be associated with a class of shoes with high probability, the shoe pattern alone is not enough to definitively identify which owner within the class of all owners of these shoes committed the crime. By contrast, a worn shoe with wear patterns unique to one individual would allow the

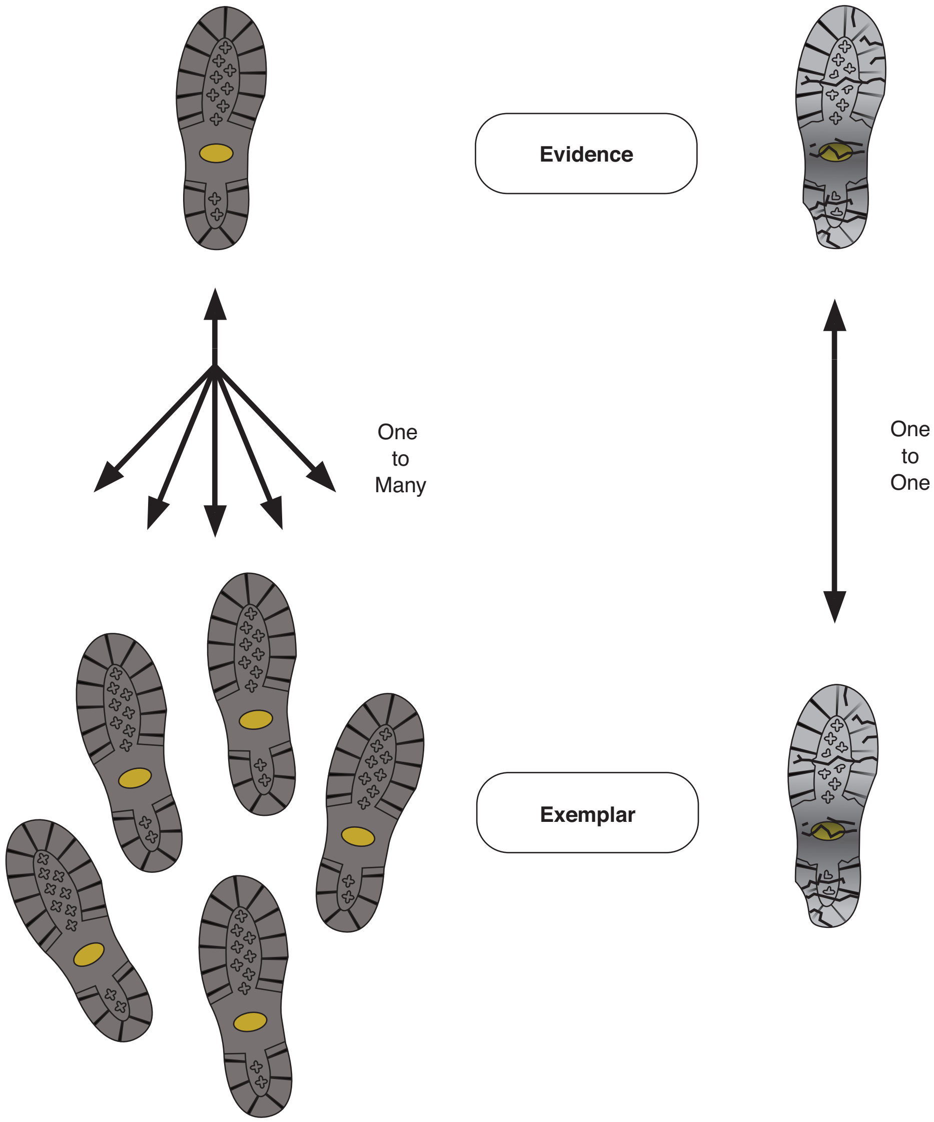


FIGURE 2-2 The difference between class characteristics and individual characteristics: The new boots on the left have only class characteristics while the worn boots on the right have individual characteristics.

forensic scientist to link this one shoe to the tread pattern found at the crime scene.

Analysis of class characteristics allows the forensic scientist to identify the object as being a member of a class of objects with high probability. Samples of drugs, fibers, hair, glass, blood, and soil all are examples of evidence that can be associated with a class. Unfortunately, without using sound, scientific information, the forensic scientist will be unable to associate the object with a single source (owner) with very high probability.

Individual characteristics may also include scratches and imprints that are left on an object that transform the object from being simply a member of a class to a unique object. For example, tool marks and impressions may turn an object with class characteristics into an object that has individual characteristics.

Tool Marks

A **tool mark** is created when some kind of tool creates an impression, cut, scratch, or abrasion in another surface. Even when the suspected tool is not recovered, marks left at one crime scene might match those found at other crime scenes. This information helps investigators link separate crimes and often leads to new investigative leads as evidence from the multiple scenes is pooled together.

Tool marks can be made by a variety of tools and are often left during the course of a burglary. Screwdrivers or crowbars, for example, may be used as levers to pry open windows and doors. Pliers and wire cutters may be used to cut through screens, vinyl windows, and padlocks.

Careful examination of the impression that a new tool leaves in a softer surface will provide class evidence, perhaps indicating the size and shape of the tool. A worn tool, by contrast, may have unique characteristics, such as a chip out of one side or a surface that is more worn on the right than on the left. If the edge of the worn tool is scraped against a softer surface, it will cut a striated line that is a mirror image of the pattern on the tool's edge.

Markings left on an object at a crime scene can be compared to an object that has been scratched in the crime laboratory with the same tool. To duplicate the tool mark, the forensic examiner makes several test marks. For example, he or she may apply different levels of pressure or change the angle at which the tool makes contact with the surface. In addition, the forensic scientist may make tool marks against a variety of surfaces. A lead- or rubber-based sheet, which is soft, is often pressed against the scored area to record the tool mark. The resulting tool mark is then compared with the tool mark observed at the crime scene using a comparison microscope.

When the impressions left at the crime scene are sufficiently unique and match the impressions made in the crime lab (FIGURE 2-3), the evidence has been individualized. A forensic examiner then can testify that the impressions could be made only by using the questioned tool.

At the crime scene, photographing the area around the impression is usually the first step in the recovery of tool mark evidence. Photos from a distance serve to show the impression's context in relation to the overall crime scene. Close-up photos taken at an optimal angle, with proper lighting, will record the unique features of the impression. Unfortunately, photography is not the best recovery method for tool marks because the finer details of the striations produced are not captured well by a photograph. Nevertheless, photography is not destructive, so additional tests can be carried out after the impression is photographed.

