Objectives

After reading this chapter, you will understand:

- How class and individual evidence can answer different questions.
- How impression analysis is used in forensic science.
- The impact of firearms in the United States.
- The importance of microscopic examination in forensic science.

You will be able to:

- Distinguish types of firearms.
- Measure individual features of bullets and cartridge cases.
- Describe how a handgun works.
- Use color tests to find gunshot residue.
- Describe the procedure for estimating the distance between muzzle blast and target.
- Make casts of different types of impressions.
- Evaluate and present scientific data.
- Communicate and defend a scientific argument.
“Every gun that is made, every warship launched, every rocket fired signifies, in the final sense, a theft from those who hunger and are not fed, those who are cold and are not clothed.”

—Dwight D. Eisenhower (1890–1969), U.S. general and 34th president
In 2004 there were 29,569 gun deaths in the United States. Suicides accounted for 56 percent; homicides, 40 percent.

In 1998, handguns killed:
- 373 people in Germany
- 151 people in Canada
- 57 people in Australia
- 54 people in England and Wales
- 19 people in Japan
- 11,789 people in the United States

That is 4.4 deaths per 100,000 people in the United States, compared to Germany with 0.45 and Japan with 0.015 deaths per 100,000 people.

Forensic analysis is vital in order to solve a crime involving a gun.

Firearms came about as the result of the invention of gunpowder in China in the second century AD. The development of modern weapons was not just the refinement of a propellant; it required progress in metallurgy, physics, chemistry, and armaments, and most important, unfortunately, the continual need to kill.

**Types of Firearms**

Modern firearms that are legal in our society generally consist of:

1. **Handguns or pistols.** These are designed to be held in one hand so they are easy to carry and conceal. They are not as accurate as other firearms and are limited to the number of bullets that can be loaded.
   
   a. **Revolver:** This handgun has a cylinder that holds the bullets, usually six (“six-shooter”). It must be reloaded by hand, and does not eject a spent shell.
   
   b. **Semiautomatic:** This type of handgun shoots one cartridge each time the trigger is pulled, ejects the empty cartridge case, and reloads
automatically. It can hold between five and 19 rounds in the magazine or clip. Note that a fully automatic weapon keeps firing as long as the trigger is held back. Machine guns are automatic weapons.

2. Rifles. These have a longer barrel than a handgun and a butt stock that fits to the shoulder to steady the firearm and minimize kickback (Newton’s third law: Every force has an equal and opposite force). Rifles can shoot more powerful cartridges than handguns; therefore, they have a greater range and better accuracy.

3. Shotguns. These are similar to rifles, but are usually used to shoot a packet of shot or spherical pellets. The inside of the barrel is not rifled.

4. Air guns or BB guns. Shot or pellets are propelled by pressurized air, spring compression, or a carbon dioxide cartridge.
Types of Ammunition

Modern ammunition consists of a cartridge case, primer, propellant, and a projectile (Figure 15.6); each can vary depending upon the weapon and the intended results. In all ammunition, a primer in the base of the cartridge is struck by the firing pin of the gun. The primer is ignited, which, in turn, ignites the gunpowder in the cartridge case. This action creates gases that push the projectile out of the cartridge case, along the barrel, and out of the weapon.

There are many different kinds of ammunition—over 300 just for handguns! Various parts and pieces of the ammunition are the evidence that is used to investigate a shooting. As with other types of evidence you have studied, there are class and individual characteristics.

The Bullet

Most bullets are made of lead which may be jacketed with brass, copper, or steel. Armor-piercing bullets are made from steel or tungsten alloys covered with a thin coating of the softer metals of lead or copper/brass in order to prevent barrel wear.

Bullet size is a measure of the diameter of the bullet, expressed in hundreds of an inch called the caliber. The caliber of a .22-caliber bullet measures 22/100 of an inch, or 0.22 inches across. The caliber also corresponds to the inside diameter of the firearm’s barrel or bore. Bullet size may also be measured in metric units, so a 9-mm bullet is approximately the same size as a .38-caliber. The size of a shotgun is described by gauge, which is related to the weight of the lead pellets or shot in a shotgun shell. A single pellet is called a slug. The larger the diameter of a shotgun bore, the smaller the gauge. Twelve-gauge is larger than 20-gauge, for example.
The expression “bite the bullet” originated in the days before effective anesthetics. Soldiers were given bullets to bite on to help them endure pain; hence its meaning, “endure pain with fortitude.”

The exception is a .410 shotgun which is measured in inches (caliber).

Bullets can have different shapes (Figure 15.7). Some have a hole in the cone (hollow point) that causes them to deform upon impact in order to decrease penetration and cause greater bodily harm. (It must be remembered that the whole point of producing weapons is to injure and kill.) Flat-nosed lead bullets are commonly used for target practice.

The weight, dimensions, shape, and type of bullet are class evidence, but can be used to help determine the type of ammunition used, and from there, the type of weapon. For example, a .38 Colt (manufacturer) “short” bullet weighs 135 grains, or 8.7 grams (1 gram = 15.4 grains); a .38 Colt “long” weighs 9.7 grams; a .38 S & W (Smith & Wesson) weighs 10.2 grams; a standard 9-mm weighs 6.5 grams; a .357 Magnum weighs 10.2 grams.

In order to increase the accuracy of shooting, handgun and rifle barrels are rifled, that is, the cylinder is machined to form a grooved spiral inside the barrel (see Figure 15.8). These grooves impart a spin to the projectile, decreasing wobbling in flight; the same principle applies when passing a football. The rifling in a barrel produces lands and grooves on a bullet that twist to either the left or the right. (Figure 15.9)

Lands and grooves are class characteristics, but may be used to identify the make and model of a weapon. For example, a .32-caliber S & W handgun has five lands and grooves with a right-hand (clockwise) twist; a .32-caliber Colt has six lands and grooves with a left-hand twist; Browning firearms also have six lands and grooves but with a right-hand twist.
The width of the lands and grooves can also be used in identification.

