Kendall Hunt

Chapter 4
Print Sampler

STUDENT EDITION | TEACHER EDITION

Instructional Options

This program is designed with a variety of teaching options in mind. The program can be offered as a one-year or a one-semester science course, or applicable units and chapters can be pulled out to use in relevant science courses. The writing and content of this text target high school, but many ideas and activities can be adapted to middle school, as well as to nonscience majors in two- and four-year colleges.

Components

Student Edition, Teacher Edition + online resources, and material kits. All purchases of the new Forensic Science for High School 4th Edition include digital licenses for Diablo Highway.

What is Diablo Highway?

Diablo Highway is a virtual crime simulation based on a real, unsolved double-homicide from the 1930s. Students begin by reading about the crime, observing associated primary source documents, and exploring the two virtual crime scenes to find and collect evidence. This evidence is used by students to complete the subsequent lessons, each of which focuses on analyzing a specific type of evidence. The lessons each include a reading, quiz, and digital lab activity.

There are nine lessons on various types of evidence:

- Blood Typing
- Hair Analysis
- Fingerprint Analysis
- DNA Profiling
- Shoe Impressions
- Tire Impressions
- Fiber Analysis
- Firearms Identification
- Crime Scene Mapping

These lessons integrate seamlessly into the ***Forensic Science for High School 4th Edition*** textbook, with each lesson pairing with a chapter in the textbook. Lessons in ***Diablo Highway*** can be completed in any order after students have read the initial lesson about the crime and collected evidence from the two virtual crime scenes. This allows flexibility and autonomy for the instructor to teach the chapters and concepts in the order that works best for them and their students.

Upon completing all lessons, students attempt to solve the crime, identifying the culprit from the list of suspects using evidence they have collected. Finally, students compose a report stating their rationale for the suspect they selected. A suggested implementation guide is included in the Teacher Edition of the ***Forensic Science for High School 4th Edition*** textbook.

DIABLO HIGHWAY

FORENSIC SCIENCE LAB ACTIVITY

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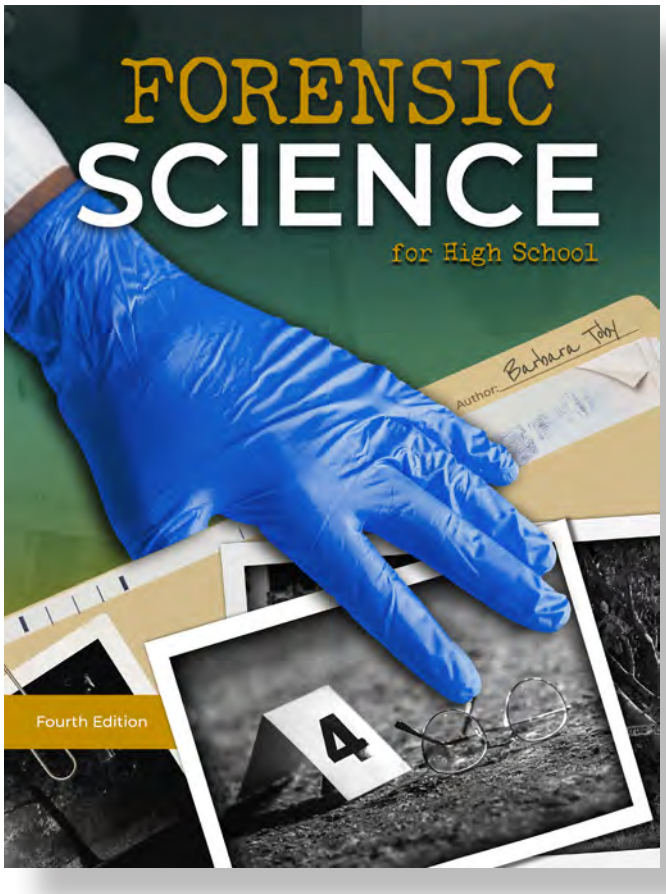


Chapter 4

Fingerprints

STUDENT EDITION

Chapter 4

Fingerprints

> **If someone hacks your password, you can change it as many times as you want. You can't change your fingerprints. You have only ten of them. And you leave them on everything you touch; they are definitely not a secret.**
>
> —Al Franken, former United States Senator

Objectives

- Explain why fingerprints are individual evidence.
- Describe why there may be no fingerprint evidence at a crime scene.
- Define the three basic properties that allow individual identification by fingerprints.
- Recognize and classify the three general ridge patterns (loops, whorls, and arches) and apply them to the primary Henry-FBI classification.
- Compare two fingerprints with at least ten points of identification.
- Identify the differences among latent, plastic, and visible fingerprints.
- Identify questions and concepts that guide scientific investigations.

Key Vocabulary

fingerprint	delta	plastic print	fluorescence
microns	core	visible print	biometrics
dactyloscopy	whorl	latent print	
anthropometry	arch	ninhydrin	
loop	minutiae	bifurcations	

At the Crime Scene

A burglar approached a house from the backyard late one evening, knowing that the owners were not at home. He tried and failed to pry open several windows behind a flowerbed. Finally, he broke a windowpane with the old pry bar he carried; reached through, scraping his shirtsleeve against a jagged shard of glass; and turned the latch. He raised the window, not thinking about how soft the putty was when his fingers touched the glass. He climbed in over the sill and was promptly bitten on the leg by the owner's golden Lab. The burglar then went upstairs to the bedrooms to collect jewelry. On his way out through the kitchen, he took a bite from a piece of cheddar cheese that was on the counter. Feeling pretty good about his haul despite his bloody leg, he left a note on a pad near the cheese: "Thanks for everthing, sukkers." He unlatched the back door and disappeared into the misty night.

Burglar

Fewer than 13 percent of burglaries are solved in the United States. Right after the crime, a "hot search" may find the burglar in the vicinity. Later, a "cold search" is usually unproductive. The trail grows cold very rapidly.

What evidence could link the burglar to the burglary? Make a list.

Let's concentrate on just the fingerprints for now. Just what is a **fingerprint**? A fingerprint is an impression of the pattern of ridges on the last joint of a person's finger. Properties that make a fingerprint useful for identification are: (1) its unique, characteristic ridges; (2) its

fingerprint

an imprint made by ridge patterns on the tip of a finger; also used to describe the characteristic pattern of DNA fragments

Magnified finger ridges

consistency over a person's lifetime; and (3) the systematic classification used for fingerprints.

Are humans the only species to have fingerprints? Why do we have them? Apes and monkeys also have ridge patterns on their fingers and toes. Ridge patterns may be an evolutionary development that provides a better grip, makes perspiration easier on a hairless surface, and improves the sense of touch. The fingers, for example, are so sensitive that a vibration with a movement of 0.02 **microns** (2×10^{-5} mm) can be detected.

microns

A micron is one-millionth of a meter or one-thousandth of a millimeter.

There are 1000 microns in 1 millimeter

The History of Fingerprints

Fingerprints left in clay by early artisans and scribes served as a kind of signature. During China's T'ang dynasty (eighth century CE), clerks used inked fingerprints on business contracts; this practice was not so different from using a seal as a mark of authenticity as was done in Europe. A number of people throughout history made note of fingerprints and even commented on the different ridge patterns, but the science of **dactyloscopy**, the study of fingerprints, really started in the 19th century in India with Sir William James Herschel.

dactyloscopy

the study of fingerprints. The word is derived from the Greek *daktulos,* meaning finger.

Herschel was a highly placed British civil servant who decided to require Indians to add their fingerprint to contracts. Later (in 1877) he introduced the use of fingerprints as a means of identifying prisoners. Meanwhile, in Japan, molded fingerprints in old pottery piqued the interest of Henry Faulds, a health missionary in Tokyo who published a scientific paper in 1880 about the possibility of using fingerprints to identify criminals. Like Herschel, Faulds thought that fingerprints were unique; he also claimed that fingerprints did not change over a lifetime and that they could be classified for sorting purposes to help in identification. He described an ink-and-transfer method of recording prints, and was the first to use fingerprints to solve a crime.

"When bloody finger marks or impressions on clay, glass, etc. exist, they may lead to the scientific identification of criminals. Already I have had experience in two such cases. . . . There can be no doubt as to the advance of having, besides their photographs, a nature-copy of the forever unchangeable finger furrows of important criminals."

—Henry Faulds in *Nature*, October 28, 1880

Identification has always been a problem for the criminal justice system. Throughout history, prisoners were often branded or tattooed or even had hands or fingers chopped off so they would be recognized as criminals. This practice was generally abolished in the Western world in the early 1800s. Police recorded descriptions of individuals, even employing men with "photographic" memories. The advent of photography helped, but without a means of classification, the police records were soon overwhelmed with too many photographs to be useful.

In 1881 Alphonse Bertillon, employed as a ledger clerk at the police headquarters in Paris, suggested using certain body measurements as

discriminating characteristics to identify habitual offenders. Bertillon first recommended recording 11 measurements, such as height, reach, width of head, length of foot, and so on. Over the years, a very consistent method of measurement, description, and classification was worked out, and by the end of the 19th century it was accepted almost everywhere. The science of human measurements is called **anthropometry**.

anthropometry

the study of human body measurements. The word is derived from the Greek *anthropos,* meaning man.

Francis Galton, a British anthropologist, studied both dactyloscopy and Bertillon's anthropometry. In 1891 and 1892, he published two books in which he showed how to classify fingerprints using loops, whorls, and arches, as well as a secondary, more complex method. Most important, however, he showed that a person's fingerprints stay the same from birth until death, that no two fingerprints are identical, that prints cannot be altered, and that it is possible to classify a very large number of prints.

In 1883 Mark Twain published *Life on the Mississippi,* in which fingerprints were used as evidence to solve a crime. He used this theme again in 1894 in his story "Tragedy of Pudd'nhead Wilson," in which a lawyer's hobby of collecting fingerprints proved the innocence of two friends. This was two years after Galton's articles were published.

By 1897, working with Galton, Edward Richard Henry, inspector general of police in Bengal, India, had simplified Galton's classification system and established the Henry classification system of identification in India, replacing Bertillon's method. Scotland Yard adopted Henry's system in 1901. Today, most English-speaking countries use some form of the Henry system.

In 1901 an Argentinean police official, Juan Vucetich, set up a workable fingerprint classification system based on Galton's method that has been refined and is used in Spanish-speaking countries. A year later, Vucetich first officially identified a criminal using fingerprints. In a small town in the province of Buenos Aires, Argentina, a woman named Francesca Rojas had murdered her two sons and blamed the attack on a neighbor. Using Vucetich's methods, police identified bloody fingerprints on a doorpost as Rojas's, which led to her confession.

The end of Bertillon's anthropometric classification system supposedly came at Leavenworth Prison in 1903 when a man named Will West arrived to serve time. As was done with all prisoners on admission, his Bertillon measurements were taken and compared to existing files. Prison officials were astonished to find that another man who was serving a life term for murder had almost identical measurements (see Table 4.1); even more

Will West

William West

Table 4.1: Bertillon Measurement Comparison of Will West and William West

Body Part	Will West's Measurements, in cm	William West's Measurements, in cm
Body height	178.5	177.5
Outstretched reach of both arms	187.0	188.0
Trunk height	91.2	91.3
Width of the head	19.7	19.8
Length of the head	15.8	15.9
Length of the right ear	14.8	14.8
Width of the right ear	6.6	6.5
Length of the left foot	28.2	27.5
Length of the left middle finger	12.3	12.2
Length of the left little finger	9.7	9.6
Length of the left forearm	unavailable	50.3

The chance of two people having identical fingerprints is 1 in 64 trillion, which is more than the population of Earth.
—*Scientific American*, 2020

amazing, his name was William West, and he looked almost the same as the new prisoner! Subsequently, the two men's fingerprints were taken and, of course, were quite different.

In the early 1900s, the fingerprint system was adopted by a number of agencies in the United States. In 1924 the Identification Division of the Federal Bureau of Investigation (FBI) was formed; by 1946 it held 100 million fingerprint cards. Today the FBI's criminal database contains around 47 million individuals (470 million prints). Their civil file contains around 30.7 million individuals (307 million prints). If piled on top of each other, these records would make 163 stacks as high as the Empire State Building!

The Anatomy of Fingerprints

Human skin is the body's first line of defense against invasion and infection (see Figure 4.1). The hills and valleys (ridges and grooves) you saw when examining your fingers with a magnifying glass make up the skin pattern that is yours alone. Friction ridges, as they are called, can also be found on your palms, feet, and lips. Most amazing, the patterns made by the friction ridges are not genetically controlled, so even identical twins who have the same "DNA fingerprint" will have different fingerprints!