If possible, the object that was marked by the tool should be removed from the crime scene for later examination at the laboratory. Care must be taken in removing, packaging, and shipping the marked object to prevent any damage to or contamination of the evidence. If the marked object cannot be removed and shipped to the laboratory, the forensic examiner should make a cast of the mark. During this process, casting material that is made of silicone rubber or other filled plastics is applied to the impression and allowed to dry. The resulting cast can then be compared with the suspect tool (FIGURE 2-4). If the tool suspected of

Courtesy of Sirchie Fingerprint Laboratories.

FIGURE 2-3 A cast of a tool mark.

Courtesy of Sirchie Fingerprint Laboratories.

FIGURE 2-4 A cast of a hammer claw.

making the tool mark is recovered, it is critical that the investigator not try to fit it into the actual tool mark, because that may alter the impression.

Impressions

Impressions of one type or another often are left at crime scenes, such as impressions left by shoes or tires. These impressions may be deep (e.g., ruts in mud) or ultra-thin (e.g., barely visible marks in dust).

The first step in recording an impression is to photograph it. This piece of evidence should be photographed both alone and with a scale inserted into the scene to give a sense of the context and scale (FIGURE 2-5). Photographs taken from a distance serve to show the impression in relation to the overall crime scene. Close-up photos taken at an optimal angle, with proper lighting, will record the features of the impression.

Some of the information gathered in relation to the impression will place the impression in a class of objects. For example, a specific tire impression might suggest that it was made by one of the 235/65/R16 tires made by Dunlop. If the impression was made by a worn tire, it may contain features that are unique, such as a surface that is more worn on the right side than on the left. The tire impression left at a crime scene then can be compared to an impression that has been made in the crime laboratory with the tire from the suspected vehicle. When the impressions left at the crime scene match the impressions made in the crime lab

Courtesy of Sirchie Fingerprint Laboratories.

FIGURE 2-6 An impression of a worn tire.

(FIGURE 2-6), the evidence has been individualized, and a forensic examiner can testify that the impressions could be made only by the questioned tire.

Ideally, the entire object containing the impression will be collected and sent to the laboratory for subsequent testing. This step may be possible with items such as paper or floor tiles. In other circumstances, the investigator may not be able to physically remove the entire object, such as when a shoeprint is left in the earth. He or she must then "lift" the impression, so that the forensic examiner can subsequently compare this information with the suspect shoe or tire.

A variety of techniques are used to lift impressions. For example, clear tape may be applied to the impression and then pressed to eliminate any air pockets. A more elaborate but reliable lifting technique uses electrostatics to lift the impression (such as from dust) onto a plastic sheet. The electrostatic dust print lifter uses a plastic-coated metal sheet to which is applied a large negative charge. The plastic coated sheet is placed on top of the dust print, and the power is turned on. Any dust under the plate will take on a positive charge and will be attracted to the negatively charged plastic plate. The dust print that is transferred to the plastic-coated sheet will appear as a precise mirror image of the original print (FIGURE 2-7). This technique works well on rough-surfaced floor tiles or flooring with an irregular surface from which it would be difficult to lift impressions with tape.

To preserve tire tracks or shoeprints made in dirt or snow, the investigator should make a cast of the impression. First, the investigator photographs the impression to record the image. Then, the investigator places a casting frame around the impression. Next, he or she pours casting material

Courtesy of Sirchie Fingerprint Laboratories.

FIGURE 2-5 A footprint with a measuring scale.

Courtesy of Sirchie Fingerprint Laboratories.

FIGURE 2-7 The electrostatic plate will lift dust from horizontal and vertical surfaces, thereby recording the impression.

made from silicone rubber or dental stone into the impression (**FIGURE 2-8**). (Plaster of Paris is no longer used for this purpose because it crumbles too easily.) The cast needs a minimum of 30 minutes to set, and it should not be examined further for 24 hours. Because most gypsum casting materials generate heat during curing, an insulating medium must be applied to a snow impression before casting is attempted with this medium. For example, specialty waxes may be sprayed onto the snow impression to lock in the impression before the casting material is applied.

The laboratory procedures for comparing a recovered impression to an impression made by the suspect are possible only if the actual shoe or tire suspected of leaving the impression has been recovered. Test impressions may be necessary to compare the characteristics of a suspect's shoe to

Courtesy of Sirchie Fingerprint Laboratories.

FIGURE 2-8 Molds of shoeprints may be created with silicone rubber.

those of the impression found at the crime scene. As the examiner compares the two impressions, he or she will determine which class and individual characteristics the two impressions share. If the two impressions were made by shoes of the same size, width, shape, and tread design, for example, the examiner concludes that the suspect's shoe cannot be excluded from the class of shoes being considered. If the two impressions also share a sufficient number of uniquely individual characteristics such as uneven wear, gouges, cracks, or broken tread, then the evidence supports a finding that both the evidence and the test impression were made by this particular shoe and only this shoe.

Crime Scene Reconstruction

The physical evidence left at the scene of the crime may also be used to establish some of the events that occurred before, during, or immediately after the crime. That is, the evidence may help investigators determine the order in which the events took place. The reconstruction of some part of the crime scene may prove to be very important in corroborating or refuting a description of events that have been reported by witnesses or suspects.

Reconstruction of a crime scene begins with an examination of the crime scene. This step is followed by the collection and analysis of physical evidence and other independent sources of information, such as witness descriptions, photographs, sketches, autopsy findings, and written reports. Reconstruction is a complex process that involves the use of inductive and deductive reasoning, probability, statistics, and pattern analysis to analyze the data provided by the physical evidence. Often the team that is attempting to reconstruct the crime scene must solicit input from specially trained experts as part of this process. Reconstruction is used often in criminal cases in which there is no eyewitness evidence or where eyewitness evidence is considered unreliable.

Pattern Evidence

The physical evidence that is left at a crime scene provides the foundation for reconstructing the events that took place and—ideally—the sequence in which they occurred. Although the evidence alone does not describe all the events of the crime, it can be considered a "mute witness" that either supports or contradicts statements given by suspects or eyewitnesses. In addition, physical evidence can generate investigative leads. The collection and analysis of physical evidence form the foundation of crime scene reconstruction.

Explosion Patterns

An analysis of damage patterns at the scene of an explosion can provide investigators with information that will allow them to form a hypothesis about how the detonation took place and then begin to reconstruct the event. Some of the features that can be observed in the damage can be of great value:

- The direction in which the blast traveled
- The location of maximum damage
- Analysis of the debris field

When investigators mark the scene with indicators that show the direction of the blast, they will be able to establish the site of the detonation. Fragments and debris will be blown in all directions from this location, but can eventually be traced back to that location. Given that what is left of that location will hold the largest amount of residue and possibly bomb fragments, investigators will have the best chance of finding chemical residue there that may help identify whether an explosive was used or whether the explosion resulted from a malfunction in a mechanical device (e.g., gas stove, gas tank, furnace).