Individual evidence can often be found on bullets. Each gun barrel has unique machining marks as well as wear patterns that can cause scratches or *striae* on a bullet, a kind of “fingerprint” that looks much like a barcode (Figure 15.10). Often these can be matched to a particular weapon, or to bullets from other crimes. A comparison microscope is the instrument required to identify these marks (see Figure 15.11).

Often, however, bullets are so badly deformed or fragmented that not enough area remains on which to find striations. Figure 15.12 shows increasing fragmentation of a .22-caliber bullet fired into loose soil, packed dirt, and wood, in that order. Note the rings in the unfired bullet; these are called *cannelures*, and their function is to aid in securely fastening the bullet to the cartridge case.

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**The Cartridge**

The cartridge consists of the bullet and a case or shell that contains the powder and a primer. The case is usually made of brass (70–75 percent copper, 30–25 percent zinc) or nickel-clad brass. The propellant is smokeless powder consisting primarily of nitrocellulose or nitrocellulose and nitroglycerine. The primer is composed mostly of lead styphnate, barium nitrate, and antimony sulfide.
The combustion products of these chemicals are expelled from the ejection port; thus the presence of lead, barium, and antimony confirm the discharge of a firearm. Most cartridges have the primer in the center of the base (centerfire); some .22-caliber ammunition uses a primer on the circumference of the brass base (rimfire).

The cartridge found at the scene of a shooting may provide both class and individual evidence. The dimension of the shell casing, the imprint on the base or head stamp (see Figure 15.13), and whether it is rim- or centerfire are all class characteristics. Individual characteristics may result from the
impression of the firing pin when it strikes the primer case (Figure 15.14). Breech marks (Figure 15.15) are imparted to the central area of the casing at the primer when the cartridge case is slammed backward as the weapon is fired. When the cartridge is automatically ejected, it is pulled out of the firing chamber by a hooked extractor and thrown clear of the chamber by the ejector. Both objects may leave identifying marks particular to that weapon (Figures 15.16 and 15.17).
Cartridges may also show scratches imparted by their movement in the **magazine**, and **chamber** marks caused by their movement across rough spots in the chamber during loading and removing (Figure 15.18).

The gross features of each mark are class characteristics, but under higher magnification, the minutiae, so to speak, are unique, and can be compared to other shell cases; see, for example, Figure 15.19 for a match.
There are some types of rifling and some types of ammunition that make individualization very difficult, such as polygonal rifling and Teflon-coated bullets.

Figure 15.20 is a cutaway drawing showing these features in a semiautomatic handgun.

**INVESTIGATORS LINK 9 SHOOTINGS TO SAME GUN IN COLUMBUS**

COLUMBUS, Ohio—Investigators have linked nine shootings at parked cars, homes, and businesses to the same gun in a city with fresh memories of a string of separate shootings that terrorized drivers and killed a woman.

Last week, police said ballistics tests connected eight shootings since Nov. 20 in residential and commercial areas in Columbus. Investigators have since linked a ninth shooting to the same 9-mm gun....

— from Lansing State Journal, 2005

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### Laboratory Activity 15.1

#### Characterization of Bullets and Cartridge Casings

**Advance Preparation**

Prepare two worksheets for each student from BLM 15.1 and 15.2 from the TRCD.

**Advance Preparation**

Obtain at least one bullet and cartridge case for each investigative group. They need not match. It is better to have many bullets and shells so you can pick which ones came from the same firearm. Possible sources are your local police department, a local firing range, or acquaintances who...

**Materials**

- magnifying glass
- stereomicroscope
- 15-cm ruler
- dial calipers
- assortment of bullets and cartridge cases
- ink pad
- balance, 0–100 grams, to nearest 0.1 gram

**Procedure**

Now that you know what you are looking for, examine the bullets and cartridge cases your teacher has given you. The markings can be observed with a good hand lens or, better, a stereomicroscope. Complete each worksheet. Be explicit,
Distance from Target

Sometimes it is important to know the distance from muzzle to target in order to reconstruct the event. As the bullet leaves the muzzle of a weapon, it carries along with it some of the unburned particles as well as the combustion products of the propellant, which spread out with distance. The primary combustion products are nitrites (NO₂⁻) which can be chemically converted to colored products by the Greiss test. Pressing the muzzle against the target causes burns and deposits a lot of soot (see Figure 15.21).

Greiss test: a color test for the presence of nitrite in gunpowder residue

Figure 15.21 Soot from muzzle at a distance of 3 inches

Precision Forensic Testing, LLC (www.precisionforensictesting.com), has marvelous kits that supply all the necessary materials to investigate firearms.
There is a myth, kept alive by portrayals of shooting victims on television and in films, of victims being hurled backwards or actually being knocked down by the force of a bullet. This is not true.

Advance Preparation

Ask a friendly policeman or target shooter to shoot at your targets, preferably with a handgun, from distances of 0 inches (muzzle next to target), 3 inches, 12 inches, 30 inches, and 60 inches. Actually, prepare two sets of targets so one can be used exclusively for the next activity. If shooting is not possible, you can simulate the targets. Make the bullet hole first. Use a heated iron rod to burn a round hole in the center to simulate the bullet hole (rerod makes a good .38-caliber hole). Drop a few salt crystals on dark fabric to practice your aim and distribution, then repeat on the dampened target with potassium nitrite. Let it dry, undisturbed, and then shake it out. Each investigative group can test one target (removed from the ceiling tile), then combine all their data to make a graph or illustration of powder spread and density with distance.