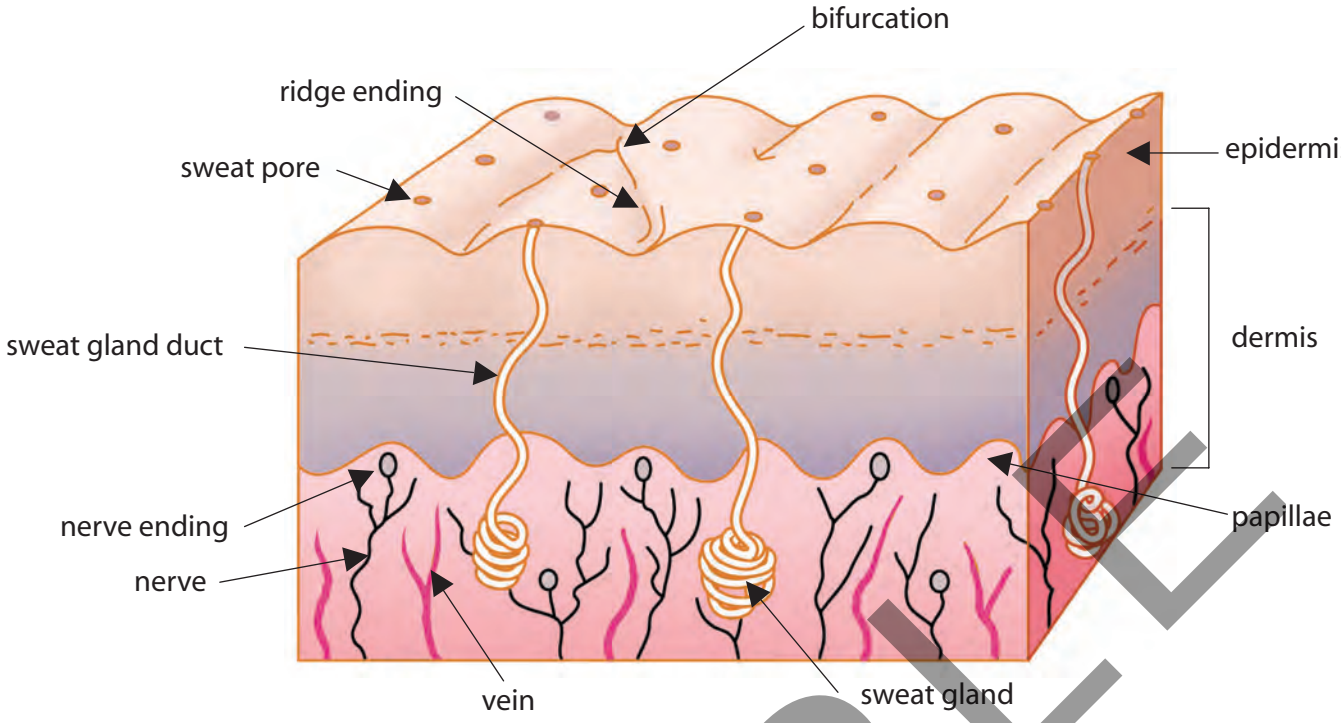


Figure 4.1 Cross section of human skin

Skin is made up of an outer epidermal layer separated from the inner dermal layer by the papillae. The papillae form a boundary that determines the friction ridge structure of the epidermis. Chemically or physically erasing the epidermal structure, as John Dillinger tried to do, causes only pain because the original print will soon grow back. Sweat pores along the ridges release perspiration, which is 98 to 99 percent water. It is estimated that a fingerprint initially may weigh 0.1 milligram (1/10,000 of a gram), so after evaporation of the water, we have left about 1 microgram (one-millionth of a gram) of residue, made up of half salt and half complex organic compounds such as amino acids, lipids, vitamins, and perhaps additional body oils picked up on the finger by touching oily or hairy parts of the body. This doesn't leave much for an investigator to work with!

Magnified finger ridges

LABORATORY ACTIVITY 4.1:
Observing and Taking Fingerprints

The FBI rejects about 2 percent of submitted criminal cards and about 10 percent of inked civil cards because of illegible fingerprints, even though these cards are prepared by professionals.

Although fingerprints can be left casually on anything you touch, there are a number of steps involved in taking clear fingerprints that can be classified and used for identification. In this lab, you will make observations about your fingerprints and use the ink and transfer method to take your fingerprint impressions.

Materials

For each group:

- stereomicroscopes

For each student:

- magnifying glass
- fingerprint ink or inkpad
- 10-print cards

Procedure

1. *Observation:* Examine the surface of your fingers beyond the last knuckle with a magnifying glass or a stereomicroscope. Describe what you see in your notebook. Make a sketch.

   Ridge patterns are not unique to fingers. Observe your palms, bare feet, and lips; they all have unique patterns.

2. *Ink and transfer:* The object is to obtain as wide and clear a print as possible—not too light, not too dark. This takes practice. The idea is to roll the finger across the ink pad, then roll it across the paper from one edge of the fingernail to the other. Do this just once, not back and forth because that will blur the print. Rolling the finger should make a large, square print showing lots of detail. Keep the finger and forearm parallel to the surface of the table. Sometimes it helps if your other hand or a partner directs the roll by holding and pressing the finger. See the diagram in Figure 4.2, showing how this is done.

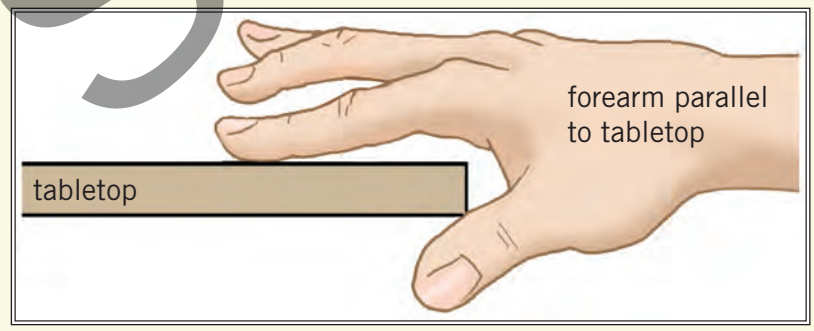


Figure 4.2 Ink and roll

(continued)

LAB ACTIVITY 4.1: Observing and Taking Fingerprints (*continued*)

Practice on scrap paper. In a good print, you should be able to follow a ridge as it enters one side of the finger and exits. Then take the cleanest, most legible print for each finger, cut it out, and paste it on the 10-print card distributed by your teacher. Some states require that students have a parent's permission to take part in this activity. If required, your teacher will hand out a permission slip prior to the fingerprinting activities. All fingerprint impressions will be returned or destroyed.

FBI 10-print card and rolling a print

Well-rolled fingerprint

Well-placed fingerprint

Blurred fingerprint—rolled back and forth

3. *Further observations:* Examine your 10-print card using a magnifying glass.

Analysis Questions

1. Note the basic similarities and differences in the patterns. What are they?
2. Which of your fingers have similar patterns and how are they different from the others?
3. Do you have any scars, cracks, or other unique features? If so, explain.

Classification of Fingerprints

All fingerprints can be classified into three basic patterns: loops, whorls, and arches.

The **loop** pattern has one or more ridges entering from one side, curving, then going out from the same side it entered from. If even *one* ridge exits the same side, it is a loop. There are two subgroups to the loop (see Figure 4.3). A radial loop opens toward the thumb, that is, toward the radius, the shorter of the two bones in the forearm; an ulnar loop opens toward the little finger, that is, toward the ulna, the minor bone of the forearm. Without knowing which hand made the print, you cannot tell if the loop is radial or ulnar (ulnar loops are more common, however).

loop

fingerprint pattern with one or more ridges entering from one side, curving, then going out on the same side entered

To this day no two fingerprints have been found to be identical. Fingerprints are different on each finger.

—*Livescience.com*, 2021

Radial Loop (left hand) Ulnar Loop (right hand)

Figure 4.3 Loops

All loop patterns show a **delta**, a triangular area usually shaped like the silt formation near the mouth of a river flowing into the sea. Loops also have a **core** near the center of the pattern. Examples of a delta and core can be seen in Figure 4.8. The relative location of core and delta must be known for complete individual classification and identification. About 65 percent of all fingerprints have loops.

delta

triangular area found in all loop and whorl patterns

core

area found near the center of all loop and whorl patterns

Whorl patterns can be subdivided into groups, as shown in Figure 4.4. All whorls must have at least two deltas and a core. Approximately

whorl

fingerprint pattern with at least two deltas and a core

Spiral Whorl Concentric Whorl Double Whorl

Figure 4.4 Whorls

20 percent of fingerprints have plain whorls. Composites (a mixture of two or more basic patterns) and accidentals (prints too irregular to fall into any other group) make up about 10 percent of all fingerprints.

arch

least common and simplest fingerprint pattern. Arches have no delta or core. All ridges enter one side and exit the other.

Arch patterns are the least common and the simplest of fingerprint patterns but can be confused with loops by inexperienced observers. The friction ridges enter from one side of the finger and exit the other while rising upward in the middle. Arches do *not* have a delta or core. They are divided into two groups, plain and tented arches (see Figure 4.5). Only about 5% of the population have arches.

Figure 4.5 Plain Arch

On your 10-print card, classify each of your fingerprint patterns according to the three basic types.

Studies have found differences in male and female fingerprint ridge density. Researchers believe males tend to have larger body proportions and a similar number of ridges are spread over a larger surface area. On average females are found to have ridge density of 12 to 15.9 ridges per 22 mm^2 of skin area and males have an average of 9.6 to 12.5 ridges over the same area.

—National Library of Medicine, 2021

Henry Classification System

Edward Henry developed a method of classifying fingerprints, later modified by the FBI, that allowed all sets of ten fingerprints in the world to be divided into 1,024 groups. Secondary and even more complex classifications were created to allow for even more groups. This is done so that, when an unknown set of prints is submitted to the FBI for comparison, most of the millions of sets of prints on file can be weeded out so that only a few dozen sets have to be compared by hand. Now, computer matching of fingerprints is used to make that first big cut; but after this, manual comparison may still be needed.

The first step in classifying a set of fingerprints is to identify the presence of any whorl patterns. These patterns are given a number based on which finger has the whorl, as shown in the chart in Figure 4.6. That number will be set up as a fraction. One is added to the numerator and denominator to avoid having zeros in the classification.

So, for example, if there is a whorl on your left thumb and right middle finger, with the rest of the fingers having loops or arches, then

$$\frac{0+0+4+0+0+1}{0+8+0+0+0+1} = \frac{5}{9} = \text{your primary classification}$$

right index **16**	right ring **8**	left thumb **4**	left middle **2**	left little **1**	**+1 =**
right thumb **16**	right middle **8**	right little **4**	left index **2**	left ring **1**	**+1 =**

Figure 4.6 Primary classification scheme based on whorls

Calculate your primary Henry-FBI classification number.

How many members of your class have the same classification number? How does the number of loops, whorls, and arches compare with the general population? About 25 percent of people have loops and arches with no whorls, so a primary classification of 1/1 is quite common. Be careful not to classify loops as arches.

Ridge Classification (Individualization)

You have now classified fingerprints according to general patterns or groups, but to individualize them you must use the fine structure of ridge characteristics, or **minutiae**. Some common minutiae are shown in Figure 4.7. Figure 4.8 shows some ridge characteristics in an inked print.

minutiae

in descriptions of fingerprints, ridge characteristics

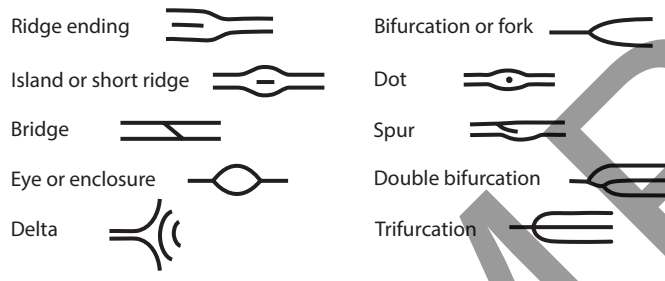


Figure 4.7 Individual ridge characteristics

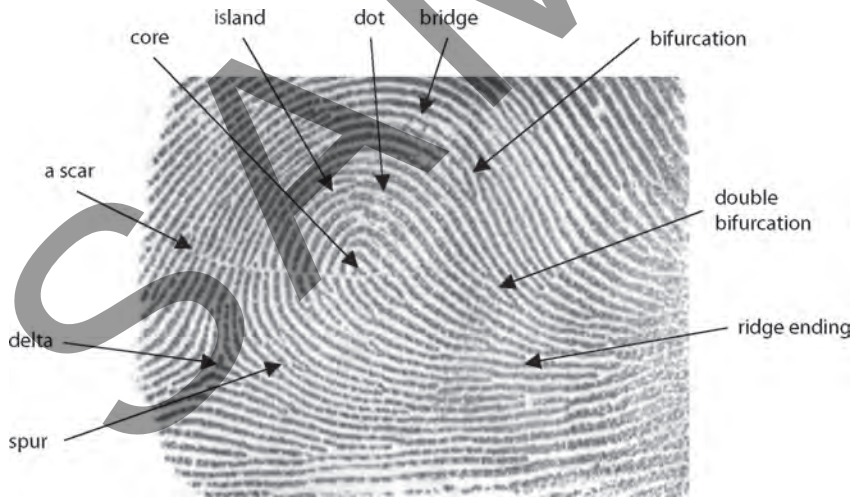


Figure 4.8 Ridge characteristics in an inked print

FADED FINGERPRINTS COST FORMER WELDER A JOB

One job applicant was turned down for a position at a nuclear power station because his fingerprints did not pass Homeland Security's guidelines. Most adults have more than 80 identification marks on each fingerprint, but years of welding had eroded ridges on this welder's fingers so that only about 30 remained.