If a powerful explosive is used, investigators can estimate the weight of the bomb by determining the size of the crater left behind. The diameter (d) of the crater, measured in meters, is used to determine the weight (w) of the bomb, measured in kilograms, by using the following equation:

$$w \cong \frac{d^3}{16}$$

Firearm Ballistics

Reconstruction of crime scenes involving firearms often is necessary to determine the cause of death—whether homicide, suicide, or accidental death. Reconstruction can also provide information that places the shooter and the victim at precise locations within the crime scene. The reconstruction of the trajectory of the bullet may also prove or disprove the testimony of a witness.

Entry and Exit Hole Geometry

In cases where the bullet passed through an object, the shapes of the entry and exit holes will indicate where the bullet entered the object. If the bullet remained intact, the entry hole is most often smaller than the exit hole. Most bullet holes are elliptically shaped, so trigonometry can be used to estimate the angle of entry. The following equation is used to estimate the angle of entry (θ) from measurements of an elliptical bullet hole:

$$\text{Cos } \theta = \frac{\text{Shorter dimension}}{\text{Longer dimension}}$$

Bullet Trajectory

Crime scene investigators use two methods to determine the trajectory of a bullet after they locate any bullet holes in walls, floors, ceilings, or other objects at the scene. The older method uses physical objects, such as rods and strings, to find trajectory. The rods are inserted into the holes, and string is used to estimate the trajectory. The newer method uses a laser to visualize the bullet's trajectory (FIGURE 2-9). The laser can be mounted on a tripod and its beam shot through a hollow plastic tube (trajectory rod) that is inserted into the bullet hole. The laser finder has a protractor attached to the laser; once the laser has been sighted through the trajectory rod, the angle of entry is then read from the protractor. The laser device is more expensive but easier to use over longer distances.

Courtesy of Sirchie Fingerprint Laboratories.

FIGURE 2-9 A laser can be used to determine a bullet's trajectory.

Bullet Ricochet

When examining a bullet's trajectory, investigators must take into account the possibility of **ricochet**. Ricochet is the deviation in the flight path of a bullet as a consequence of impact with another object. That is, the bullet hits a hard surface and rebounds to hit someone or something at the scene. If the investigator finds that the victim was shot because of an accidental ricochet rather than an intentional shot aimed at the individual, then the investigation changes to an accident investigation.

Not all projectiles have the same tendency to ricochet. Low-velocity, heavy bullets are more likely to ricochet. By contrast, high-velocity, lightweight bullets tend to expand on contact and are more likely to break up on impact with a hard surface. Careful examination of the scene will indicate ricochets as damage to the walls, floor, and ceiling. Ricochet is more likely in scenes involving concrete or brick walls. Bullets recovered from a victim may have markings that indicated that they struck a very hard surface. Furthermore, particles of paint, plaster, or soil that were picked up at the ricochet impact site may still be found attached to the bullet.

Shell Casings

Shell casings from automatic and semiautomatic weapons found at a crime scene can provide useful information. Shell casing patterns at crime scenes are difficult to interpret, however. Although most semiautomatic weapons eject casings to the right, many factors influence the ejection pattern—for example, how the shooter's body is positioned, how the shooter holds the gun, whether the shooter is stationary or in motion, and how hard the ground is. Once the suspect's weapon has been located, forensic firearms experts can experiment by varying these factors as they try to reconstruct the events involving the gun.

Bloodstain Patterns

In violent crimes, interpretation of bloodstain patterns may provide vital information about what actually happened at a crime scene. Often, bloodstain patterns open a window to the events that occurred during the commission of the crime. The size, shape, and pattern formed by bloodstains found at a crime scene all can be used to reconstruct events.

The bodies of adult males hold approximately 5 to 6 quarts of blood; the bodies of adult females contain 4 to 5 quarts of blood. Thus it is not surprising that in violent crimes, large amounts of blood are often found at the scene. If the crime is committed indoors, the walls, the floors, and even the ceiling may all be spattered with bloodstains. Bloodstain evidence may even be present in rooms other than the one where the crime was committed.

Active Bloodstains

Active bloodstains are caused by blood that travels because of force, rather than because of gravity. Active bloodstains could result from an impact to the victim's body by a weapon, such as a knife, hammer, or bullet. Bloodstains caused by impact usually form a spatter pattern in which numerous small droplets of blood are dispersed. Active bloodstains are produced by pumping pressurized blood onto a surface when an artery is cut and the heart continues to pump. Depending on the nature of the wound, the volume of blood may be large (gushing) or relatively small (spurts). The overall pattern of the projected bloodstains may reflect the oscillation of pressure produced as the heart pumps. An object that is covered with blood, such as a knife, also may produce an active bloodstain: Blood can be thrown from the knife as it is moved or if it is stopped suddenly. Bloodstains produced in this way are known as cast-off stains.

By observing the shape of a bloodstain, an experienced investigator may be able to determine the direction in which the droplets were traveling when they hit a surface. If the bloodstain is elliptically shaped with a tail, the direction of travel may be easily determined. The tail of the bloodstain points to the direction of travel of the blood droplet (FIGURE 2-10). Conversely, a round spatter pattern indicates that the angle of impact is perpendicular to the object or at 90°. An investigator must be careful with these stains because one exception is possible: If the large drop of blood throws off a smaller droplet on impact, the tail of the smaller "satellite" stain will point toward the "parent" drop (FIGURE 2-11). Once the investigator determines that a small stain is a satellite, however, the information presented by the bloodstain tails will be consistent.

FIGURE 2-10 The tails of these bloodstains indicate their direction of travel.

The angle of impact of a bloodstain can be determined from its dimensions. The trigonometric calculations that follow are based on the fact that a drop of blood that is moving through the air will assume a spherical shape. When it hits a surface, the blood will produce a stain that is longer than it is wide (oval or elliptical) if it is falling at any angle other than 90° (FIGURE 2-12).

In this example, the width of the stain is the same as the diameter of the drop before impact. The length of the stain, however, is related to not only the diameter of the drop, but also the angle of

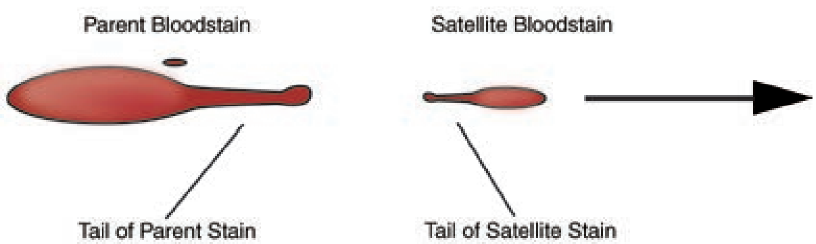


FIGURE 2-11 This larger bloodstain created a satellite bloodstain, as can be seen by the satellite's tail.