Materials

- 15 percent acetic acid
- sulfanilic acid
- 2-naphthol
- potassium nitrite
- methanol
- photo tray or equivalent
- 250-ml beakers
- inkjet photo paper (Epson photo paper works best)
- cotton towel
- cheesecloth
- electric iron
- targets: pieces of white cotton cloth stretched and anchored across 1-foot ceiling tiles

SAFETY ALERT! CHEMICALS USED

Always wear goggles and an apron when working in the laboratory

SAFETY NOTE Also wear disposable laboratory gloves. Avoid inhalation, ingestion, or skin contact with chemicals. Also be aware that the iron may be hot.
Laboratory Activity 15.2, continued

**Procedure**

1. Be sure the target you have been given is labeled.
2. Place the test sheet of paper on a cotton towel, emulsion side up, in a hood or well-ventilated area (the smell of acetic acid can be quite strong).
3. Place the target on top of the paper, with the powder residue in contact with the emulsion side of the paper.
4. Soak a strip of cheesecloth with the 15 percent acetic acid for one minute; wring it out.
5. Place the cheesecloth on the back of the target, cover it with a paper towel to protect the iron, and iron it on medium heat for about 1 minute or until the cheesecloth is dry.
6. Orange-red specks indicate the presence of nitrites.

Examine your target. Note if the density of nitrite particles decreases with distance from the bullet hole. Devise a procedure for estimating the overall density of nitrate particles in your target. This will be useful when examining all the targets.

**Gunshot Residue**

As the primer ignites the powder charge, the hot gases that propel the bullet from the firing chamber blow out from the ejector port as well as from the muzzle. The blowback disperses combustion products of the primer back to the shooter’s hand, as well as blanketing the area alongside and behind the weapon. Thus, the presence of lead, barium, and antimony is indicative of the firing of a weapon, but these particles may not necessarily be traceable to the shooter since they spread so readily and are known to be easily transferred. The ejector particles, combustion residues of the powder, and any unburned powder particles are collectively known as gunshot residue (GSR). When a bullet enters a target, it may leave behind traces of its constituents, usually lead, or copper from the jacket.

**GSR:** gunshot residue consisting of burned and unburned powder, vaporized and particulate lead, primer residues of lead, barium, and antimony

**Reminder**

blowback: material that is scattered backward from the direction of a force or blow. In firearms, it is the backward escape of gases and unburned gunpowder as a gun is fired.

Sulfanilic acid is available from suppliers like Flinn Scientific; 2-naphthol can be obtained from Aldrich Chemical (www.sigmaaldrich.com) at a better price than other suppliers. 2-naphthol is an irritant to skin, eyes, and respiratory tract, so wear gloves and goggles. The amount of material you are using here can be flushed down the sink with lots of water.

**Advance Preparation, continued**

**Solution preparation**

1. Add 0.75 g sulfanilic acid to 150 ml distilled water and mix.
2. Add 0.42 g 2-naphthol to 150 ml methanol and mix.
3. Mix both solutions in a clean photo tray.
4. Separately saturate each sheet of photo paper in the solution, placing the paper emulsion side down to prevent curling.
5. Remove the paper after five minutes or so and allow it to dry in a fume hood or well-ventilated area for 15–20 minutes.
6. Confirm the sensitivity of the test paper by dipping a cotton swab in a 0.5 percent solution of KNO₂, drying it, dipping it in 15 percent acetic acid, and touching it to a corner of the paper you have prepared. An orange color should result.
sodium rhodizonate test: a color test for the presence of lead in gunshot residue

buffer: a solution containing either a weak acid and its salt or a weak base and its salt, which is resistant to changes in pH

Advance Preparation

As in Laboratory Activity 15.2, you can simulate GSR distribution as you did for the Greiss test using granular lead acetate. It should be a tighter distribution than the nitrite around the bullet hole, but the density should decrease more with distance. Mix some lead acetate with a small amount of water, dip your finger in it, and press the “bullet hole” so only the rim is wetted. Sprinkle the lead salt as you did in Activity 15.2.

Sodium rhodizonate at a pH of 3 makes a very bright pink in contact with lead metal and purple with the lead ion, so a buffer is required. It is made by adding 2.0 g sodium biphosphate (NaH₂PO₄ • H₂O) and 17.8 g citric acid to 1 L of water. Make up a minimum amount of 2 percent sodium rhodizonate in distilled water. This solution does not keep, even in the refrigerator. Figure T15.1 shows a simulated test where the lead acetate was poorly aimed. This image is also provided on the TRCD as Blackline Master 15.3.

Sodium rhodizonate complexes with many metals; spraying with 5 percent HCl turns the color blue, confirming the presence of lead. Combine the group data as you did with the Greiss test.

Materials

- sodium rhodizonate
- citric acid
- sodium biphosphate
- three spray bottles
- lead acetate or lead nitrate
- 5 percent hydrochloric acid
- targets as described in Laboratory Activity 15.2

SAFETY ALERT! CHEMICALS USED

Always wear goggles and an apron when working in the laboratory.

SAFETY NOTE Also wear disposable laboratory gloves. Avoid inhalation, ingestion, or skin contact with chemicals.

Procedure

1. Be sure the target you have been given is labeled.
2. Spray the target area with the sodium rhodizonate solution; record any coloration. Note: Spray all the reagents in a fume hood or a large cardboard box.
3. Then spray with the buffer solution and note the colors (Figure 15.23).
4. Spray with the hydrochloric acid solution and observe any color change. Use caution: Even at this strength, the acid can damage your eyes and cause cuts to sting.

Figure 15.23 Spraying a 3-inch target with buffer solution
Laboratory Activity 15.3, continued

Examine your target. Note if the density of lead particles decreases with distance from the bullet hole. Devise a procedure for estimating the overall density of lead particles in your target. This will be useful when examining all the targets.

The Corpse in the Closet

Some kids playing in an abandoned, half-finished house found the badly decomposed remains of a man in a closet. Police noted that it was mostly skeletonized, with just a few beetles working on the remaining skin. The cause of death was not immediately apparent, although the man's rumpled, dark shirt appeared to have a hole in it. The shirt has been directed to your forensic lab to be analyzed for GSR evidence. It is immediately obvious that the color of the shirt will mask any color development from the rhodizonate test. What do you do?

The Greiss test is a transfer, so the color of the shirt will not interfere with the result. Fortunately, you remember from your CSI training class the Bashinski transfer technique for the sodium rhodizonate test. In this technique, filter paper is dampened with 15 percent acetic acid and placed on the suspected area. The paper is covered with several dry paper towels and ironed until the paper is dry. The filter paper is then sprayed with each of the normal reagents, with the standard interpretation of results. Of course, controls and blanks are performed, as usual.