Presenting Fingerprints as Evidence

Scarred fingerprint

There are no legal requirements in the United States regarding the number of points (minutiae and their relative location) that must match before deciding that a fingerprint belongs to a certain individual. Criminal courts will generally accept 8 to 12 points of similarity as sufficient proof. Considering there are 150 to 200 minutiae in a properly rolled fingerprint, the problem is getting a good, readable print to work with. This is why a partial print can be used to positively identify someone.

Fingerprints cannot lie, but the analysis and identification are subject to error. What types of errors do you think could happen when using a fingerprint to identify someone? As you continue reading, re-evaluate your answer to this question.

Identify the 15 points in Figure 4.9. What type of print is this?

How would scars affect identification? Missing fingers?

Working in certain professions can affect a person's fingerprint. For example, the ridges of concrete workers and plasterers can become rather indistinct over time because the alkalinity of cement and gypsum can dissolve proteins. Sherlock Holmes would note this.

John Dillinger, public enemy number one in the early 1930s, paid a doctor $5,000, plus $25 per day for room and board, to "dissolve" his fingerprints with acid and perform some minor surgery on his face.

DOCTOR IS FINGERED IN PRINT REMOVAL

It could be a scene straight from a Hollywood movie. The drug dealer is picked up at the border with mysterious bandages on his hands. His Mexican plastic surgeon is later arrested and charged with performing a surgery to remove his fingerprints and replace them with skin from his feet.

—from a Mexican newspaper, June 2007

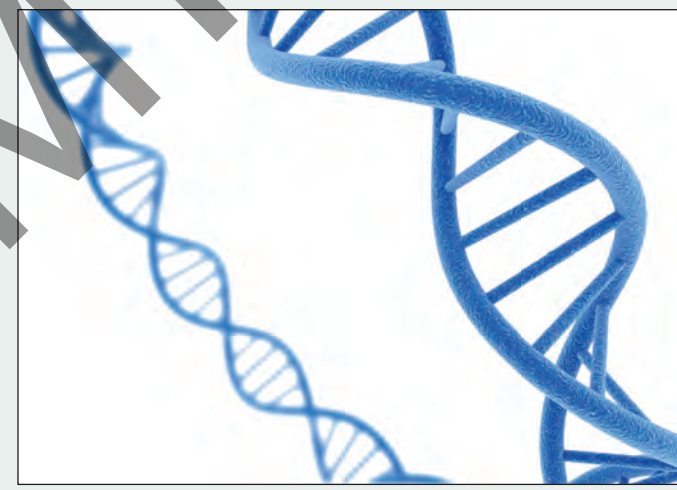
Figure 4.9 Fingerprint minutiae

The operation created lots of scar tissue that obscured the ridges in the center of his fingers, but there were still plenty of minutiae for identification. Also, if he had been identified with his "new" prints, the scars would have provided a unique characterization.

CASE STUDY 4.1
Donald and Ronald Smith

Donald Smith was arrested in 2008 for the murder of a preschool teacher, and carjacking in Gwinnett, GA. There was DNA evidence placing him at the crime scene as well as surveillance footage and witness descriptions that matched Smith's appearance at the crime scene. Despite all of this evidence, Donald Smith continued to proclaim his innocence. He offered an unusual defense; he claimed his twin brother Ronald Smith was the culprit.

When investigators found fingerprints at the crime scene did not match Donald, they tried matching them with Ronald's. It was a perfect match; Ronald when presented with the evidence, admitted to the crimes.



An interesting fact is that identical twins have the exact same DNA, but do have different fingerprints. "This is an unusual case," Gwinnett County Police Cpl. David Schiralli told ABC News. "No. 1, I'm glad that we were able to find the right brother and that we were able to find evidence to exonerate the other brother. Our investigators were faced with a tough task, dealing with identical twins."

This is a rare case where the highly reliable, high-tech DNA testing had to take a backseat to the ages old practice of fingerprinting.

Analysis Questions

1. How is this case similar to the case of Will and William West discussed earlier in this chapter?
2. What is the significance of this case?

Types of Prints

plastic print

three-dimensional print made as indentations in soft material such as fresh paint, putty, or wax; also called an indented or molded print

visible print

fingerprint left by a finger that has touched blood, paint, ink, or the like

latent print

fingerprint made by the deposit of perspiration or body oils

A **plastic print** (or indented or molded print) is made by pressing a finger against a plastic-like material to form a negative impression of a fingerprint. Such material could include fresh paint, putty (as in our crime scene), soap, candle wax, gum or a candy bar that has softened in the hand.

A **visible print** is left by a finger that has touched colored material such as blood, paint, ink, grease, chalk, mud, or sometimes even dust.

A **latent print** is essentially invisible and must be developed by chemical or physical means. These prints result from deposits of perspiration and body oils.

Plastic print

Visible print

Latent print

Reminder

probative value: the ability of evidence to prove something that is material to a crime. Fingerprints are said to have high probative value because they can be individualized to one person.

Back to the Crime Scene

Think back to the crime scene described at the beginning of this chapter. Where would you find the burglar's fingerprints? What types of prints are most likely to be found?

Make a list of the people whose fingerprints you might expect to find in the house. Suppose fingerprints that do not belong to anyone living in the house are found where the burglar went. Which ones have *probative value* or evidentiary value? Why?

Visualizing Latent Prints

One of the most common methods of visualizing (developing, or making visible) a latent print is by carefully dusting it with a fine powder. This method is most effective on hard, nonabsorbent surfaces. The color of the powder is chosen to stand out against the surface being examined. So, for example, a white or gray powder would be used on dark surfaces, a black powder on light ones. The developed print can then be "lifted" by means of clear sticky tape and collected for analysis.

There are various chemical methods for developing latent prints. They are generally more effective for soft, porous surfaces such as paper, Styrofoam cups, and leather. Iodine (I_2) reacts with the fatty oils from the finger to form a visible but short-lasting print. Iodine works

best for prints on porous paper. **Ninhydrin** is also most commonly used with paper and porous surfaces. It reacts with the amino acids left by the finger to make an orange to purple image. Silver nitrate ($AgNO_3$) reacts with salt (NaCl) left from perspiration in a dried print to form silver chloride (AgCl), which is then converted to dark silver oxide (Ag_2O). This is the same process used in developing photographs.

ninhydrin

a biochemical reagent used to detect free amino and carboxyl groups in proteins and peptides; the resulting color is called Ruhemann's purple

An interesting method of chemically developing fingerprints was accidentally discovered in Japan in the late 1970s. This method is now widely used for developing latent prints on nonporous surfaces such as metals, glass, adhesive tapes, and plastic articles. It involves evaporating superglue in an enclosed container. The glue, a cyanoacrylate ester, reacts with print residues to make a white, permanent impression that can then be treated with powders or fluorescent dyes to create a sharper contrast and allow for easier photography or lifting.

NO NEED TO DUST FOR PRINTS; COPS HAVE THIEF'S FINGERTIPS

A bandit sliced off two fingertips in his haste to cut the wires from an antiquated hard drive during a break-in at a state weighing station.
—abstracted from *Lansing State Journal*, 1997

Often, as with many analytical procedures, the order of the steps in developing prints is important. When you have just one piece of evidence, first use tests that won't harm that evidence. You want to get as much information as possible, so you may have to perform several tests. For example, to get the best image of latent fingerprints, you might first use iodine fuming; then you might try ninhydrin. You would save the silver nitrate method until last because this procedure will wash away traces of fatty oils and proteins.

A method that can be used to compare a latent print to an inked one is to use a photocopier to uniformly enlarge the prints. Overlay a clear acetate sheet on the inked print and delineate points of reference, such as the core, delta(s), and arch top, with a red marker. Now use the marker to outline particular minutiae—**bifurcations** are good ones to use because they are easy to see and there are many of them—working out from each reference point. This "known" print can then be overlaid on other latent prints for comparison.

bifurcations

common minutiae, shaped like a two-pronged fork

Figure 4.10 shows an example of two fingerprints for comparison. The one on the left is the same as the one in Figure 4.8; note the red highlighted ridge characteristics. Do they match the digitized image on the right? Is the latent print on the right from the same finger?

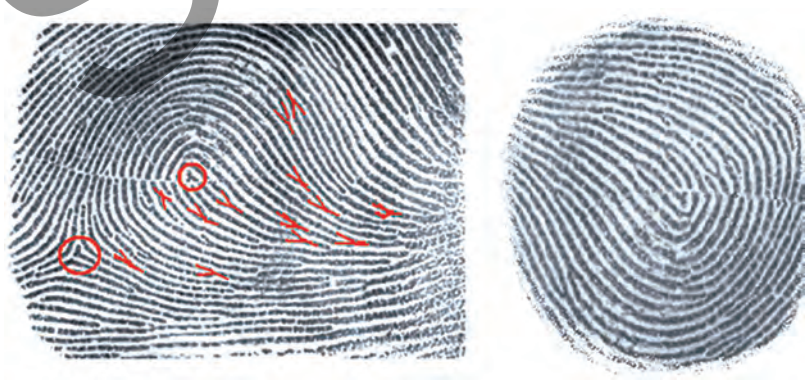


Figure 4.10 Identification algorithm

LABORATORY ACTIVITY 4.2:
Developing Latent Fingerprints

One job of the crime scene investigator is to find latent fingerprints—those that are left by perspiration or grease and are not immediately visible to the naked eye—and develop them, that is, treat them so they can be seen and inspected. There are several physical and chemical methods of visualizing latent fingerprints. In this lab, you will obtain latent fingerprints using many of these techniques.

Materials

- ceramic tiles
- white powder
- fingerprint brushes
- 2-inch cellophane tape
- black or gray fingerprint powder
- white paper
- smooth black paper
- beaker and cover
- glossy white or photo paper
- iodine crystals
- forceps
- starch solution
- ninhydrin solution in atomizer
- zinc chloride solution
- gloves
- heat gun
- UV lamp
- silver nitrate solution
- "fixer"
- paper towels
- microscope slides
- plastic bags
- Styrofoam cups
- fuming chamber and cover
- superglue
- copying machine
- clear acetate sheets
- red markers

PHYSICAL METHODS

Dusting and Lifting Latent Fingerprints Procedure

SAFETY ALERT	CAUTION
	• *Wear goggles when using the zinc chloride solution.* • *Wear gloves and apron.* • *Do not ingest or inhale. Iodine is toxic by inhalation and ingestion.*

1. Clean an area on a black tile.
2. Gently press your thumbprint on the edge.
3. Select a contrasting powder (white) and its brush. *Make sure you do not mix brushes.* When using the brush to apply powder, first fluff it up by rolling the handle rapidly between your fingers or palms.
4. Lightly touch the brush to the powder. Tap off any excess in a petri dish or on a newspaper.

Dusting technique

Dusting for fingerprints

5. Move the brush gently back and forth over the print surface. If a print begins to appear, continue brushing in the direction of the ridges. *If you brush too hard, the print will be wiped away or smeared and become useless.*
6. Gently blow off the excess powder from the print.
7. This takes practice; you may need to repeat several times before you get a good visible print. *Hint: If you are having difficulty getting enough oil on your fingers to make a latent print, run your fingers through your hair several times.* Once your print looks clear, move on to step 8.
8. Cut 3 inches of lifting tape.
9. Attach the tape to the base of the print. Holding the tape taut and beginning at the base of the print, gently begin pressing the tape down as you move upward and beyond the print. This should eliminate air bubbles and smearing.
10. Gently pull back the tape, lift the print, and place it on a 2-inch square of contrasting paper (black paper when using white powder or white paper when using black powder). Place the square with the print in your notebook and label which finger it came from and how you developed it. Keep in mind that you may have to develop and lift several prints to get one that is clear enough to identify characteristics.
11. Repeat steps 1–10 using the following materials: white tile with black powder; glass and metal with gray, white, or black powder.
12. Repeat steps 1–8 using porous surfaces such as white paper or an index card. Place the tape on the dusted print to protect it and place it in your notebook. Label your print.
13. A latent fingerprint on the surface of human skin can sometimes be lifted and developed. Try pressing several fingers on your wrist.

(continued)

14. Press a 1-inch square of glossy photographic paper against the prints on your skin for 2 to 3 seconds. Try using a clean microscope slide if photographic paper is unavailable.
15. Develop with an appropriate powder. If using photographic paper, protect it with tape in your notebook. If using a microscope slide, lift the print using tape and place it on contrasting paper, then place it in your notebook. Most people find it very difficult to lift prints from skin; you may not be able to find very many ridge characteristics. Save one or more latents from your skin for subsequent chemical developing (below).