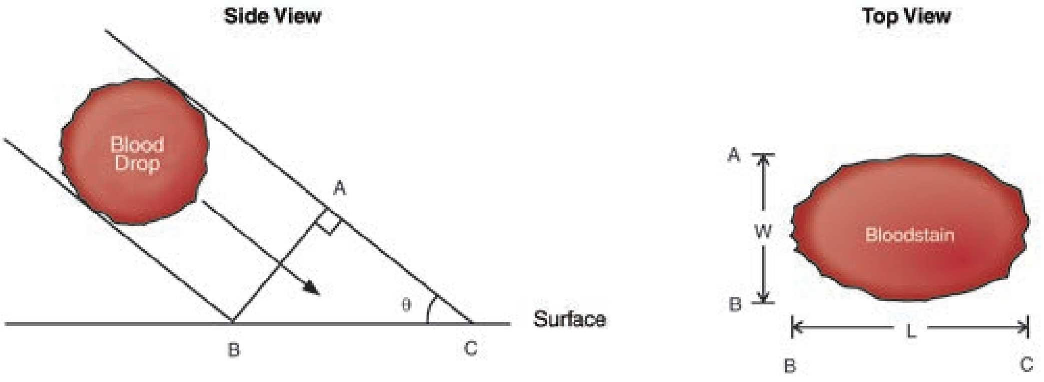


FIGURE 2-12 The dimensions of a blood drop reveal the angle of impact.

impact (θ). The width of the drop is equal to AB, which is one side in a right triangle that lies opposite to angle θ. The length of the drop is equal to the hypotenuse (BC) of the triangle. The ratio of the width (short side) to the length (long side) of the bloodstain is equal to the sin of the impact angle:

$$\text{Sin}\ \theta = \frac{\text{Width}}{\text{Length}}$$

Example

Determine the angle of impact of a bloodstain that is 10 mm wide and 20 mm long.

Solution

Use the equation

$$\text{Sin}\ \theta = \frac{\text{Width}}{\text{Length}}$$

to determine the ratio.

$$\text{Sin}\ \theta = \frac{10\ \text{mm}}{20\ \text{mm}} = 0.5$$

Take the arcsine of 0.50 to find the angle.
The arcsine of 0.50 is 30°.
The angle of impact is 30°.

Transfer Bloodstains

Transfer bloodstains are deposited on surfaces as a result of direct contact with an object that has wet blood on it. Examination of transfer bloodstains may indicate points of contact between suspects and objects present during a crime. Transfer bloodstains also are used to establish the movement of individuals or objects at the crime scene.

Transfer stains are left behind when an object that is covered with wet blood, such as a knife or an assailant's hand, contacts another object, such as a dishcloth used to wipe off the blood. The pattern produced by the transfer might be detailed enough that it will establish the type of object that left it. If a particular pattern (such as a shoeprint) is found repeatedly at the scene, the movement of the object (i.e., the person wearing the shoes) can be determined. After the initial transfer, the amount of blood deposited decreases with each successive step until no more blood is left and the trail disappears. Even when the trail of transfer stains becomes too faint to be seen by the naked eye, however, it may be possible to visualize the print by using a chemical treatment.

Point of Convergence

When there is more than one spot where blood spattered, the point where the blood was released can be determined. As can be seen in FIGURE 2-13, a straight line is drawn down the middle of the long axis of each of the blood spatters. The point at which the drawn lines intersect is the point of convergence, the place where the blood originated.

When multiple bloodstains appear to have originated in the same place, investigators may be able to use trigonometry to determine their **point of convergence**. The point of convergence is the most likely point of origin of the blood that made the stains (FIGURE 2-14).

Passive Bloodstains

Passive bloodstains are formed from the force of gravity. They may take the form of drops, a pool, or a blood flow. Passive bloodstains might cover a victim, the area under the victim, and objects near the victim. Examining the passive bloodstain may

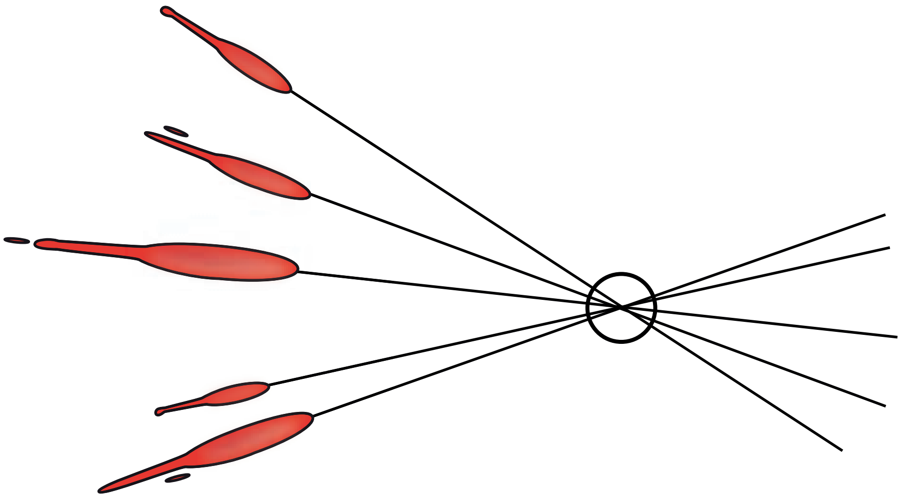


FIGURE 2-13 Where the lines converge indicates the point where the blood originated.

suggest how much time has passed since the blood was deposited. The drying times of drops and pools can be estimated from experiments carried out in the laboratory on the same surface material and at the same temperature and humidity.

The pattern produced by dropping blood is caused by the surface tension of the blood drop and the high viscosity of blood. Blood has a viscosity (thickness) that is four times greater than the viscosity of water. Vertically dropping blood generally produces a circular pattern. As the distance between the source of blood and the floor increases (i.e., the distance the blood falls increases), the size of the circular pattern increases (FIGURE 2-15). Once the distance the drop must fall exceeds 48 inches, the drop sizes remain the same.