Work up a test protocol for the analysis of the shirt, have it approved by your teacher, and then carry it out. Write a report on what you did and what you found, and state your opinion on cause of death.

SAFETY ALERT! CHEMICALS USED

Always wear goggles and an apron when working in the laboratory

SAFETY NOTE Also wear disposable laboratory gloves. Avoid inhalation, ingestion, or skin contact with chemicals.

A well-equipped crime lab will confirm GSR residues from a shooter's hand using sophisticated and expensive instruments, such as in atomic absorption spectroscopy, neutron activation analysis (NAA), and scanning electron microscopy with an energy-dispersive X-ray analyzer (SEM-EDX).

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The problem of blowback contaminating areas other than the shooter’s hand still arises, although sampling on the top of the thumb and forefinger and comparing it to the palm should aid in interpretation. Why? Why would there be no GSR on a shooter’s palm?

In Chapter 9, an additional project involved the use of 8-hydroxyquinoline (quinolinol) to reveal the imprint of a metal object on a person’s hand. This technique can be applied to a shooter as well. Spraying the hand with a 2 percent alcoholic solution of this product and then viewing it with a UV light can show an imprint of a pistol grip. The color of the fluorescence can also indicate the finish on the metal or pistol grip.

The Bureau of Alcohol, Tobacco, Firearms and Explosives’ National Integrated Ballistic Information Network (NIBIN) maintains a forensic database, the Integrated Ballistics Identification System (IBIS), that contains bullet and cartridge casings that have been retrieved from crime scenes and test-fires of guns found at crime scenes or on a suspect. From NIBIN’s inception until 2007, 1,286,500 pieces of evidence and more than 20,300 hits have been registered. A hit is a match of evidence associated with a firearm in the database with other such evidence submitted by a state agency. This match may link a firearm to a crime, an event, and/or a person.

On December 29, 1998, Anselmo Vasquez was killed by a single .22-caliber bullet to the chest. His girlfriend, Delia Contreras, was accused and went through three trials before being convicted of murder in September, 2003. There had been a confused confession by her, later recanted, and rumors of another while she was in prison, but both had been discounted.

The bullet, examined at the autopsy, was a copper-clad hollow point with 16 lands and grooves with a right twist, which indicated it was fired from a Marlin-manufactured rifle. The bullet was partially mushroomed and showed strange striations. The bullet hole in Mr. Vasquez’s undershirt was larger than expected for a small-caliber weapon such as a .22. Ms. Contreras was taken into custody and found to have GSR on her hands; however, her hands had not been bagged to prevent contamination from the officers’ vehicle.
A single drop of blood, about ½ inch in diameter, was found in the alley outside the apartment. DNA analysis showed it to be the victim’s. Blood spatter analysis suggested that it was a wet drop, not a transfer, from a source moving toward the apartment courtyard.

The state (prosecution) stated that the strange striations on the fatal bullet were caused by its tumbling and rotating through the body after impact. The GSR evidence spoke for itself. The victim’s blood came from the accused as she was getting rid of the murder weapon (it was never found). The size of the hole in the undershirt resulted from the type of weave. The scenario the state painted was that Ms. Contreras shot her boyfriend, got rid of the rifle, and then called 911.

A defense expert witness meticulously examined the fatal bullet, finding embedded glass in the nose. Test-firing through window glass found that this commonly occurred. The embedded glass was analyzed by SEM-EDX and found to be consistent with window glass. The state’s expert countered that the silicon found in the bullet came from the clay mount the defense witness used when examining the bullet, yet analysis of several similar clays found no silicon (the clay that was used was never produced).

The defense’s expert postulated that the strange features on the fatal bullet were the result of it passing through a cracked bedroom windowpane. Generally, a lead bullet will completely mushroom when passing through window glass. The other bedroom window had apparently just been broken because Mr. Vasquez had been cleaning it up.

![Figure 15.24](image1.png)  Test bullet similar to fatal bullet

![Figure 15.25](image2.png)  Analysis of embedded glass

![Figure 15.26](image3.png)  (l-r) Broken window in apartment, test window, actual window
Many tests were conducted by the defense expert by shooting a .22 at a previously cracked window in an effort to duplicate the glass pattern a bullet might make, and to replicate the extraordinary marks on the bullet itself. Both efforts were mostly successful.

The defense noted that there apparently had been some sort of physical altercation in the alley between Mr. Vasquez and an unknown person. The victim had been wearing short pants; his legs and hands showed abrasions.

The defense reconstructed the shooting based on exhaustive testing, as follows: The altercation in the alley resulted in sufficient damage to draw blood. The GSR on Ms. Contreras's hands was caused by contamination from the police car transporting her to the station.

The glass embedded in the bullet came from it passing through the bedroom window. It entered the windowpane close to the existing crack, which limited mushrooming, imparted a wobble to the bullet that caused the abnormal markings, and made the impact hole in the undershirt larger than a clean shot would have.

—condensed from http://meixatech.com/CONTRERAS.pdf, courtesy Bryan Burnett

Discussion Questions

Where was the cartridge case? Was it ever looked for? What was Ms. Contreras's state of mind when she called 911? Why did she confess, yet not know what she did with the rifle? Why wasn't GSR tested around the bullet hole to determine the distance of travel? Why didn't the state consider a shot from outside?

What do you think happened? What's missing?
The purpose of including this particular case is to show the many different facets of an investigation, the importance of photographs, and the amount of thought, testing, and time (and therefore, money) that goes into a thorough investigation. Further, the case illustrates the logic and deductive reasoning required to advance a hypothesis (reconstruction of events) with justification, and the many unanswered questions that always linger. Some expert witnesses may not do as complete a job or be as forthright as expected or desired, whereas some do exemplary work. Lawyers do not always look for all possible answers, but may follow their own agendas. Justice may not always be served in the real world. And justice and truth may not be synonymous.