Analysis Questions

1. Which surfaces were easier to develop and lift prints from? Which surfaces are most difficult?
2. Choose your best developed print and identify ridge characteristics.

CHEMICAL METHODS

Iodine Fuming Procedure

SAFETY ALERT	CAUTION
	Iodine is toxic by ingestion or inhalation. This procedure should be performed under a hood.

1. Place a fingerprint on two pieces of paper or index card.
2. Put each print in a beaker containing several crystals of iodine and cover the beaker. Solid iodine sublimes; that is, it passes directly from the solid phase to the vapor phase without going through the liquid phase. Both mothballs and dry ice also do this.

Iodine fuming

3. When the prints become visible, remove them with forceps or tweezers. Make sure you re-cover the beaker so fumes don't escape. Watch carefully as your prints develop. Leaving them in for too little time will not give enough detail; leaving them in for too much time will give you a big brown blotch.

4. Dip one of the prints in a starch solution. Allow to air dry.
5. Cover both prints with clear tape to preserve them.
6. Wash your hands thoroughly with soap and water.

Analysis Questions

1. What happened when you put the print in the starch solution? Why?
2. Identify five ridge characteristics on each print. Place the prints in your notebook. Label. Check them in a day or two and note any changes. Explain.

Ninhydrin Procedure

SAFETY ALERT	CAUTION
	Ninhydrin will stain skin and clothing. Wear gloves.

1. Place several fingerprints on a piece of paper.
2. Hang the paper in a hood or well-ventilated place and spray it with the ninhydrin solution.
3. Wait 24 hours for the print to develop, or warm gently with a hot plate.

Ninhydrin print

Analysis Question

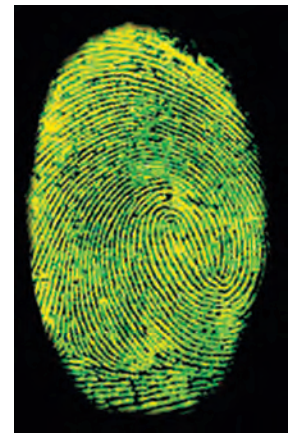
1. Identify five ridge characteristics. Place the print in your notebook. Label.

Further Development with the Ninhydrin Print Procedure (*optional*)

SAFETY ALERT	CAUTION
	• *Do not look directly into a black light; the UV radiation can harm your eyes.* • *You should wear gloves because zinc chloride solution is a skin irritant.*

1. Dip your ninhydrin prints in a zinc chloride solution. This should turn the print orange, making it easier to visualize.
2. Place the print under a black light (ultraviolet [UV] lamp).
3. Allow the print to dry and place it in your notebook. Label the print and describe what you saw under the black light.

(continued)



Fluorescent print

Prints developed by fuming

Lifting prints from a can

fluorescence

the absorption of light at one wavelength (often in the ultraviolet range) and its reemission at a longer wavelength (often in the visible part of the spectrum)

The zinc chloride treatment causes the prints to fluoresce. Basically, **fluorescence** occurs when a material absorbs light and reemits it at wavelengths longer than those of the light source. Substances are added to textiles and papers to cause them to fluoresce white (optical brighteners). Many fingerprint powders now contain fluorescent agents.

Superglue (Cyanoacrylate) Fuming Procedure

SAFETY ALERT

CAUTION

- *Do not get superglue on your skin and do not breathe the fumes, because they irritate the mucous membranes.*
- *Keep your face away from the top of the developing chamber when you slowly remove the lid. Open the lid towards the back of the hood.*

1. Wipe clean a microscope slide, a portion of a plastic bag, or a piece of Styrofoam cup. Write your initials on the sample.
2. Add fingerprints.
3. Place in the developing chamber.
4. Squeeze three or four drops of superglue on the aluminum foil or tin can that rests upon the heater (a lightbulb with a can over it).
5. Replace the lid on the chamber and turn on the light.
6. Prints should be visible after five to ten minutes. Carefully remove the item from the chamber. Be sure you do not breathe the fumes or allow them to get in your eyes as you lift up the lid.
7. You can enhance the prints even more with powder.
8. The print can then be lifted (several times) using tape.

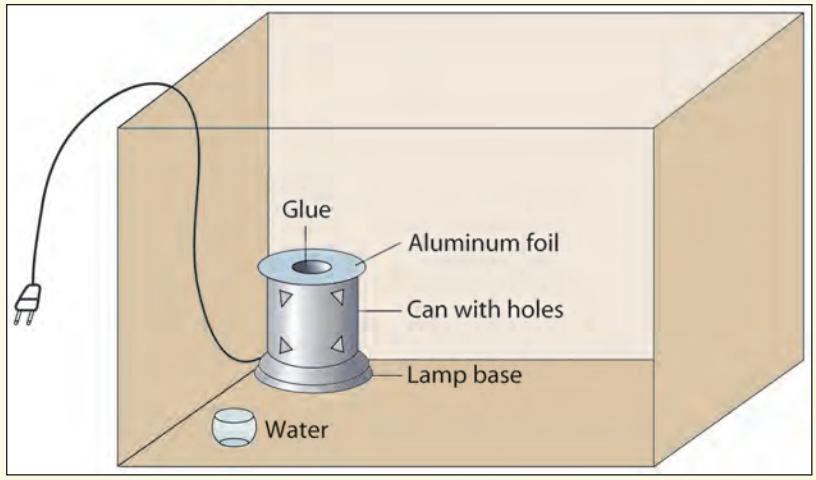


Figure 4.11 Superglue developing tank

Analysis Questions

1. Using a magnifying glass, identify ridge characteristics.
2. Label each print and how it was developed. Place in your notebook.

Silver Nitrate Procedure (*optional*)

SAFETY ALERT

CAUTION

- *Wear gloves because silver nitrate will darken your skin when it is exposed to sunlight.*
- *Do not look directly at the UV light. UV radiation can harm your eyes.*

1. Place a fingerprint on a piece of paper.
2. Using forceps, immerse it in the silver nitrate solution for 5 to 10 minutes.
3. Remove the paper with forceps and drain the excess liquid.
4. Sandwich the fingerprint paper between paper towels and dry it. Then expose the print to bright sunlight or long-wave UV light.
5. Watch the development carefully so that it does not become overexposed. Developing time will vary between 1–3 minutes depending on room conditions. If the print has been overexposed, it will become a blur.
6. To develop or "fix" the print, immerse it in the fixer solution for 15 to 20 minutes.

(continued)

LAB ACTIVITY 4.2: Developing Latent Fingerprints (*continued*)

7. Remove and blot dry with paper towels.
8. Place in your notebook, label, and identify five ridge characteristics.

   This is a good method to use on older fingerprints. The silver nitrate reacts with the sodium chloride that is left after other materials from the print have evaporated or deteriorated. It also works well with fingerprint impressions on wood. Try it on a popsicle stick, wood splint, or some other small piece of wood.

MAN PLEADS GUILTY TO 1979 MURDER

In 2005, Ronnie Lee Bullock of Burton was sentenced to serve at least 20 to 30 years in prison for the death of Vadah Warner. Warner's body was found in her Flint home on February 3, 1979. The only evidence discovered at the scene was two fingerprints.

Bullock, who was 19 at the time, was interviewed twice by police after the killing. He acknowledged knowing Warner but said he had never been in her house.

A break in the case came in 2003, when fingerprints from the crime scene were entered into the Automated Fingerprint Identification System and a match with Bullock was found. The system did not exist in 1979.

—condensed from *Lansing State Journal*, 2005

Other Methods

Police investigators routinely photograph fingerprint images to preserve them for further examination. Try photographing prints with a digital camera and enhance the image by computer. The latest innovation in fingerprinting is all digital—no more ink! The fingers are pressed against a glass plate and scanned to a screen, where they can be enhanced, compared, and sent to an Automated Fingerprint Identification System (AFIS), all in a matter of a few minutes.

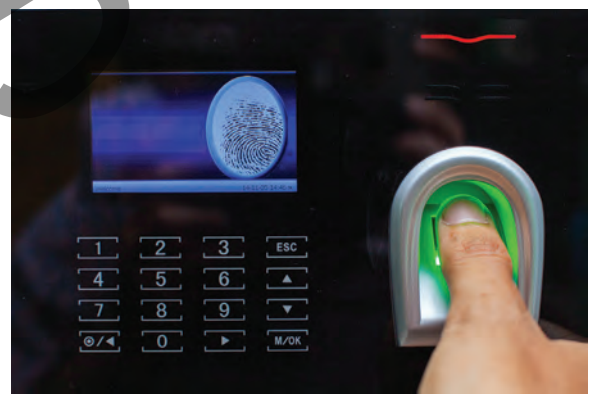
More sophisticated chemical methods of visualizing fingerprints use fluorescent dyes and special lighting or lasers to make the prints easier to see. Magnetic developing powder is also used in certain circumstances. Digital imaging can capture the print no matter how it has been developed. An impression is converted into a digital file that can then be manipulated to make the print easier to see. Work is being done to improve the resolution of these "e-prints."

A digital print's ridge characteristics can be recorded in geometric patterns relative to a fixed point. The resulting array may look like a drunken spider's web, yet a computer search algorithm can compare hundreds of thousands of these webs in less than a second. Automated systems still require manual intervention of incoming data to complete a fingerprint search and identification against existing digital files. The FBI phased in a system known as the Integrated Automated Fingerprint Identification System (IAFIS)

Taking a digital fingerprint

in 1999 that completely replaces the traditional fingerprint card and operator intervention. The FBI has been collecting and analyzing fingerprints for more than 80 years. With the IAFIS system they add more than 104,000 fingerprints to the database each day, and establish about 9,000 new criminal records each day. Now electronic fingerprint scanning devices can transmit prints at the time of arrest or booking to a central IAFIS database to provide immediate positive identification, check for a match with any suspect latent fingerprints on file, and provide a criminal history. IAFIS can also include criminal history, mug shots, photos of scars or tattoos, height, weight, hair and eye color, and aliases. With automatic scanners, inked impressions may eventually become obsolete.

The Next Generation Identification (NGI) system is gradually replacing IAFIS. The more efficient and precise system has increased matching accuracy to about 97 percent. The goal of the next generation system is to include additional bio markers such as voice, facial recognition, and iris or retinal scans. NGI is creating a complex database that will eventually include all the details law enforcement knows about a person.



Computer image of digitized prints

A man was arrested for resisting arrest and obstructing an officer. As part of the booking process, his fingerprints were submitted electronically to the FBI for processing in IAFIS. Within 20 minutes, the FBI learned that the offender had used a false name at the time of arrest, had a criminal history in four states, was on parole, and had been wanted for a parole violation.

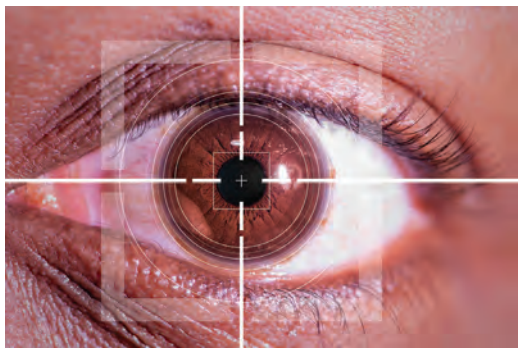
In 2015, Florida deputies initiated a traffic stop on a 2015 Mercedes that had been reported stolen. The driver gave authorities false identification but was arrested for driving a stolen vehicle. He was also carrying a handgun and three fraudulent credit cards. Once placed in the backseat of a squad car, deputies noticed the suspect trying to chew off his fingerprints. Deputies stopped him and were able to scan his fingerprints at the station. The driver was correctly identified as Kenzo Roberts, who had two felony warrants for aggravated assault and he was in the United States illegally.

Biometrics

using measurable biological characteristics for the purpose of authentication or identification.

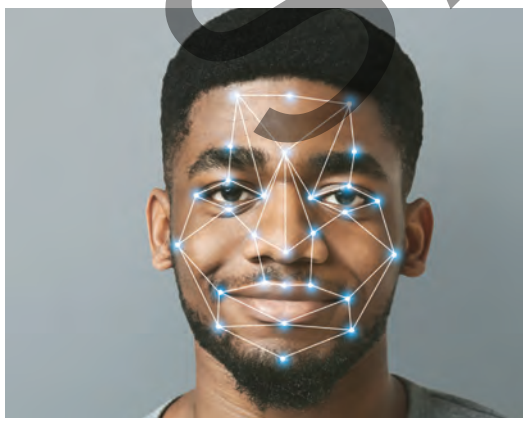
Other Biometrics

Fingerprints have been the most widely used **biometrics** or bio-identification markers for decades, but new ones are becoming possible with recent advances in technology. DNA profiling became widespread in the late 1980s and has changed the criminal justice system significantly. Other types of bio-identification methods that are becoming more common are:



Iris scan

Retina scan



Face recognition

- Iris: The iris is the colored portion of the eye that surrounds the pupil. If you look closely at your own iris you will see slightly different colors, freckles, rings, furrows, etc. These features and their locations can be read and then digitized for a database.
- Retina: On the back side of your eye you have a unique pattern of blood vessels that come from the optic nerve and are distributed throughout the retina. This pattern never changes throughout your lifetime, and everyone's is different. Just like fingerprints, identical twins have different retinal patterns. Retina scans are used as a security standard in military and government installations.
- Face recognition: Facial features are categorized in measurements and their relative geometry on an individual's face. For example: the distance between the eyes, distance from nose to upper lip, distance from outer eye to ear, distance from lower lip to chin, and the width of the nose. When enough of these are available, an individual's face can be "mapped." The person does not need to be present; this can be done from photographs using highly complex, sophisticated computer software.
- Voice: Your voice can be converted into electrical signals that then can be digitized and stored in a database. Again, the individual does not have to be present, a cell phone or recording can be used. Sometimes it is for voice verification or authentication.