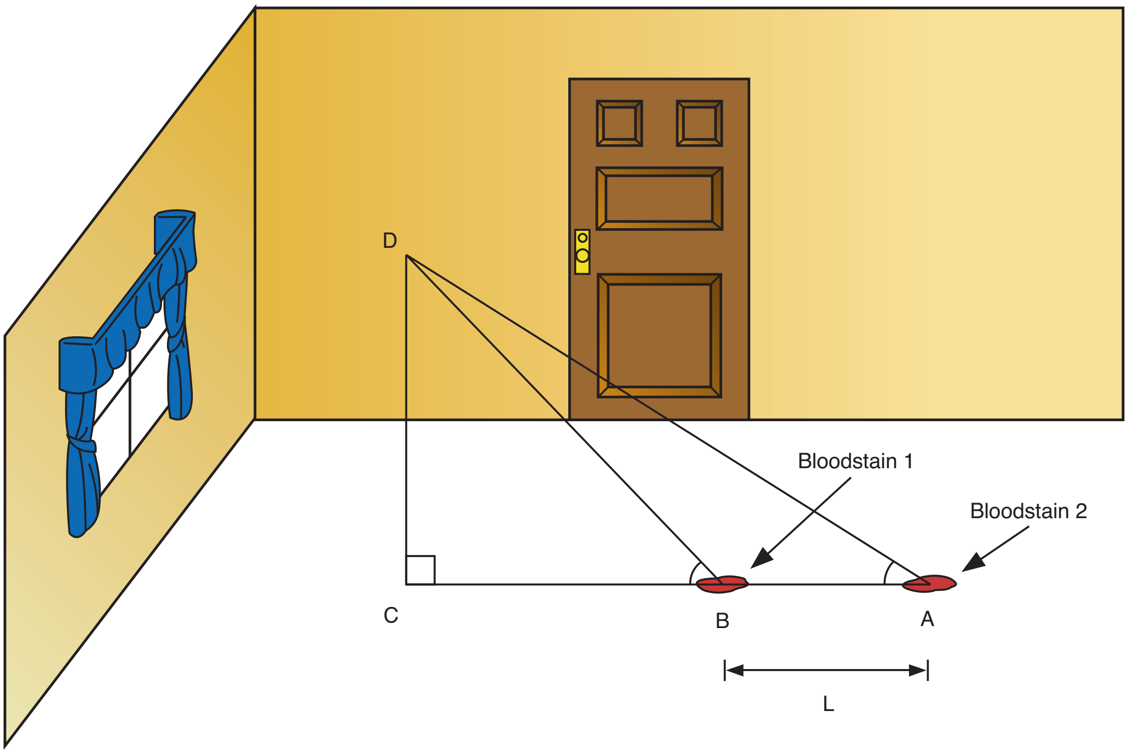


FIGURE 2-14 Investigators may use bloodstains found at a crime scene to calculate the position from which the blood originated, known as the point of origin (D).

Example

Suppose that stain 1 is 10 mm long and 5 mm wide, and stain 2 is 8 mm long and 6 mm wide. Using the earlier equation, we can determine that the incident angle is 30° for stain 1 and 48.5° for stain 2. If the blood that caused these stains originated from the same place, we can then identify that origin.

Solution

To do so, we draw a line from the center of each stain to a point where each line intersects. At the point of intersection (C), we draw a line at a right angle to the floor and high enough that it will show the origin of the blood. At this point, we draw two right triangles that have a common point of intersection on the line just drawn (D) and that share a common line (CD). We can use either of these triangles to calculate the length of CD and the height of point D, the origin of the blood. Suppose we take triangle ACD, where the side of the triangle (AC), which is adjacent to the point of impact, is 0.75 yd from point C. The length of CD is calculated by the following equation:

$$(\tan 30°)(0.75 \text{ yd}) = 0.433 \text{ yd}$$

This calculation tells us that the blood originated 0.433 yd from the floor at point D in the diagram. Of course, this assumes that both stains originated at the same moment and were not deposited at two different times. Such complications illustrate the complexity and the limitations of blood pattern analysis.

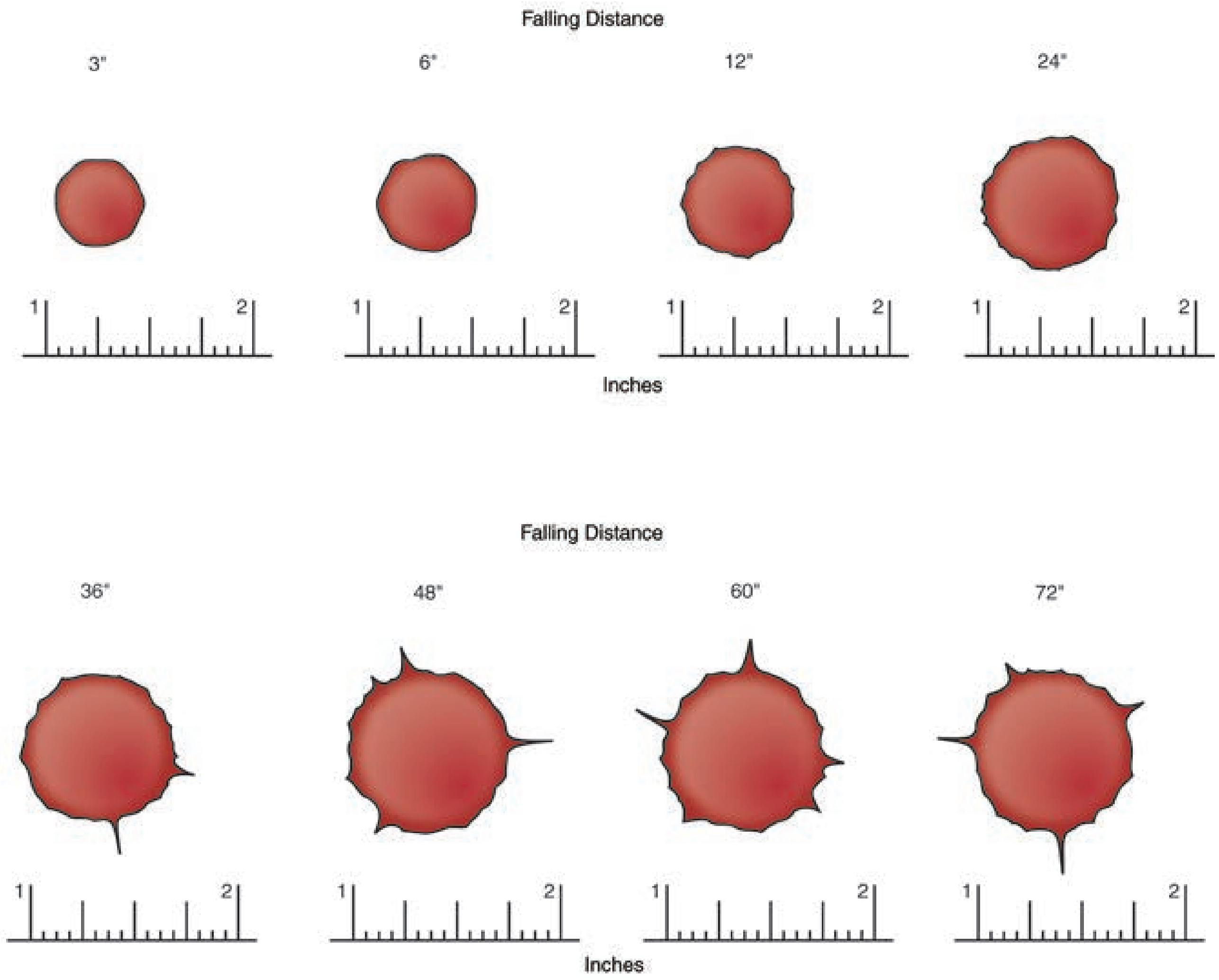


FIGURE 2-15 The diameter of the bloodstain increases with the distance it falls. At 48 inches and higher, all droplets have the same diameter.