**Toolmarks**

Tools are often used in burglaries to pry open a window or door to gain entry, to open a safe or strongbox or other enclosure, or to steal a car. Toolmarks are caused by the use of a tool against a usually softer object; for example, a screwdriver used to open a window may be pressed into the softer windowsill, leaving a mark. Tools can be anything, such as screwdrivers, hammers, pry bars, wire or metal cutters, or saw blades. It is really the purpose for which the object is used, not the object itself, that defines a tool.
As with the marks found in firearms, there are class and individual characteristics of toolmarks. Class characteristics are the features that define the tool—its size and shape. As the tool becomes worn or damaged, it acquires particular markings that can differentiate it from others of its class; it becomes individualized. It is a matter of how closely you look.

Toolmarks associated with a crime are first photographed and/or sketched. Oblique viewing accentuates the details. If possible, the marked item is taken to the crime lab for examination. If this is not possible, the mark is saved by casting with a silicone, plaster, or clay material. From this casting, a three-dimensional replica can be made. The first step in the examination is to identify the class of tool so the police can be notified what to look for among suspects. The features of any tool recovered are then compared to the toolmark evidence. Characteristics that may be unique are compared in the hope of finding a match.

Matching Toolmarks

The purpose of this activity is to hone observational techniques with the intent of presenting evidence to a jury.

Materials

- an assortment of hand tools
- an assortment of toolmarks
- examples of toolmarks
- digital camera
- ruler
- dissecting microscope
- magnifying glass
- casting cement or silicone
- wooden blocks
- ink pad
- modeling clay
- lead or aluminum metal
- aluminum foil
- copper or aluminum wire
- Sculpey clay
- oven

SAFETY ALERT! CHEMICALS USED
Always wear goggles and an apron when working in the laboratory

Caution: Wear chemical safety goggles to protect your eyes from plaster of paris dust. Work carefully so that plaster dust does not become airborne. Do not inhale plaster dust.

Procedure

1. Toolmarks
   a. Examine the toolmarks on each object assigned to you. Record the identification number. Take a photograph, if possible; otherwise, sketch it (remember oblique lighting). Measure the dimensions. Include a scale
Laboratory Activity 15.5, continued

in any photograph. Make an educated guess as to what tool made the mark.

b. Observe the impression with a good hand lens or a stereomicroscope. Draw what you see. If applicable, make a cast of the impression using a casting cement or silicon. Also make one using a soft modeling clay that can be baked to harden, like Sculpey. These casts can be used as molds to cast a 3-D model of the marks the object made.

2. Tools

a. You will now match a tool to the toolmark studied. Select the type of tool you think is applicable. Examine it under magnification to see if it is the particular tool that made the mark. If so, photograph the part that left the toolmark; otherwise, draw it. Record make, model, and dimensions.

b. Duplicate the surface imperfections of the tool itself, using applicable methods such as casting, using an ink pad, molding with modeling clay, etc. For screwdrivers, draw the tip at

Figure 15.29 Impression of a hammer; (l-r) in wood, photo of hammerhead, inked hammerhead

Figure 15.30 Comparison of two bolt cutters

Figure 15.31 Toolmark from pliers

Advance Preparation, continued

Step 2: Put out all the tools you used (and maybe some you didn’t).

Step 3: Supply fresh wooden blocks, bolts, and/or wire. Let the students label these.

Step 4: Here is where the students must succinctly organize their data to support their conclusions. A digital camera is really important because any photographs can be enlarged and enhanced to illustrate the toolmarks that match the suspected tool, or those that do not match it and thereby exclude the suspect.

A good drawing, large enough to show to a jury, will do. Figures 15.29–15.31 show what can be done using a variety of methods—a close-up lens on a digital camera, a good scanner, and Photoshop or Paint.

Firearms, Toolmarks, and Impressions
Impressions

Footwear Marks or Shoeprints

List three circumstances, each with a different medium, where shoeprints could be used as evidence; for example, a burglar walking across a dusty floor.

Footwear marks can provide information about a crime such as:

- Direction of approach and departure
- Point of entry and exit
- Mode of entry
- Sequence of events that took place
- Class and perhaps individual evidence linking suspect to the scene

The word “investigate” is derived from the Latin *vestigium*, which means “footprint.”
Following the murders of Nicole Brown Simpson and Ronald Goldman in the summer of 1994, photographs depicting shoeprint impressions in blood from the Brentwood, California, crime scene were delivered to the FBI Laboratory. The Los Angeles Police Department requested a determination of the brand and size of footwear that made the impressions. The impressions submitted were mainly from a path adjacent to the home of one of the victims, Nicole Brown Simpson. However, other partial impressions were on the victims’ clothing.

By examining these impressions and researching the FBI reference and standards files, an FBI examiner was able to positively link some of the crime scene impressions to size 12 Bruno Magli Lorenzo shoes. The examiner issued a report directly to the judge in the case and was subsequently called to testify. Although the shoeprints from the crime scene could be positively linked to a particular brand and size of shoe, at the time of the criminal trial no evidence was available that defendant O. J. Simpson owned such shoes. In the interval between the criminal and civil trials, pictures depicting Mr. Simpson in such shoes were discovered. The shoes became evidence in the civil trial, when the examiner restated his testimony.

—from www.fbi.gov/hq/lab/fsc/current/held

The standard method of documenting impression evidence is photography. Oblique-angle viewing can make all the difference in the world; see, for example, Figure 15.33. Collection and preservation can be accomplished by casting in some cases, and by electrostatic or adhesive lifting when the imprint is on a hard surface. Chemical enhancement, such as using a dye on a bloody shoeprint, can sometimes be effective.

Matching shoeprint evidence to a shoe involves class characteristics such as manufacturer, type, model, and size. There are available databases that make searching through thousands of different shoeprints manageable; for example, SoleMate is a commercial...
A database containing manufacturer, date of market release, an image or offset print of the sole, and pictorial images of the shoe itself for more than 12,000 sports, work, and casual shoes. TreadMark is a database that stores and compares imprints from a crime scene. As footwear becomes worn and damaged, the outsoles become more individualized, just as with toolmarks.