- Hand geometry: A camera can take an image of the hand, and geometrical characteristics are determined. Measurements of about 100 points on the hand are digitized for the database, characteristics such as length of fingers, size of knuckles, etc. This method does require cooperation and presence of the individual to make the initial scan. You see this used as a security measure to gain access to a secure area. The hand is placed on a sensor with guiding poles between the fingers for proper placement. No fingerprints or palm prints are recorded in this method.

Hand Geometry

- Artificial Intelligence (AI) is the use of computer systems and machines with the ability and intelligence to do human tasks. AI machines simulate human "thinking" and behavior. AI use in biometrics is an ongoing debate because it can lead to identity fraud and errors in identification. Even though AI-powered identity verification systems can work faster and better than human identification systems, human involvement and verification in finding fraudulent identifications or misidentifications can correct AI and machine learning system errors. Other applications of AI, include behavior analysis and risk assessment.

KIDNAPPING VICTIM FOUND ALIVE THANKS TO RANSOM NOTE

In 2023, a nine-year-old girl was reported missing when she failed to return from a brief bike ride at a campground in New York. Her parents found her abandoned bike on the bike trail, but no sign of their daughter. Local, state, and federal agencies immediately began an extensive search and investigation. According to authorities, a ransom note was placed in her parents' mailbox after a two-day search for the missing child. The note was taken to a lab and tested for fingerprints. Fingerprints were recovered, and a fingerprint match was found in the database, allowing police to identify Craig Nelson Ross as their prime suspect. Ross's fingerprints were in the system from a 1999 drunk driving charge. The fingerprint identification led police to the suspected kidnapper's residence, where two state and federal SWAT teams found the missing girl alive, hidden in a cabinet. The suspect was taken into police custody. The missing girl was taken to a hospital to be evaluated and was later safely returned to her family. Craig Nelson Ross faces several charges following the the kidnapping.

CASE STUDY 4.2
Madrid Bombings

Is fingerprint evidence infallible, or do political pressures sometimes cause "mistakes?" On March 11, 2004 (911 days after the 9/11 attack), coordinated train bombings in Madrid, Spain killed 191 people and wounded 2,050.

The Spanish National Police found fingerprints at the scene and shared them with the FBI and Interpol. The FBI database, IAFIS found 20 "possible" matches, one of which was Brandon Mayfield.

After an extensive and intrusive investigation, the FBI arrested Mayfield, an Oregon lawyer. A bag found by Spanish police containing detonating devises had fingerprints that were identified by the FBI as belonging to Mayfield. Mayfield stated that he had not been to Madrid and in fact there was no evidence to show that he had left the continent in over 11 years.

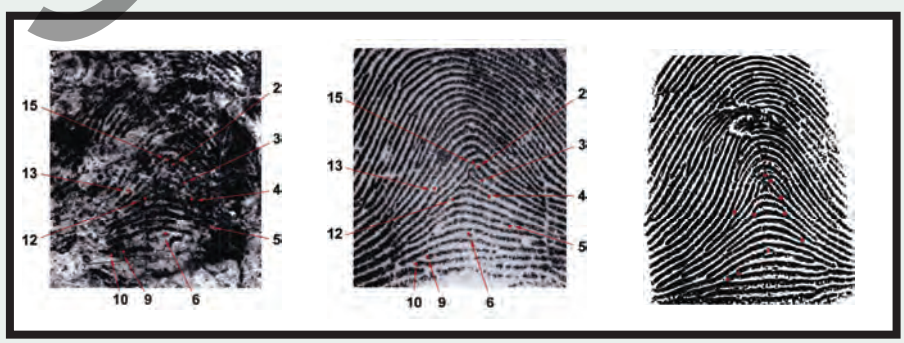
The FBI sent the "verified" prints of Mayfield to Spanish authorities, who then contested the match. Furthermore they had found other suspects in the case, Moroccan immigrants not linked to anyone in the U.S. The FBI however, continued surveillance on Mayfield and his family.

On May 19, Spanish authorities announced that the fingerprints belonged to an Algerian national, Ouhnane Daoud. When the arrest was published in the international press the next day, Mayfield was released.

During a court case that followed, the FBI admitted "serious errors" in the identification and apologized. Mayfield sued the U.S. government and settled for a reported $2 million.

Analysis Questions

1. Examine the fingerprints shown: the latent print from the crime scene, a known print from Brandon Mayfield, and a known print from Ouhnane Daoud. How are they similar?
2. How are the prints different?
3. What is the significance of this case?



Latent print from the crime scene (left); known print from Mayfield (middle); known print from Daoud (right)

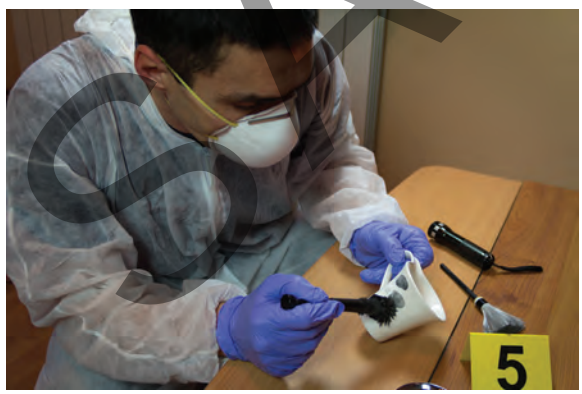
Career Connection: Biometric Forensics Specialist

When you think of someone who works in forensic science, what initially comes to mind? Do you picture a crime scene investigator out in the field surveying a crime scene, or do you visualize a scientist in a lab coat studying evidence and conducting experiments in a lab? A **biometric forensics specialist**, or a fingerprint forensics specialist, spends the majority of their time analyzing fingerprints, and other prints such as palm prints, and utilizing their pattern-matching skills in a laboratory setting. They can also work alongside detectives and crime scene investigators out in the field and may be called in off-hours and on weekends if their services are required at an active crime scene.

A biometric forensics specialist is an expert in fingerprint collection, categorization, and analysis. They collect fingerprint evidence from crime scenes and bring it back to a lab where they study it and try to extract information about the crime scene. As part of the process, they will enter collected fingerprints into a database called the Automated Fingerprint Identification System (AFIS) to look for a match that may already exist in the system. The AFIS is a critical tool used by local, state, and national law enforcement officials to classify, match, and store fingerprints.

Fingerprint experts play a key role in solving crimes—their work is both exciting and rewarding. Fingerprint analysis has been used for more than 100 years and the career has become more popular in recent years due to its portrayal on television and in movies.

Related careers include fingerprint analyst, fingerprint technician, latent print examiner, biometric fingerprint technician, and law enforcement. Each has its own set of requirements and skills. To learn more about these occupations, requirements, pay, and job outlook, go online to the occupational outlook handbook on the U.S. Bureau of Labor Statistics.



Fingerprint expert


Biometric forensics specialist

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.

From the 25 impressions in Figure 4.12, match the ones that are made by the same finger. Write your answers on the handout from your teacher in the 11 answer spaces listed. There are a total of 10 fingerprint matches, and one print that has no match. In some cases, one print may appear two, three, or even four times. An example has been given.

1. _____
2. B = K _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____

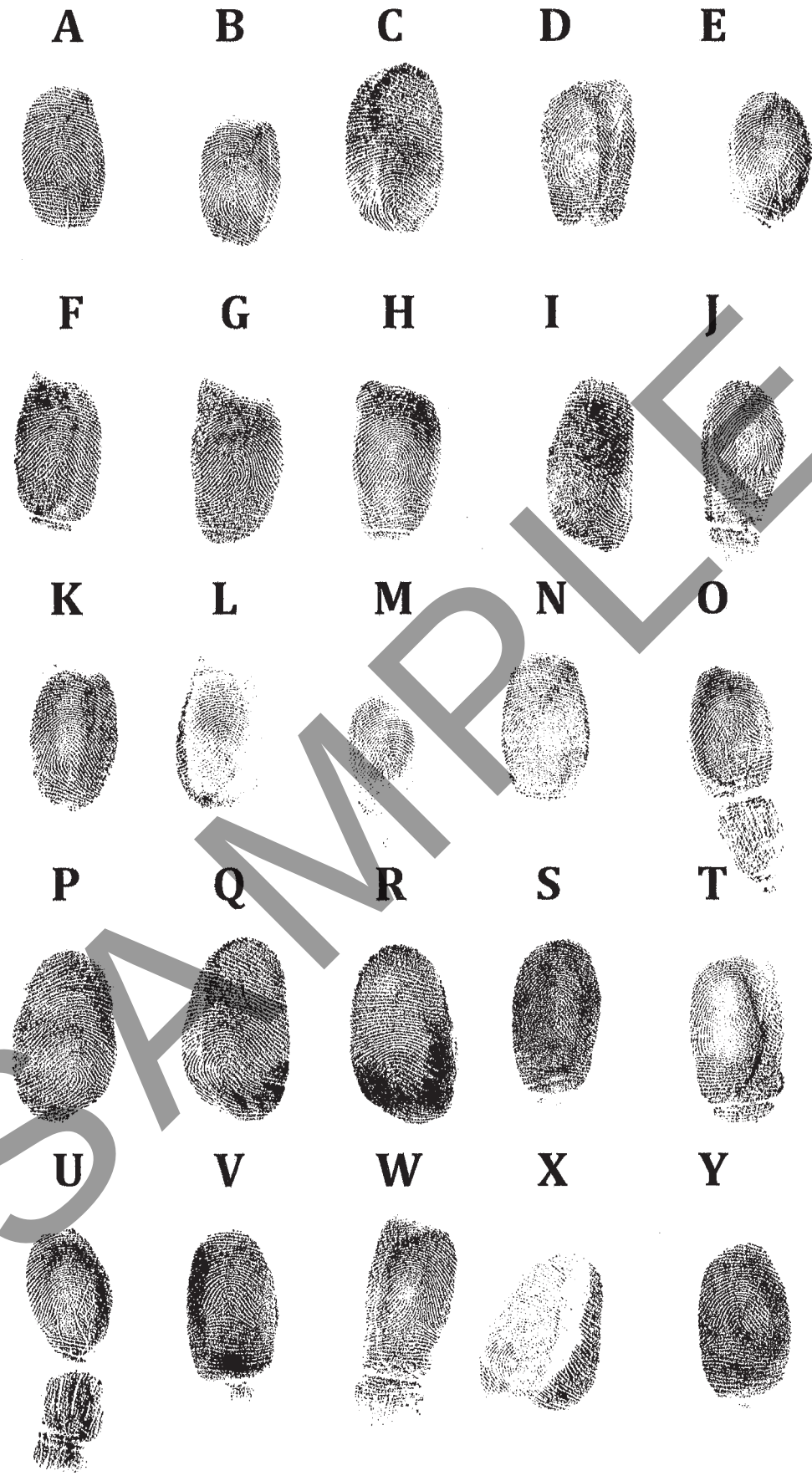


Figure 4.12 Match fingerprints

Checkpoint Questions

12. All fingerprints have class characteristics such as loops, whorls, arches, cores, deltas, bifurcations, ridges, spurs, and the like. Why, then, are fingerprints considered individual rather than class evidence?

13. What are fingerprints composed of, and how are they deposited?

14. What is the difference between a fingerprint pattern and a ridge characteristic?

15. How can fingerprint patterns be changed?

16. The most common type of fingerprint pattern is _____.

17. The least common type of fingerprint pattern is _____.

18. A loop pattern that opens toward the thumb is known as a _____.

19. All whorl patterns have _____ deltas.

20. What is meant by a latent print, and how can one be developed?

21. Explain what IAFIS is and how it is used.

22. How is the "final verification" made using the IAFIS system?

23. What type of fingerprint (plastic, visible, latent) would be likely to be found in, on, or by means of the following materials?