The texture of the surface on which the drop falls also affects its size and shape. Hard, nonporous surfaces produce a circular stain with smooth edges. Softer, porous surfaces produce stains that have scalloped edges.

Physical Evidence in Court

Physical evidence has value in court proceedings only when the forensic scientist who testifies about it understands—and can explain to a jury—how the evidence was analyzed and how the results of this analysis may be interpreted in the context of the crime scene. The procedures and technologies that are used in the crime laboratory not only must be based on sound scientific principles but must also satisfy the criteria of admissibility previously established by the courts. Consequently, the forensic expert needs to understand the judicial system and the standards of admissibility for scientific expertise, which may vary from state to state and sometimes even from court to court within states.

During the early part of the 20th century, the guidelines for determining the admissibility of scientific information were governed by what is known as the Frye standard (*Frye v. United States*, 1923). At that time the judge decided whether the techniques used by the forensic scientist to examine evidence could be admitted to court as evidence. Such a "general acceptance" test required the scientific test to be generally accepted by the scientific community. Today, courts expect experts to present scientific papers that have been reviewed by other respected scientists and books that have been written about the test procedures. In addition, if other courts have admitted the procedure in prior judicial proceedings, then that precedent is taken into consideration. As a specific test has become more commonly used in courts, some jurisdictions have issued judicial notices that the test is generally accepted and that experts do not have to prove the test valid every time it is used in an individual court. More recently, the Frye standard has generated debate about its inability to deal with new and innovative scientific tests that may not be generally accepted.

In federal courts, the FRE govern the admissibility of all evidence, including expert testimony. FRE rule 401, for instance, allows anything that materially assists the finding of fact (by the jury) and is deemed relevant by the law (by the judge). FRE rule 702 regulates the admissibility of testimony by experts:

> *If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts of data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.*

SEE YOU IN COURT

Defense attorneys often question whether critical evidence was not collected because the crime scene technicians favored some evidence over other evidence owing to their operating theory of the crime. Of course, the task of selecting which prosecutorial evidence to present in court actually belongs to investigators working with prosecutors; this decision is not made by crime scene technicians. Crime scene and laboratory technicians should know as little as possible about the testimonial evidence. As a result, crime scene technicians may collect a great deal of physical material that in the end proves worthless. That is part of the job.

At the time a crime scene is examined, some evidence will be obvious; other evidence will not. Scene technicians must be able to indicate with certainty that nothing that could have been analyzed remains uncollected. Similarly, lab technicians must be able to justify the testing protocols employed and the failure to perform other tests. Where samples are too small to preserve any material for a defense testing lab, justifications must be clear why that is so. Technicians must be familiar with the use of their testimony, evidence, and findings in a courtroom and the limits of that use.

Coppolino v. State (1968) reinforced the wide discretion and flexibility that a judge has when deciding admissibility of scientific evidence. In this case, the medical examiner testified that the victim died of an overdose of succinylcholine chloride, a drug prescribed as a muscle relaxant. A toxicology report had found an abnormally high concentration of succinic acid (a by-product of the body's metabolic breakdown of succinylcholine chloride) in the victim's body, and the medical examiner relied on these results in determining the cause of death. The defense argued that the toxicology data were gathered by a new test that had not gained wide acceptance in the scientific community. The court ruled in favor of the prosecution, however, and admitted the evidence. In its decision, the court noted that scientific progress is inevitable—new tests are constantly evolving to solve forensics-related problems. This ruling led to the Coppolino standard, under which a court is allowed to admit a novel test or a controversial scientific theory on a particular issue if an adequate foundation proving its validity can be laid even if the scientific community as a whole is not familiar with it.

A landmark ruling in the early 1990s led to the Daubert standard (*Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 1993), the test applied today in federal courts to determine admissibility of scientific evidence. The Daubert test requires special pretrial hearings for scientific evidence and special procedures on discovery. This rather strict test requires the trial judge to assume the responsibility of "gatekeeper" in ruling on the admissibility of scientific evidence presented in his or her court. Judges can use the following guidelines to help them gauge the validity of the scientific evidence:

1. Has the scientific technique been tested before?
2. Has the technique or theory been subject to peer review and publication?
3. What is the technique's potential rate of error?
4. Do standards exist that can verify the technique's results?
5. Has the technique or theory gained widespread acceptance within the scientific community?

Although the Daubert standard was considered overly restrictive when it was first proposed, it was affirmed in 1999 (*Kumho Tire Co. Ltd. v. Carmichael*). In this case, the court ruled that the trial judge should play the "gatekeeper" role for expert testimony as well as scientific evidence:

> *We conclude that Daubert's general holding—setting forth the trial judge's general "housekeeping" obligation—applied not only to testimony based on "scientific" knowledge, but also to testimony based on "technical" and "other specialized" knowledge. . . . We also conclude that a trial court may consider one or more of the more specific factors that Daubert mentioned when doing so will help determine that testimony's reliability. But, as the court stated in Daubert, the test of reliability is "flexible" and Daubert's list of specific factors neither necessarily nor exclusively applies to all experts in every case.*

Expert Testimony

Factual evidence often is given by a lay witness who can present facts and observations. That is, the layperson's testimony should be factual and should never contain personal opinions. The expert witness, by comparison, must evaluate the evidence and provide an analysis that goes beyond the expertise of the layperson. The expert's opinion must rest on a reasonable scientific certainty that is based on his or her training and experience. That opinion may be attacked by the opposing counsel, so the expert needs to be prepared to defend the conclusions reached. At the same time, the expert should be willing to concede limitations to the tests that are being presented. The forensic scientist should present a truthful, persuasive opinion and not serve as an advocate for one side or the other.