**Laboratory Activity 15.6**

**Casting Shoeprints**

**Teacher Note**

Pick out students who are wearing similar footwear. They will be exemplars. Have them make an imprint outside in soft soil or inside in damp soil (a shoebox works well). Do not label them or use a coded ID. The remaining students are the investigators. They will mix up the plaster and make and clean the casts. Be sure to instruct the exemplars to wear the same footwear to the next class.

A new product called BIO-FOAM is available to make three-dimensional exemplars. It is a solid block of foam similar to the kind used by florists and hobbyists. Shoes are pressed into the foam, and then sealed with hair spray. Each kit comes in a cardboard box container suitable for storage and protection. This method is easy, takes only seconds, and does not dirty the shoes. Casts can then be made from the imprinted foam blocks.

Another way of recording a shoeprint uses fingerprint powder rather than paint and a self-adhesive, 2-mm-thick, white lined paper mounting board with coated backer. The Lo-Tack version is best for this application. The front of the board has peel-off protective

**Materials**

- soil, preferably screened to remove large particles and debris
- shoeboxes
- dental stone (preferred over plaster of paris, which needs reinforcing to prevent breaking apart)
- paint stirrer or tongue depressor
- hair spray (a pump spray is better than an aerosol because it will disturb the soil less)
- toothbrush or a bristle brush
- black poster paint
- paintbrush
- white paper, 8½” × 11” or larger

**SAFETY ALERT! CHEMICALS USED**

Always wear goggles and an apron when working in the laboratory

Caution: Wear chemical safety goggles to protect your eyes from plaster of paris dust. Work carefully so that plaster dust does not become airborne. Do not inhale plaster dust.

**Procedure**

1. Pour about an inch and a half of soil into a shoebox and smooth it out.
2. Place your foot on the soil with all your weight, being careful not to wiggle.
3. Carefully remove your foot from the box.
4. Spray the impression with hair spray.
5. Mix up a paste of dental stone and water according to the directions. You will probably need about 400 g of powder. You can use a sealable plastic bag. Put the required amount of warm water in first, then add the powder. Mix it by massaging the bag until the material is smooth and has the consistency of pancake batter.
6. Pour the mix into the impression along an inclined paint stirrer or something similar in order to diffuse the flow. Never pour mixture directly into the impression, as this will damage it.

7. Let the cast set for at least 30 minutes, then remove it by prying it up from underneath.

8. Let the cast harden overnight before brushing it clean.

9. Match the cast to the shoe.

10. Use the brush to make a light but thorough coat of poster paint on the base of the cast. Press the cast against white paper until you get a good print. Label it.

11. Repeat this process with the actual shoe, label it to identify it with the cast, and add manufacturer, model, and size.

12. Compare the two prints. How well do they match? How do they differ from other prints made in class? Are there any specific features that could be used to individualize the shoe? If so, note them on the print. Which was easier—comparing the cast to the shoe or comparing the prints? How would you present your findings to a jury?
**Personal Traits**

Can you tell something about a person from his/her footprints? A set of footprints can sometimes tell you about the person or situation. For example, the length of stride and the way the footprint has dug into the ground can suggest running. In a walking **gait**, the length of stride may be related to the height of the individual. Is shoe size related to height?

**gait**: a manner of walking or moving on foot, said to be as individualized as your personality

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**Laboratory Activity 15.7**

**Relating Shoe Size to Height**

This is an exercise in statistical analysis.

**Materials**

- a 12-inch ruler and a tape measure

**Procedure**

1. Measure the length of the shoe you are wearing by standing on the ruler.
2. Have someone measure your height.
3. Collect similar data from your classmates.
4. Plot height (y-axis) against shoe length (x-axis); one set for females, one set for males.
5. Is there a correlation between shoe length and height?
Tire Treads

Tread marks in tires are treated much the same as footwear marks. Shoes and tires are mass-produced. Class characteristics include design, size, type, and model. Wear and damage cause defects that can lead to individualization.

Vehicles are very often involved in crimes. Many times, tire marks are the only way to identify a vehicle. Impressions in mud, dirt, or dust or imprints left on a smooth surface by a moist or dirty tire can be photographed and collected using the same techniques as those used for footwear. One difference lies in the fact that a vehicle weighs at least ten times more than a person, so tire marks may be found on a body.

Figure 15.37  Tire tread; (l-r) tire, impression, imprint
As with footwear, databases contain information on tread designs, manufacturer, date of market release, etc.; for example, TreadMate contains data on more than 5,000 vehicle tires and tread patterns. Other databases consider wheelbase and stance, both of which can be used to identify a vehicle. Bald spots, marks such as a patch or nail head, cuts, or a split tread can often be seen in a cast impression. Sometimes, caked soil or a rock wedged in a tread can provide a distinctive identifying feature for an important period of time. This is called a “temporary characteristic.” Such characteristics can also be seen in tools; go back and look at Figure 15.27.

Tire marks such as skid marks are used in the reconstruction of accidents, including hit and run. Tire marks can also be used to assess tire failures in moving vehicles.

A recent article in *The Journal of Forensic Science* suggests that pyrolysis gas chromatography–mass spectrometry, PGC-MS (see page 157, Chapter 6), can be used to match the residue left on a road surface from a sudden braking or a spinning wheel to the tire manufacturer. This can assist investigators in tracing vehicles involved in hit-and-run incidents.

**Bite Marks**

Bite marks may be found in some crime cases, most often involving an assault or sexual attack. Bite mark evidence is common with victims of domestic violence. Everyone has teeth that are of slightly different shapes and slightly different widths, and they’re arranged in slightly different ways. As they grow, different things happen; there are chips, fillings, crowns, and caps that make a person’s teeth unique. Indeed, it has been estimated that the odds against two persons with a full set of 32 teeth producing identical bite marks are 2.5 billion to 1! Of course, impressions of only a few teeth are usually present on a victim. Bite marks were a prime piece of evidence used to convict serial killer Ted Bundy.