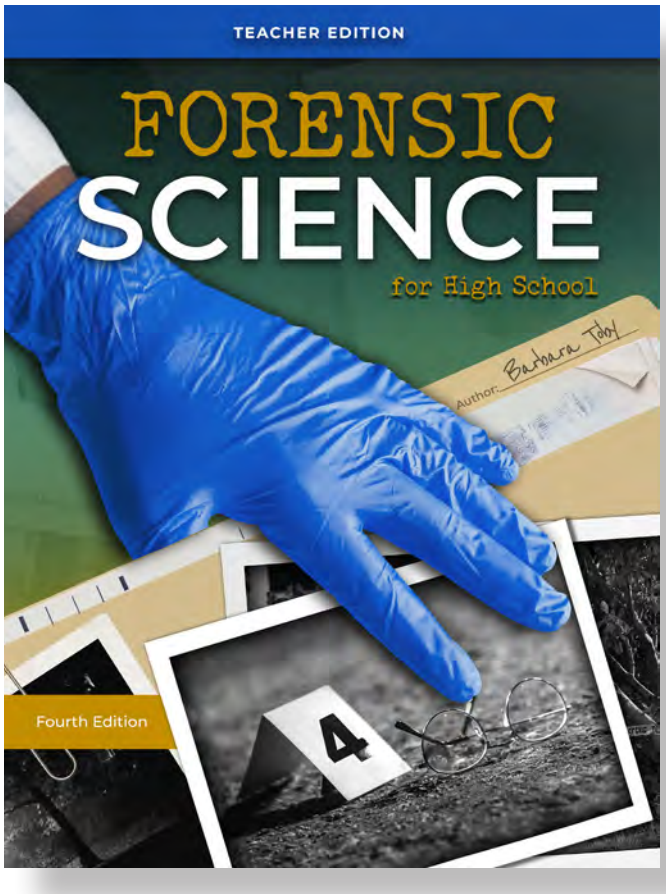
a. blood
b. mud
c. wood tabletop
d. windowpane
e. Romano cheese
f. chalk
g. skin
h. polyethylene bag
i. fudge
j. dust
k. newspaper
l. leather jacket
m. gun barrel
n. snow

24. In the crime scene presented at the beginning of the chapter, what would be the best way to develop the latent prints at each area? How would you preserve them? How would you preserve those in the putty?

Checkpoint Questions

25. What would be the best way to visualize latent fingerprints on the following materials?

a. matchbook cover
b. Popsicle stick
c. vinyl upholstery
d. cigarette butt
e. broken bottle
f. handkerchief
g. toilet seat
h. lightbulb



Chapter 4

Fingerprints

TEACHER EDITION

Chapter

4

Fingerprints

> **If someone hacks your password, you can change it as many times as you want. You can't change your fingerprints. You have only ten of them. And you leave them on everything you touch; they are definitely not a secret.**
>
> —Al Franken, former United States Senator

Objectives

- Explain why fingerprints are individual evidence.
- Describe why there may be no fingerprint evidence at a crime scene.
- Define the three basic properties that allow individual identification by fingerprints.
- Recognize and classify the three general ridge patterns (loops, whorls, and arches) and apply them to the primary Henry-FBI classification.
- Compare two fingerprints with at least ten points of identification.
- Identify the differences among latent, plastic, and visible fingerprints.
- Identify questions and concepts that guide scientific investigations.

Key Vocabulary

fingerprint	delta	plastic print	fluorescence
microns	core	visible print	biometrics
dactyloscopy	whorl	latent print	
anthropometry	arch	ninhydrin	
loop	minutiae	bifurcations	

Alignment to NGSS

Chapter 4: Fingerprints

Overarching Essential Questions	Overarching Enduring Understandings
• Why are fingerprints individual evidence? • How have computers made fingerprint identification easier? • How can the various methods of collecting, analyzing and processing fingerprints help in an investigation? • Why might there be no fingerprint evidence at a crime scene?	• Processing and analysis of evidence must be done carefully to help investigators solve crimes. • Fingerprints are unique to individuals. • The history of fingerprinting has evolved into a sophisticated method used in a criminal investigation.

Student Learning Objectives

After instruction, students should be able to:	NGSS Standards
Explain why fingerprints are individual evidence.	HS-LS1-2
Describe why there may be no fingerprint evidence at a crime scene.	HS-LS1-2
Define the three basic properties that allow individual identification by fingerprints.	HS-LS1-2 HS-ETS1-2
Recognize and classify the three general ridge patterns (loops, whorls, and arches) and apply them to the primary Henry-FBI classification.	HS-LS1-2 HS-ETS1-2
Compare two fingerprints with at least ten points of identification.	HS-LSI-2
Identify the differences between latent, plastic, and visible fingerprints.	HS-LSI-2
Identify questions and concepts that guide scientific investigations.	HS-ETS1-2

What national or state standards were used to inform this course's performance indicators?
Source: NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academic Press.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems: Ask questions that arise from examining models or a theory to clarify relationships. **Planning and Carrying Out Investigation:** Plan and conduct an investigation individually and/or collaboratively to produce data to serve as the basis for evidence. **Engaging in Argument from Evidence:** Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. **Obtaining, Evaluating, & Communicating Information** Compare, integrate, and evaluate sources of information presented in different media or format as well as in words in order to address a scientific question or solve a problem.	All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. **(HS-LS1-1)** The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. **(HS-LS1-6)** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. **(HS-LS3-3)** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering **(HS-ETS1-2)**	**Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. **Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **Influence of Science Engineering, and Technology on Society and the Natural World** New technologies can have deep impacts on society, including some that are not anticipated and the environment. **Connections to Nature of Science** Science is a human endeavor. • Technological advances have influenced the progress of science and science has influenced advances in technology. • Science and engineering are influenced by society and society is influenced by science and engineering.

Embedded English Language Arts/Literacy

RST.11-12.1. Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
RST.11-12.2. Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
RST.11-12-3 Follow precisely a multistep procedure when carrying out investigations
RST.11-12.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11–12 texts and topics*.
RST.11-12.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Diablo Highway

This chapter pairs well with the *Diablo Highway*™ virtual crime simulation. Before, during, or after this chapter, you may want to have students complete the *Fingerprint Analysis* lesson, quiz, and lab activity on *Diablo Highway* online.

Student Sheets

Student Sheet 4.1 *(10-Print Card for Laboratory Activity 4.1)*

Student Sheet 4.2 *(Permission Letter for Laboratory Activity 4.1)*

Student Sheet 4.3 *(Grading Rubric for Laboratory Activities 4.1 and 4.2)*

Student Sheet 4.4 *(Fingerprint Minutiae Identification)*

Student Sheet 4.4: Answer Key *(Fingerprint Minutiae Identification)*

Student Sheet 4.5 *(Fingerprint Analysis)*

Student Sheet 4.6 *(CASE STUDY 4.2 Madrid Bombings: Comparison of Fingerprints)*

Student Sheet 4.7 *(Matching Fingerprints)*

Student Sheet 4.7: Answer Key *(Matching Fingerprints)*

Student Sheet 4.8 *(Crossword Puzzle)*

Student Sheet 4.7: Answer Key *(Crossword Puzzle)*

Additional Online Resources

- Chapter 4 Slides
- BONUS CASE STUDY 4.A: Yvette Budram
- CASE STUDY 4.1: Donald and Ronald Smith
- CASE STUDY 4.2: Madrid Bombings

Warm-Up

> **If someone hacks your password, you can change it as many times as you want. You can't change your fingerprints. You have only ten of them. And you leave them on everything you touch; they are definitely not a secret.**
>
> —Al Franken, former United States Senator

- Show students the quote on the chapter opener. Then ask: Who is Al Franken? (*a former U.S. Senator and comedian*) What do you think he was referencing when he said these words? Do you agree with his perspective and concerns? Why or why not?
- Explain to students that when Franken was a U.S. Senator, he wrote a letter and sent it to Apple's CEO Tim Cook in 2013. He was concerned about fingerprint scanning (Touch ID), a new feature that was available on the latest iPhone. An Apple spokesperson explained that users' fingerprint data was stored locally and that fingerprint images were not stored. Further, third-party applications should not be able to access or hack people's fingerprints.

At The Crime Scene

Teacher Tip

As a class, read the crime scene scenario in the student book. Then working as a class or in small groups, have students generate a list of the evidence that they might find at the scene.

Evidence at the scene might include:

- fingerprints
- footprints
- bite marks
- pry bar impressions
- fabric
- blood
- handwriting

Potential evidence might also be found with the suspect:

- fingerprints
- shoe prints
- the pry bar
- dog hair
- the torn shirtsleeve
- blood type
- DNA
- handwriting and poor spelling
- damaged pants leg
- wounds on leg
- broken glass
- soil
- stolen jewelry
- teeth

You may want to keep this list for future reference to have students categorize the types of evidence.

Background Note

Students may ask whether a person's fingerprint changes if he or she has a cut or if it wears down or changes as the person ages. Explain to students that ridges in a person's fingerprint do change over time. As a person gets older, the ridges in the fingerprint get worn out. However, fingerprints do not change substantially as a person's skin ages. With age, the skin loses its elasticity and patterns are less visible. Fingerprint ridges can also be lost if a person washes their hands excessively or gets an abrasion or cut. However, such scars or conditions are only temporary. Fingerprints are usually restored in several weeks.

Ask students if they can visualize how small a micron is. Read aloud the sentence from the text, "The fingers, for example, are so sensitive that a vibration with a movement of 0.02 **microns** (2×10^{-5} mm) can be detected." Show students the photo of the ruler with the pencil pointing to a centimeter to show how small microns are. Explain that with even the slightest movement (less than half of a micron), a vibration of a person's finger can be detected. Point out these examples below so that students can visualize how small a micron is. If possible, bring in some of these materials such as coffee grounds or sand.

Other Materials Measured in Microns	
Beach sand	0.3 to 60 microns
Corn starch	0.1 to 0.8 microns
Pet dander	0.5 to 100 microns
Coffee ground	5 to 400 microns

There are 1000 microns in 1 millimeter

The History of Fingerprints

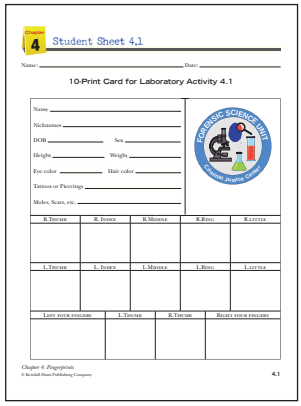
Background Note: Anthropometry

With the use of anthropometry, the science of human measurements, key physical details could be recorded on identification cards. Those details could then be used to narrow down the number of cards that match a description. The remaining cards could be matched to an actual photograph or name of a suspect or criminal. However, the anthropometric system could not distinguish two people who had similar physical characteristics.

Possible Discussion Questions

- Why is fingerprinting a more effective method of identification than the anthropometric system?
  No two fingerprints are identical, fingerprints cannot be altered, and it is possible to classify a very large number of prints. Anthropometric measurements can be similar and even nearly identical to others, as illustrated in the case of Will West and William West.

- Which method is more time-consuming? Why is the time factor important?
  Using anthropometry is more time-consuming than fingerprints, as multiple measurements must be taken, recorded, and compared. Agencies have a backlog of cases, so the faster suspects can be identified using fingerprints, the better.


Chapter 4 Student Sheet 4.1

Name: _____ Date: _____

10-Print Card for Laboratory Activity 4.1

Name _____
Nickname _____
DOB _____ Sex _____
Height _____ Weight _____
Eye color _____ Hair color _____
Tattoos or Piercings _____
Moles, Scars, etc. _____

R. Thumb	R. Index	R. Middle	R. Ring	R. Little
L. Thumb	L. Index	L. Middle	L. Ring	L. Little
Left four fingers		L. Thumb	R. Thumb	Right four fingers

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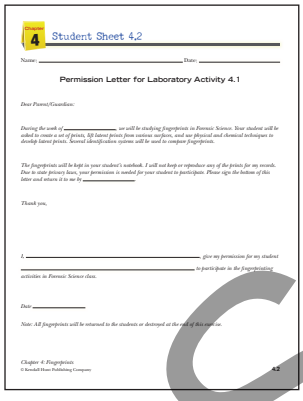
Chapter 4 Student Sheet 4.2

Name: _____ Date: _____

Permission Letter for Laboratory Activity 4.1

Dear Parent/Guardian:

During the week of _____, we will be studying fingerprints in Forensic Science. Your student will be asked to create a set of prints, lift latent prints from various surfaces, and use physical and chemical techniques to develop latent prints. Several identification systems will be used to compare fingerprints.

The fingerprints will be kept in your student's notebook. I will not keep or reproduce any of the prints for my records. Due to state privacy laws, your permission is needed for your student to participate. Please sign the bottom of this letter and return it to me by _____.

Thank you,

I, _____, give my permission for my student _____ to participate in the fingerprinting activities in Forensic Science class.

Date: _____

Note: All fingerprints will be returned to the students or destroyed at the end of this exercise.