Because a forensic expert's results may be an important factor in determining the guilt or innocence of a suspect, experts are often required to present to the court the results of their tests and their conclusions. Judges are given the responsibility of accepting a particular individual as an expert witness. The expert must establish that he or she possesses particular knowledge or skill or has experience in a trade or profession that will help the jury in determining the truth of the issues presented.

The court usually limits the subject area in which the expert is allowed to present testimony. Before testifying, the prosecution qualifies the expert by presenting his or her education, experience, and prior testimony to the court in a procedure known as *voir dire* (French, but originally from the Latin *verum dicere*, meaning "to speak the truth"). This interrogation of the expert may be quite intense, because acceptance of an unqualified expert (or, conversely, exclusion of a qualified expert) is considered grounds for overturning the verdict in a higher court.

During the *voir dire* process, counsel often cites information that emphasizes the expert's ability and proficiency relative to the information to be presented, such as degrees, licenses, awards, and membership in professional organizations. If the expert teaches, has authored books, or has written scientific papers on the scientific issues, this information also helps to establish his or her competency. Generally, courts rely on the training and experience of experts to assess their knowledge and experience. In addition, judges are more likely to qualify an expert if the expert has been qualified previously by other courts.

Also during the *voir dire* process, the opposing attorney is given the opportunity to cross-examine the expert and to highlight any weakness in his or her education or experience. The question of precisely which credentials are suitable for expert qualification is subjective and is an issue that courts tend to avoid. Although the court may not necessarily disqualify an expert because of a perceived weakness in education or experience, many attorneys nevertheless want the jury to be aware of the expert's weaknesses.

Once an expert is deemed qualified, the judge will require the expert's testimony to stay within the limits previously set. Just how much weight a judge or jury will place on an expert's testimony depends on the information presented by the expert. Although experience and education are important factors, the expert's ability to explain complicated scientific data in clear, down-to-earth language may be even more important in establishing his or her credibility. The prosecution and defense counsel will try to lead the jury to accept their opposing theories of what happened, but it is up to the expert to present evidence and results to the jury in a clear and objective manner.

During cross-examination, the opposing counsel often challenges the accuracy and interpretation of test results obtained during the forensic examination of the evidence. When challenging the accuracy of the test results, the defense may raise the specter of cross-contamination during collection, transportation, storage, and testing of the evidence. The likelihood of cross-contamination of evidence has decreased significantly in recent years as the training for crime scene investigators has improved and clear chain of custody documentation for all physical evidence has been established.

The forensic scientist's interpretation of the scientific test results is likely to be the most significant area of disagreement during cross-examination. The forensic scientist forms an opinion based on what he or she considers the most probable explanation of the results. During his or her testimony, this individual must be careful to express an expert opinion that has a solid foundation based on test results.

WRAP UP

YOU ARE THE FORENSIC SCIENTIST SUMMARY

1. Fibers from the chair were found on the suspect's jacket, and fibers from his jacket were found on the chair. This evidence strongly supports the hypothesis that the suspect sat in the chair wearing his jacket. At the same time, fibers from the suspect's sweater were found on the chair, but no chair fibers were found on his sweater. This evidence suggests that the fibers from his sweater were transferred to the chair by a secondary transfer. The suspect got sweater fibers on his jacket earlier, and, when he sat in the chair, the sweater fibers on the jacket were transferred to the chair.
2. No, the fiber evidence indicates that the suspect sat in the chair. The evidence does not indicate how many times the suspect sat in the chair.

Chapter Spotlight

- Four types of evidence are distinguished: testimony, physical, documentary, and demonstrative evidence.
- There are approximately 350 crime labs in the United States. The FBI and the ATF laboratories are the two primary federal crime labs.
- Crime labs typically have six different divisions, dealing with the following areas: biological/serological analysis; chemistry/toxicology; trace evidence or microscopy; ballistics, firearms, and tool marks; latent fingerprints; and questioned documents.
- A variety of professional boards and societies are employed to accredit laboratories in regard to specialized kinds of evidence. Accreditation generally requires the establishment in the lab of quality control and quality assurance (QA) manuals, testing protocols, and proficiency testing procedures.
- The forensic scientist performs seven major steps as part of evidence analysis: recognition, documentation, collection and preservation, analysis, interpretation, reporting, and presentation of testimony.
- A forensic scientist's examination of the evidence can serve many purposes, ranging from determining the MO employed to linking a suspect to the crime scene. Nevertheless, the overall goal is to establish the unique status of the evidence, crime, and suspect.
- The conditions of the crime scene can affect the evidence available for collection.
- Evidence collected at a crime scene can be used to recreate or reconstruct the scene and determine how the crime occurred.
- A forensic scientist must be familiar with *Changes in the Standards for Admitting Expert Evidence in Federal Civil Cases Since the* Daubert *Decision* and the use of evidence in a courtroom.
- The Daubert test requires special pretrial hearings for scientific evidence and special procedures on discovery.
- Expert witnesses are usually challenged on one of two bases: accuracy of testing procedures and interpretation of the evidence.

http://criminaljustice.jbpub.com/Criminalistics3

Key Terms

Active bloodstain A bloodstain caused by blood that traveled by application of force, not gravity.

Associative evidence Evidence that associates individuals with a crime scene.

Class characteristic A feature that is common to a group of items.

Corpus delicti The "body of the crime."

Evidence Information about a crime that meets the state or federal rules of evidence.

Exemplar Representative (standard) item to which evidence can be compared.

Explainable differences A sound scientific explanation for any differences between the evidence and the reference material.

Federal Rules of Evidence (FRE) Rules that govern the admissibility of all evidence, including expert testimony.

Identification The process of matching a set of qualities or characteristics that uniquely identifies an object.

Individual characteristic A feature that is unique to one specific item.

Locard's exchange principle Whenever two objects come into contact with each other, there is an exchange of materials between them.

Modus operandi The "method of operation," also known as the MO.

Passive bloodstain A pattern of blood formed by the force of gravity.

Point of convergence The most likely point of origin of the blood that produced the bloodstains.

Ricochet Deviation of a bullet's trajectory because of collision with another object.

Tool mark Any impression, cut, scratch, or abrasion caused when a tool comes in contact with another surface.

Transfer bloodstain A bloodstain deposited on a surface as a result of direct contact with an object with wet blood on it.

Putting It All Together

Fill in the Blank

1. Whether an object is considered evidence is determined by its ____________ to the crime.
2. In court, it is the responsibility of the ____________ to determine what is relevant.
3. Investigators must move quickly to identify and protect evidence before ____________ effects begin to alter its appearance.
4. ____________ (Biological/chemical/physical) evidence is most susceptible to change.
5. Another name for physical evidence is the ____________ sample.
6. Another name for the known sample is the ____________.
7. If a piece of paper that is evidence is exposed to the sun and changes color, a forensic expert may match it to a known sample of paper that is a lighter color. The court must then be told about these ____________ (unexplainable/explainable) differences.
8. ____________ is the determination of the physical and chemical identity of a substance with as much certainty as existing analytical techniques will permit.