Previously, the only way to capture bite mark evidence on a victim was to take a photograph and/or make a drawing, and overlay a transparency of a
suspect's tooth pattern. Now, saliva of the perpetrator can be collected and amplified by PCR, and its profile compared to that of a suspect.

In Figure 15.38, which impression matches the bite mark in the skin?

**Answer**

Impression B
Laboratory Activity 15.8, continued

6. If using Sculpey, bake the mold according to directions.
7. Pour a casting compound onto one side of the mold, building it up so it will come off in one piece. Allow it to harden.
8. Turn the mold over and repeat for the other side of your bite.
9. Mark the top and bottom and remove the casting from the mold. You now have a replica of your bite.
10. Press the castings into a smoothed piece of dark-colored modeling clay.
11. Scan each side of the clay with a scanner, protecting the glass with a sheet protector. You may be able to manipulate the image to enhance the depressions, and print it out enlarged. A copier may work also. You now have a two-dimensional bite mark that can be easily compared to those of your classmates.

Are the 2-D bite mark impressions all different? What characteristics differentiate the imprints? Mark any specific characteristics in your bite marks, such as a filling, a chip, twisted or crooked tooth, etc.

Figure 15.39 Can you relate the coauthor’s top bite mark to his X ray?

The Case of the Bitten Bonbon

Your teacher found her favorite chocolate, half eaten! It was a “Chocopologie” by Knipschildt, which everyone knows is a handmade chocolate with 70 percent Valrhona cocoa powder rolled over a French black truffle. It cost her $250—she was savoring it a little at a time. Fortunately, the churlish chocolatophile left tooth impressions in the top of her treat.
Laboratory Activity 15.9, continued

It is your team’s job—no, it’s your team’s duty—to find the culprit, who is probably one of your (gasp!) classmates. Your bereft teacher has made several casts of the tooth marks, which will be distributed. Find the cowardly culprit!

Advance Preparation
Surreptitiously select one of your students to be the culprit, sworn to silence. A logical plan for your student investigators would be to initially compare 2-D top bite marks, eliminating the obvious. Then try to match 3-D casts to the culprit’s cast. (You may have to buy your culprit’s complicity with a chocolate bar.)

Restoration of Serial Numbers
Many items of value have serial numbers stamped into them for identification. People who do not want an item traced—usually those who stole it—attempt to obliterate the identification number, usually by grinding it off. Objects most often found with obliterated serial numbers are motor vehicles (the original vehicle ID number [VIN] on the engine block is missing), motorcycles, bicycles, and firearms.

The Federal Gun Control Act of 1968 mandated that all weapons manufactured or imported show a readily visible serial number.
When a metal is stamped or punched, the crystal structure beneath the impression is deformed. This area reacts to an etching solution more readily than the surrounding area. The chemical processes involved are merely oxidation-reduction reactions. Restoring serial numbers on ferrous metals is usually accomplished by first polishing the area with emery cloth and then repeatedly swabbing it with an acidic cuprous chloride solution. Figure 15.40 shows the effect of HCl-CuCl₂ on tool steel.

Restoration of manufacturing information and serial numbers can also be accomplished on wood, plastic, and precious metal articles.

Coauthor John Funkhouser had a case that involved a man falling off a wooden stepladder when it broke apart. He suffered severe injuries. His lawyer felt that the ladder was defective, but the manufacturer’s identity that had been stamped into the ladder was unreadable. Wetting the area caused the undisturbed wood around the impression to swell enough so that with oblique lighting, the company name could be read.
Checkpoint Questions

Answer the following questions. Keep the answers in your notebook, to be turned in to your teacher at the end of the unit.

1. An automatic weapon
   a. fires each time the trigger is pulled.
   b. is a revolver.
   c. is a machine gun.
   d. is illegal in the U.S.

2. Could “Dirty Harry” use .38-caliber ammunition in his .357 Magnum?

3. What bullet would you use for target practice? For hunting small game? For maximum damage to your target?

4. Why are lands and grooves important?

5. Name areas of a cartridge case that may yield individual evidence.

6. If the chances of finding a round firing pin in a cartridge are 1 out of 3, parallel breech marks 1 out of 2, and evenly spaced chamber marks 1 mm apart 1 out of 20, what are the odds of finding all three characteristics on a cartridge case? Refer to Chapter 4, pages 82–83. (Be careful, this is a trick question.)

7. What constitutes GSR?

Answers

1. C and D are correct.
2. Yes, the diameter is close enough to fit, but the punch would be less.
3. Flat-nose wad-cutter cuts a clean hole in the target; full metal jacket to keep lead out of the meat; a hollow point.
4. They are a result of rifling, which increases accuracy of fire; lands and grooves are class characteristics that can be used to identify the weapon’s manufacturer and sometimes the type or model.
5. Firing pin in central breech, breech marks in center of base, extractor marks at the rim, ejector marks on or near the rim, chamber marks on the side of the cartridge. Magazine marks on the side of the cartridge perpendicular to its length may also be useful.
6. Apparent answer: \(\frac{1}{3} \times \frac{1}{2} \times \frac{1}{20} = \frac{1}{120}\) if these were unrelated events. However, one gun can repeatedly produce the same cartridge case with all three features, so they are not independent variables. Be careful with how you use statistics!
7. Primarily, primer composition (lead, barium, antimony), burned and unburned powder, nitrates...
8. Name three circumstances where a burglar could enter a house without leaving a toolmark.