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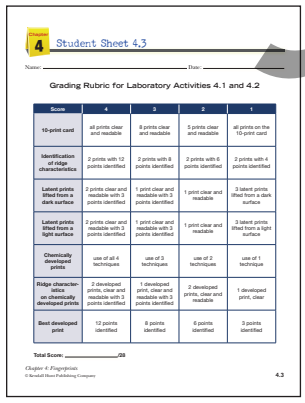
Chapter 4 Student Sheet 4.3

Name: _____ Date: _____

Grading Rubric for Laboratory Activities 4.1 and 4.2

Score	4	3	2	1
10-print card	all prints clear and readable	8 prints clear and readable	5 prints clear and readable	all prints on the 10-print card
Identification of ridge characteristics	2 prints with 12 points identified	2 prints with 8 points identified	2 prints with 6 points identified	2 prints with 4 points identified
Latent prints lifted from a dark surface	2 prints clear and readable with 3 points identified	1 print clear and readable with 3 points identified	1 print clear and readable	3 latent prints lifted from a dark surface
Latent prints lifted from a light surface	2 prints clear and readable with 3 points identified	1 print clear and readable with 3 points identified	1 print clear and readable	3 latent prints lifted from a light surface
Chemically developed prints	use of all 4 techniques	use of 3 techniques	use of 2 techniques	use of 1 technique
Ridge characteristics on chemically developed prints	2 developed prints, clear and readable with 3 points identified	1 developed print, clear and readable with 3 points identified	2 developed prints, clear and readable	1 developed print, clear
Best developed print	12 points identified	8 points identified	6 points identified	3 points identified

Total Score: _____/28

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The Anatomy of Fingerprints

LABORATORY ACTIVITY 4.1:
Observing and Taking Fingerprints

Time: 2 class periods

In this lab, students will make observations about their fingerprints and use the ink and transfer method to take their fingerprint impressions.

Student Sheets

- Student Sheet 4.1 *(10-Print Card for Laboratory Activity 4.1)*
- Student Sheet 4.2 *(Permission Letter for Laboratory Activity 4.1)*
- Student Sheet 4.3 *(Grading Rubric for Laboratory Activities 4.1 and 4.2)*

Teacher Tips

- Some states require parental permission to fingerprint students under the age of 18. A permission slip can be sent home a few days prior to the lab. **Student Sheet 4.2** ***(Permission Letter for Laboratory Activity 4.1)*** is a sample permission letter that can be printed and

distributed to students. Emphasize that all fingerprints will be returned to the students or destroyed at the end of this exercise. All Student Sheets can be found in the *Online Teacher Resources*.

- You'll need a good magnifying glass or stereomicroscope; a special ink pad for fingerprinting or printer's ink rolled onto a glass or plastic plate (however, a black ink office pad will do); a 10-print card; soap; and towels. A good forensic fingerprint pad, one sold specifically for fingerprinting, is best. A less expensive method that works pretty well is to rub a soft, black pencil point on paper, then rub and roll the finger through the graphite. Have someone hold each end of a piece of 2-inch-wide, clear sticky tape while the finger is rolled onto it. The tape can then be stuck to the 10-print card. You may want to project a copy of the 10-print card and demonstrate the method you want used.

- **Student Sheet 4.1** ***(10-Print Card)*** should be printed and distributed to students to complete the lab. **Student Sheet 4.3** ***(Grading Rubric for Laboratory Activities 4.1 and 4.2)*** offers a grading rubric chart that can be used to assess proficiency in the lab activities for this chapter. All Student Sheets can be accessed in the *Online Teacher Resources* and printed.

Student Instructions

Although fingerprints can be left casually on anything you touch, there are a number of steps involved in taking clear fingerprints that can be classified and used for identification. In this lab, you will make observations about your fingerprints and use the ink and transfer method to take your fingerprint impressions.

Materials

For each group:

- stereomicroscopes

For each student:

- magnifying glass
- fingerprint ink or inkpad
- 10-print cards

Teacher Tip

In Step 1, students should be able to see the pattern of ridges forming beads of sweat at the pores if the finger is close enough to the microscope lamp. Encourage them to look at other things under the scope, such as scars, blisters, cuts, dirt under the fingernails, and jewelry.

(continued)

Procedure

1. *Observation:* Examine the surface of your fingers beyond the last knuckle with a magnifying glass or a stereomicroscope. Describe what you see in your notebook. Make a sketch.

   Ridge patterns are not unique to fingers. Observe your palms, bare feet, and lips; they all have unique patterns.

2. *Ink and transfer:* The object is to obtain as wide and clear a print as possible—not too light, not too dark. This takes practice. The idea is to roll the finger across the ink pad, then roll it across the paper from one edge of the fingernail to the other. Do this just once, not back and forth because that will blur the print. Rolling the finger should make a large, square print showing lots of detail. Keep the finger and forearm parallel to the surface of the table. Sometimes it helps if your other hand or a partner directs the roll by holding and pressing the finger. See the diagram in Figure 4.2, showing how this is done.

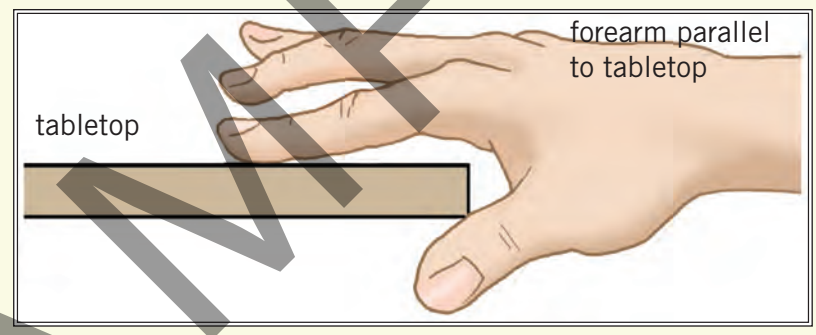


Figure 4.2 Ink and roll

Practice on scrap paper. In a good print, you should be able to follow a ridge as it enters one side of the finger and exits. Then take the cleanest, most legible print for each finger, cut it out, and paste it on the 10-print card distributed by your teacher. Some states require that students have a parent's permission to take part in this activity. If required, your teacher will hand out a permission slip prior to the fingerprinting activities. All fingerprint impressions will be returned or destroyed.

FBI 10-print card and rolling a print

Well-rolled fingerprint

Well-placed fingerprint

Blurred fingerprint—rolled back and forth

3. Further observations: Examine your 10-print card using a magnifying glass.

Analysis Questions

1. Note the basic similarities and differences in the patterns. What are they?
   Answers will vary.
2. Which of your fingers have similar patterns and how are they different from the others?
   Answers will vary.
3. Do you have any scars, cracks, or other unique features? If so, explain.
   Answers will vary.

Suggested Assignment

Have students go back and label the prints on their 10-print cards as loops, whorls, or arches. Ask each student to have at least two other students check to see if they agree with the identification. Have students sign the print cards they examined.

Background Note: Digital Fingerprint Scanners

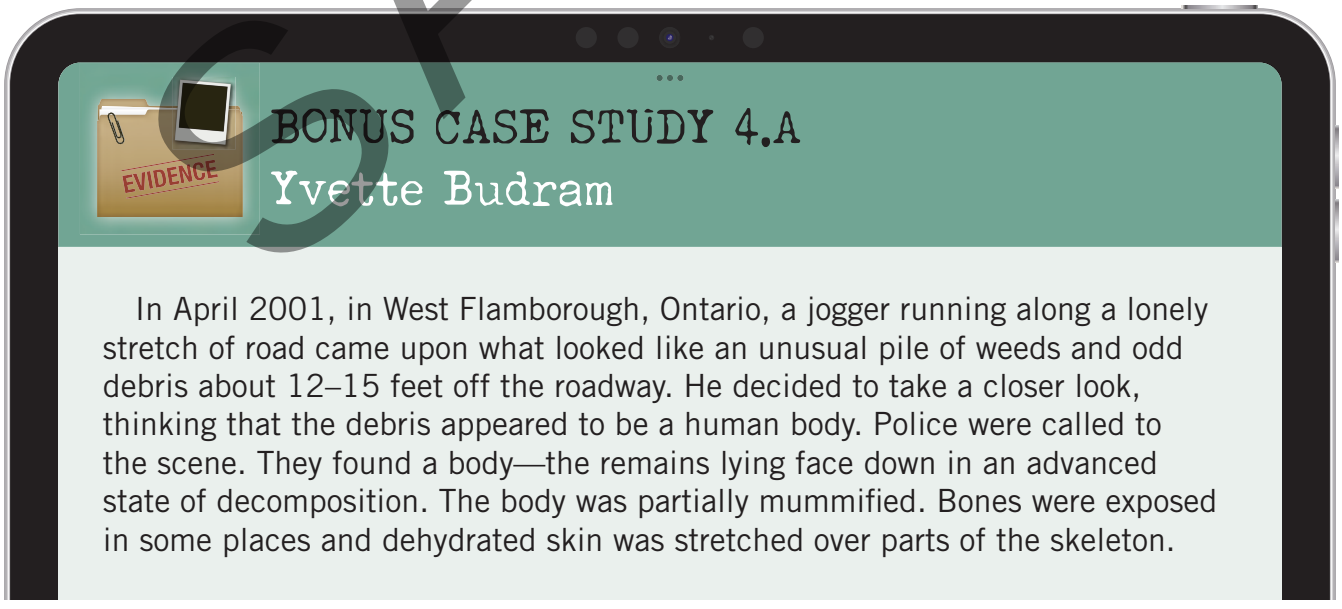
Used for decades since the late twentieth century, fingerprint scanners make access faster and easier than keying in a security code or password manually. They use a person's finger ridge pattern information that is captured during the setup of a device or system. A first, they were mostly used by governments or businesses. However, in the second decade of the 2000s, they started to become a common lock/unlock feature in smartphones because of their security capabilities and convenience. Fingerprint scanners were also put to use to unlock doors (car, house, etc.). One drawback of fingerprint scanners is that in an emergency situation, someone else will not be able to unlock a phone or door unless they know the phone or door security password or code, which are often used as a backup for unlocking. More information on digital fingerprint scanners can be found in the student book section Other Methods later in the chapter.

Possible Discussion Question

You may wish to direct students back to Al Franken's quote at the beginning of the chapter to think about how our fingerprints are not a secret, but they are used as a security measure. **What makes our fingerprints a better security tool?**

Bonus Case Study

The following case study is not included in the student edition. You may choose to use it as a replacement for one of the case studies in the student book, as a short reading assignment, or as an assessment of students' analysis skills. Bonus Case Study 4.A is available to print in the *Online Teacher Resources*.



At first glance the body appeared to be that of a young woman. The body was taken to the hospital morgue and examined by a forensic pathologist, a forensic anthropologist, and a forensic entomologist. They needed to determine the time of death, and if it was an accident, a hit-and-run, or a homicide. The position of the remains indicated that it had been dumped. There were no fractures, which would have been expected if it had been a hit-and-run. Most importantly, who was this person?

They found that the woman had died of strangulation and blunt force trauma to the head, and it had been approximately six months since her death. The team had difficulty determining who she was, as there were no obvious identifying characteristics. They tried using dental records and DNA, but there were no missing persons reports from the area in the last 6 months. Asking for help from the press and community, photographs of clothes and jewelry found at the scene were published, but to no avail.

Would investigators be able to get fingerprints? Or were they too decomposed for identification? Alan Yates, one of the investigators, noticed there was some shrunken skin on the fingers, though too shriveled up and hardened to identify prints. He had the idea of rehydrating the fingers by soaking them in a hydrating solution for several hours. After soaking, the fingers were still too hardened to make a usable print. Yates then massaged some lotion on the index finger to soften it. The finger was then rolled in ink, and a good print was printed and submitted to the CPIC (Canadian Print Identification). They got a hit. It had taken seven weeks to get a positive identification.

Yvette Budram had been arrested in September 2000, seven months before her body was discovered. She had been arrested for domestic assault using a hammer and knife. The victim of the assault was her husband, Mohan Ramkisson, a citizen of Guyana living in Canada. Yvette had failed to show up for her court date on September 20, resulting in a warrant for her arrest.

In June 2001, police told Ramkisson that his wife's body had been found. The next day Ramkisson bought one-way tickets to Guyana for himself and his three children. Because he was under investigation, he was arrested at the airport for trying to flee the country. In investigating Ramkisson, police found traces of blood in the master bedroom and in the trunk of his car. He had never reported his wife missing. The investigation found that Yvette had been killed in her home by her husband in September 2000. He then put her in the trunk of his car and drove 60 miles to West Flamborough before dumping her body at the side of the road. Ramkisson pleaded innocent but was charged in September 2004 with second-degree murder. He maintained his innocence until 2009 when he confessed to the murder. In November 2020, after serving 16 years, he was paroled and immediately deported to Guyana.

Analysis Questions

1. Three experts, a forensic pathologist, a forensic anthropologist, and a forensic entomologist were asked to examine the body to help with identification. Research each of these professions and write one sentence for each describing the job.
   Answers will vary.
2. Why would a dried, hard piece of skin not work well to get a usable print?
   Cannot roll the print if it is too hard and details may be obscured.
3. Think about what happens to your fingers after you spend a long time in a bath or the pool. How would that affect getting a usable print?
   If there is too much water in the finger, the print may be distorted, leaving out details.