9. Before a test method can be adopted as a routine test in a crime laboratory, it must be shown to give reproducible, accurate results for a(n) ____________ sample.
10. The FBI has established ____________ that developed testing protocols and standard tests.
11. When an expert has drawn a conclusion "to a reasonable degree of scientific certainty," it means the conclusion has been substantiated beyond any ____________.
12. Size, shape, color, style, and pattern are all considered ____________ characteristics.
13. When an object is classified as belonging to a certain class, it is ____________ from other classes.
14. Evidence that can be associated with a single source with extremely high probability possesses ____________ characteristics.
15. A(n) ____________ is any impression, cut, scratch, or abrasion caused when a tool comes in contact with another surface.
16. Tool marks are encountered most often in cases of ____________.
17. ____________ is the first step in the recovery of tool mark evidence.
18. Impressions can be lifted from rough surfaces by the use of ____________.
19. Impressions left in snow can be cast by spraying ____________ into the impression before adding casting materials.
20. In reconstructing a bombing, investigators mark the scene with indicators to show the direction of the blast so that they can establish the ____________.
21. The weight of explosives used in a bombing can be estimated by the ____________.
22. Two methods are commonly used to determine bullet trajectory; the older method uses rods and strings, whereas the newer method uses ____________.
23. A(n) ____________ is the deviation in the flight path of a bullet as a result of its impact with another object.
24. Low-velocity, heavy bullets are ____________ (more/less) likely to ricochet.
25. A(n) ____________ bloodstain is formed when blood travels because of force, not gravity.
26. A(n) ____________ bloodstain is formed from the force of gravity.
27. Drops of blood falling on hard, nonporous surfaces will have a(n) ____________ shape.
28. Drops of blood falling on soft, porous surfaces have ____________ edges.
29. The "general acceptance" test that requires the scientific test to be generally accepted before it can be admitted as evidence in court is known as the ____________ standard.
30. The ruling that allows the court to admit novel or new tests is the ____________ standard.
31. The ____________ standard requires that the trial judge act as a gatekeeper for the admission of scientific evidence.
32. Before the judge qualifies an expert witness, the opposing attorney is given the opportunity to ____________ the expert.

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True or False

1. The forensic examiner should try to fit the suspected tool into the tool mark at the crime scene.
2. The tail of an elliptically shaped bloodstain points to the direction of travel of an active bloodstain.
3. The angle of impact of an active bloodstain can be determined by its dimensions.
4. Transfer bloodstains can be used to establish the movement of individuals at the crime scene.
5. The court never limits the subject area in which an expert witness is allowed to present testimony.
6. Testimony by an expert witness will include that person's opinion about the results of the tests that he or she has observed.

Review Problems

1. A crater left in concrete after a bombing in a parking garage measures 2 m. Estimate the weight of the bomb in kilograms.
2. A crater from a bomb that was left on the sidewalk outside a business measures 1.5 yd. Estimate the weight of the bomb in pounds.
3. A bullet hole in a door at a crime scene indicates that the bullet was shot from inside the room, then passed through the door and into the hall. The bullet hole is elliptically shaped. The shorter dimension is 11 mm, and the longer dimension is 15 mm. What is the angle of entry?
4. A bullet hole in a wall at a crime scene indicates that the bullet was shot from outside the room, then passed through the wall and into the room. The bullet hole is elliptically shaped. The longer dimension is 20 mm, and the shorter dimension is 14 mm. What is the angle of entry?
5. If a bloodstain is 5 mm long and 3 mm wide, what is its angle of impact (θ)?
6. If a bloodstain is 10 mm long and 3 mm wide, what is its angle of impact (θ)?
7. A circular drop of blood at a crime scene was measured to have a diameter of 0.8 in. What distance did it fall? What was the angle of impact?
8. A circular drop of blood at a crime scene was measured to have a diameter of 0.5 in. What distance did it fall? What was the angle of impact?
9. If bloodstain 1 in Figure 2-13 is 5 mm long and 3 mm wide, and distance BC is 3 ft 6 in, how far off the floor did the blood originate?

Further Reading

Becker, R., & Dutelle, A. W. (2013). *Criminal investigation* (4th ed.). Burlington, MA: Jones & Bartlett Learning.

Bevel, T., & Gardner, R. M. (2008). *Bloodstain pattern analysis with an introduction to crime scene reconstruction* (3rd ed.). Boca Raton, FL: CRC Press.

Bodziak, W. J. (2008). *The tread and tire track evidence: recovery and forensic examination*. Boca Raton, FL: CRC Press.

Crime scene investigation: a guide for law enforcement. (2013). Key Largo: National Forensic Science Center. http://www.nfstc.org/bja-programs/crime-scene-investigation-guide/

Dixon, Lloyd, Brian Gill, *Changes in the Standards for Admitting Expert Evidence in Federal Civil Cases Since the Daubert Decision*, http://www.rand.org/pubs/monograph_reports/MR1439.html

DuPasquier, E., et al. (1996). Evaluation and comparison of casting materials in forensic sciences: application to tool marks and foot/shoe impressions. *Forensic Science International, 82*, 33.

Federal Bureau of Investigation. (2007). *Handbook of forensic services* (rev. ed.). Washington, DC: U.S. Department of Justice, http://www.fbi.gov/about-us/lab/handbook-of-forensic-services-pdf.

Federal Judicial Center. (2000). *Reference manual on scientific evidence* (2nd ed.). Washington, DC: Author.

Fisher, B. (2012). *Techniques of crime scene investigation* (8th ed.). Boca Raton, FL: CRC Press.

Nordby, J. J. (2012). *Scientific foundations of crime scene reconstruction: introducing method to mayhem*. Boca Raton: CRC Press.

Scientific Working Group on Bloodstain Pattern Analysis (SWGSTAIN). *Forensic Science Communications, 11*(2). http://www.fbi.gov/about-us/lab/forensic-science-communications/fsc/april2009/standards/2009_04_standards01.htm/.

Vince, J. J., Jr., & Sherlock, W. E. (2005). *Evidence collection*. Sudbury, MA: Jones and Bartlett.

Wonder, Y. A. (2006). *Bloodstain pattern evidence-objective approaches and case applications*. New York: Elsevier.

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Answers to Review Problems

Chapter Objectives

Interactive Glossary

Flashcards

Crossword Puzzles

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