9. What is the most important tool for a firearms and toolmark examiner?

10. How can marks be accentuated for viewing?

11. Why are shoeprints important?

12. What does Laboratory Activity 15.7 have to do with Bertillon?

13. How could an obliterated serial number in plastic be restored?

14. How would one determine if an individual has recently fired a pistol?
   a. by smelling the trigger hand
   b. by testing with the Greiss reagent
   c. by swabbing the hand and analyzing it using SEM-EDX
   d. by spraying the gun hand with 8-hydroxyquinoline and observing it in UV light

15. How would you define the following terms to a jury?
   a. GSR
   b. caliber
   c. semiautomatic handgun
   d. Greiss test
   e. weapon blowback
   f. IBIS
   g. TreadMate
   h. ATF

Answers, continued

8. open an unlocked door or window, use a stolen key, make an unforced entry using the threat of violence, use a disguise such as a delivery person
9. the microscope
10. oblique lighting
11. They can provide information about a crime such as direction of approach and departure, point of entry and exit, sequence of events that took place, and class and perhaps individual evidence linking the suspect to the scene. Also, they are always at a crime scene unless someone levitates. However, they are often overlooked or trampled, and even though the Locard principle holds, traces may not be visible.
12. using body measurements as a personal identifier
13. This depends on the plastic color, type, and thickness. A good answer will involve a Web search. If it is a clear plastic, polarized light might show the molecular crystallite deformation. If it is colored plastic, slight heating may create surface imperfections that delineate the original impression. Students should use their imagination and knowledge base; the question is intended more to get them thinking of ways to approach the problem, not to get a “right” answer.
14. B is logical, but contamination is a factor (see Case Study 15.1: The Case of People v. Contreras); A is better, but contamination is still a problem. D is probably the best answer, especially if the imprint of a pistol grip is evident.
15. a) gunshot residue, primarily primer composition (lead, barium, antimony), burned and unburned powder, nitrates; b) diameter of cartridge or bore of firearm barrel; c) handgun that fires at each pull of the trigger; d) a color test for nitrite in GSR; e) backward escape of gases and residues as a gun is fired; f) Integrated Ballistics Identification System, a database used to match bullets to firearms; g) a database of tread patterns and tires; h) Bureau of Alcohol, Tobacco and Firearms, a federal government agency
16. What type of soil would make the best impressions?

17. What kind of shoe would give the least probative imprint?

18. Do any of these shoeprints match?

19. What general types of evidence were found in the Contreras Case Study that have been covered in this textbook?

20. Was the identification of O. J. Simpson's rather uncommon shoes class or individual evidence? Could further investigation have helped?

Answers, continued

16. A fine, sifted soil. Stones, sticks, and leaves will mask features.

17. One with a smooth sole, e.g., a woman's high heel, although the heel could be distinctive.

18. No; they are all from different shoes.


20. Class evidence, although the rarity of the shoes would make such evidence much more probative. If the shoeprints from the crime scene were of sufficient detail, and shoeprints could have been made of Simpson's shoes, perhaps manufacturing imperfections, wear patterns, and damage marks could have individualized the prints.

Teacher Note

The image of the shoe-prints in question 18 can also be found as Blackline Master 15.4 on the Teacher Resource CD.

Optional Website Activity

Have students conduct the virtual autopsy case that can be found in the Chapter 15 student resources area (SCSI tab) on the Forensics website. See the teacher resource section on the site for more information.
Project: Both Sides of the Issue; Gun Control Laws

“A well regulated Militia, being necessary to the security of a free State, the right of the people to keep and bear Arms, shall not be infringed.”

—U.S. Constitution

Write an analysis paper of the arguments surrounding gun control laws. In order that you gain an understanding of both sides of the issue, and acquire experience in identifying assertions and evidence, structure the paper in the following manner:

TITLE: Should Gun Sales and Ownership Be Subject to Federal Regulation?

AUTHOR: Your name

INTRODUCTION: Write one or two paragraphs briefly explaining current gun control laws. Are they federal laws? Are they state laws? Does your state have both? Are the current laws being enforced? Do we need new laws? Do the current laws need to be revised?

PRO SIDE: Write one sentence stating that gun sales and ownership should be subject to federal regulation.

SUPPORT: Write a short statement of why gun sales and ownership should be subject to federal regulation. Write at least three paragraphs supporting the statement, using at least three different sources.

CON SIDE: Write one sentence stating that gun sales and ownership should not be subject to federal regulation.

SUPPORT: Write a short statement of why gun sales and ownership should not be subject to federal regulation. Write at least three paragraphs supporting the statement, using at least three different sources.

PERSONAL OPINION: Write your views and conclusions based on the above arguments. You must support one side or the other.

WORKS CITED: List references for all the sources you have used.
**Additional Projects**

1. If your school has a machine shop, stamp a short identification number into a piece of iron. Take a picture of it. Then have the number ground off. Restore it with Fry’s reagent (30 g CuCl₂, 60 ml 15 percent HCl) by wiping the reagent in a cotton ball across the area until you get a good impression. Wash it off and take another photograph. **Wear gloves and safety goggles.** Repeat the process with obliterated aluminum using the same reagent, as well as a different one (6 g FeCl₃ • 6H₂O in 94 ml H₂O or 1 M HCl). Which reagent works the best?

2. Developing latent shoeprints. Obtain a square of linoleum, tile, or painted wood. Wipe the bottom of your boot or heavy-soled shoe with a moist cloth. Step on the sample of flooring. Try different methods of developing: Consider sprinkling fingerprint powder or a colored water-soluble powder on it. Try superglue fuming. Think of more ideas and try them. This is what research is all about.

3. You have studied the relationship between foot size and height. Is there a correlation between stride and height?

**References**

**Books and Articles**


**Websites**

www.precisionforensictesting.com/index.html; a place to get firearms and toolmark kits geared for high school classes

http://library.med.utah.edu/WebPath/TUTORIAL/GUNS/GUNBLST.html; good background information

www.genitron.com/IntPistol.html; interactive handgun firing

http://nfstc.org/projects/firearms/index.htm; detailed description of many aspects of firearms examination

www.forensic-evidence.com/site/ID/bitemark_ID.html; case of erroneous bite mark evidence

www.firearmsid.com; excellent site for identification of firearms

www.firearmsid.com/A_historyoffirearmsID.htm; a very thorough history of firearms

http://members.aol.com/varfee/mastssite/index.html; good site for footwear and tires