Classification of Fingerprints

Henry Classification System

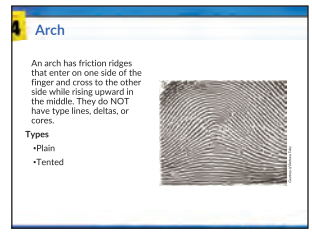
Suggested Assignment

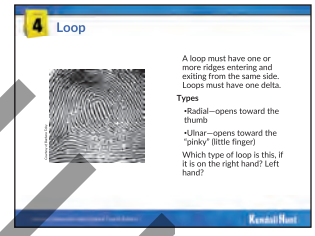
Have students classify family members' fingerprints, using just a stamp pad, paper, and a hand lens. In the absence of a stamp pad, the student could rub a #1 or #2 pencil on paper, press the finger in the graphite dust, and either transfer the pattern to a clean white paper or press the dusted finger against clear sticky tape, mounting the tape for examination.

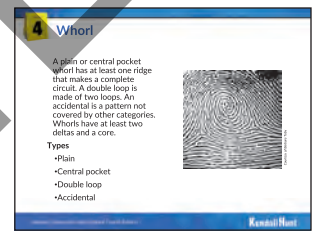
Teacher Tips

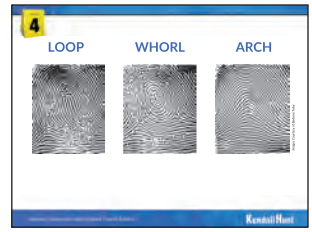
- If your state requires permission to obtain fingerprints from minors, you may want give students a permission slip to be signed if they are collecting fingerprints from a minor. Or, distribute to students a simplified letter that parents sign acknowledging they are aware and agree to have fingerprints from family members used for the assignment.
- The student book includes instructions for students to calculate their primary classification based on the number of whorls in their fingerprints. You may want to allow students

to do a gallery walk to see if anyone else has the same primary classification as them. This is also an opportunity to look at the prevalence of the different patterns in the class and compare it with the given percentages in the general public.









Slides

Use these slides to help students identify the differences between arches, loops, and whorls.

Cross-Curricular Connection

Optional Bonus Content: Consider sharing the statistics section with students. The text is available in the teacher slides. This content is not in the student text.

Statistics

This is a good point to think about simpler statistics (see Chapter 2). For example, what is the probability of one person having two arches? Let's start with something simple.

A tossed penny will land "heads up" or "tails up." The probability that it will land heads up is one out of two possibilities, or 1/2. Probability is merely the likelihood that a specific event will occur and can be defined numerically. So the odds that a penny will land heads up, no matter how often it is tossed or how often heads actually comes up, are 1 to 1.

Probability $(p) = n/N$, where:

$$\frac{n}{N} = \frac{\text{number of one kind of possible outcomes (heads)}}{\text{total number of all possible outcomes (heads } \textit{and} \text{ tails)}}$$

Odds n to $(N - n)$

What are the odds that heads will come up twice in two tosses of the coin?

$n = 1$ heads-heads

$N = 4$ the possible outcomes being heads-heads, heads-tails, tails-heads, and tails-tails

so

$$p = \frac{1}{2} \times \frac{1}{2} = \frac{1}{(2)^2}$$

The odds are

$$O = \frac{n}{N - n} = \frac{1}{4 - 1} = \frac{1}{3}$$

which means 1 to 3 in favor, or 3 to 1 against, getting two heads in two tosses.

In three tosses,

$$p = \frac{1}{(2)^3} = \frac{1}{8} \text{ and } O = \frac{1}{8-1} \text{ or } \frac{1}{7}$$

The odds are therefore 7 to 1 against getting three heads in three tosses.

Note that we are determining the probability of a particular sequence of events, that is, the chances that heads is going to come up every time. In 100 tosses, the chances that heads will come up 50 times are 1 to 1 because we aren't being specific about what the sequence has to be.

Mathematical probability as shown above works only if the outcomes do not affect one another, that is, if they are independent.

Forensic science often uses probability when judging the probative value of evidence. For example, what are the odds that a portion of a fingerprint came from a particular suspect, or that a piece of automobile paint came from a particular car? Unfortunately, it is very rare that you can assign a sure number to the odds, except for blood typing and DNA typing where population statistics are well known.

Now let's get back to comparing the primary patterns of the 300 or so fingerprints from your class to those of the general population as given in Table 4.2. The probability, in a large population, of having an arch is 5 percent, which means that, on average, 5 out of 100 fingers would have an arch; that is, there are 5 arches per 10 people, or, on the average, every other person has an arch. However, in a limited population, arches are not necessarily evenly distributed, so it's more likely that some students may have two fingers with arches. This is described in the Rule of Large Numbers, which states that the larger the population, the greater the likelihood that the actual numbers will approach those of the computed probability, P:

If a given outcome or event is repeated N times, then

$$\text{as } N \rightarrow \infty, \text{ then } P_{\text{actual}} \rightarrow P$$

Table 4.2: Frequency of Fingerprint Patterns

Loops		Whorls		Arches	
ulnar	radial	plain	other	plain	tented
60%	5%	20%	10%	4%	1%

Ridge Classification (Individualization)

Background Note

Explain to students that certain jobs wear down a person's fingerprints. Bricklayers are the most common because bricks are heavy and are made out of rough materials that wear down their hands. Manufacturing jobs that handle lime (calcium carbonate) deal with the wearing away of the top layer of their skin. This layer gets stripped away from repeated exposure to lime. In the past, people who handled a lot of paper (printers, etc.) also lost their fingerprints, but in a digital age there are fewer of these jobs. Over time, a person's fingerprints will be restored.

Possible Discussion Questions

- How does losing your fingerprints relate to forensics and identifying a criminal?

Since fingerprints are unique, hard to read fingerprints or fingerprints that are worn down may lead to a misidentification or no identification at all. They can even lead to wrongful convictions.

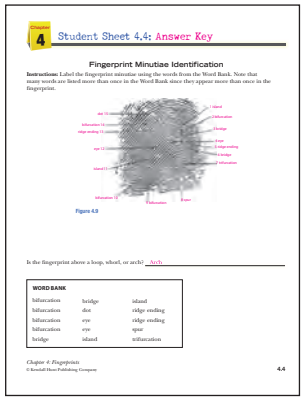
- Why does it make it harder to identify a suspect beyond reasonable doubt?

If there is insufficient evidence—such as a match cannot be made between a fingerprint at a crime scene and a suspect because the suspect's fingerprints are worn down. Fingerprint evidence alone is not often viewed as reliable in a court of law to make a conviction.

Presenting Fingerprints as Evidence

Teacher Tip

Have students read "Doctor Is Fingered in Print Removal," explain to students that even though such surgeries have some success that all layers of the skin from a person's fingertips would need to be removed and altered or replaced in order for there to be complete success. If only some of the layers of the skin are taken away or changed, ridges on the fingerprints may still be visible.



Chapter 4 Student Sheet 4.4: Answer Key

Fingerprint Minutiae Identification

Instructions: Label the fingerprint minutiae using the words from the Word Bank. Note that many words are listed more than once in the Word Bank since they appear more than once in the fingerprint.

Figure 4.9

Is the fingerprint above a loop, whorl, or arch? Arch

WORD BANK		
bifurcation	bridge	island
bifurcation	dot	ridge ending
bifurcation	eye	ridge ending
bifurcation	eye	spur
bridge	island	trifurcation

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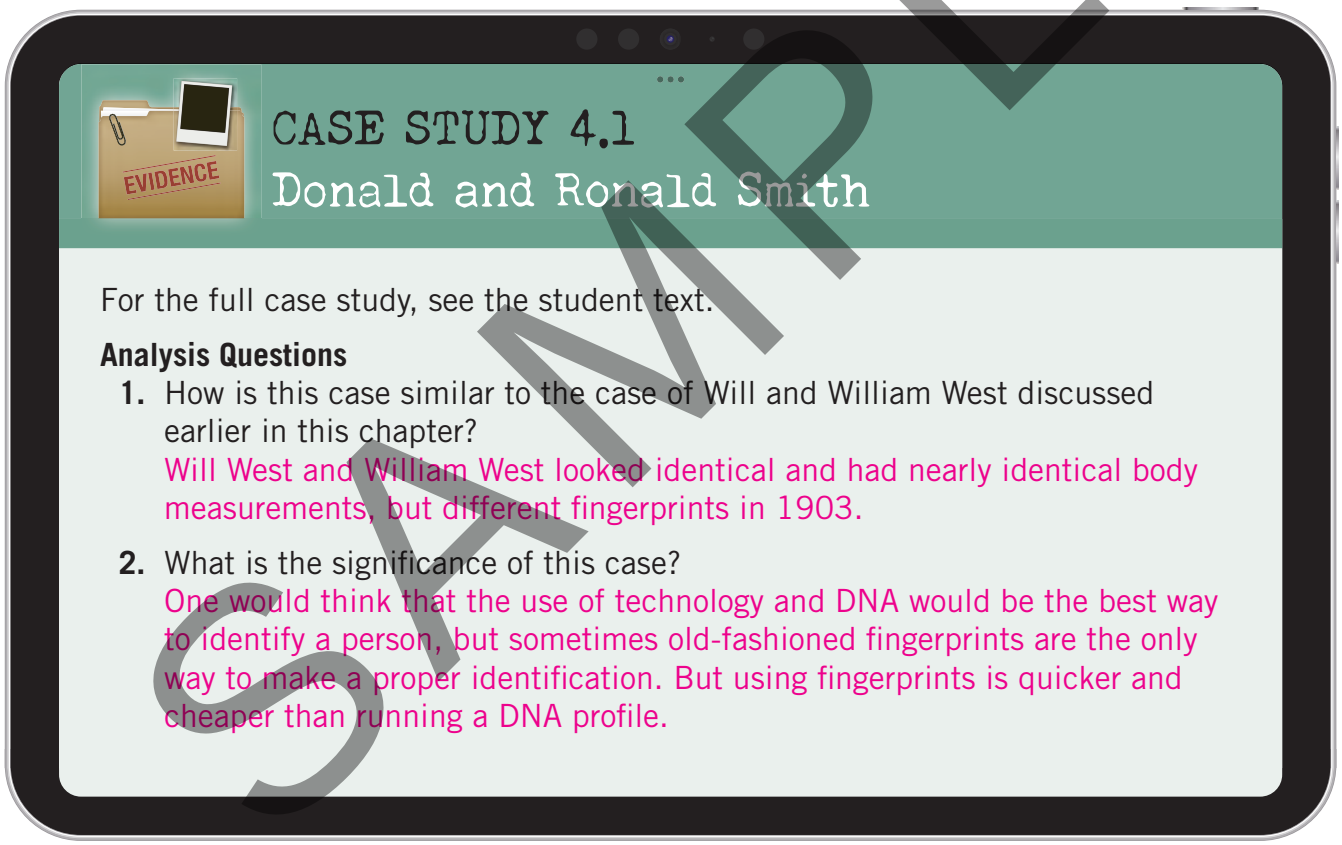
4.4

Suggested Assignment

- Ask students to use the minutiae in Figure 4.7 to identify the 15 points on Figure 4.9. Ask what type of print is shown. The fingerprint shown in Figure 4.9 can be printed and distributed to students from the *Online Teacher Resources*. It can be found on **Student Sheet 4.4** ***(Fingerprint Minutiae Identification)***. A word bank is included for students to label the minutiae. A reduced image of the answer key, **Student Sheet 4.4: Answer Key** ***(Fingerprint Minutiae Identification)*** is shown.

- Have students label 12 ridge characteristics on two of their best prints from Lab Activity 4.1. If they do not have two that are good enough to ID 12 points, have them make new inked prints.



Types of Prints

Back to the Crime Scene

Classroom Activity

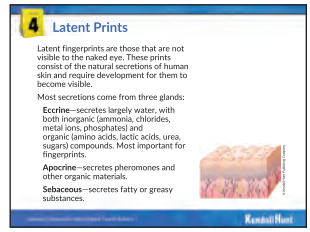
Looking back at the scenario from the beginning of the chapter, it may be helpful for students to draw a floor plan of pertinent sections of the house that was robbed, then take on the role of the burglar as he tries to enter the house, recreating his path and noting what he has touched. The first item would be the latch on the window, where a latent print would possibly be left. Next, the soft putty might yield a plastic print. Prints may have been left on door and drawer knobs and the jewelry cases upstairs; however, these areas may have many of the occupants' prints. On his way out, the burglar took a bite of cheese, possibly leaving a plastic print on what was left. If he was as careless as described, perhaps he even left an oily latent print of cheese on the pad of paper, the pen, or the back doorknob and latch. What characteristics will investigators look for in all of these prints? Good, clear prints with 8-12 points of identification. It can even be a partial print. Even if it's not a perfect print it may lead investigators in a particular direction of elimination of a particular suspect.

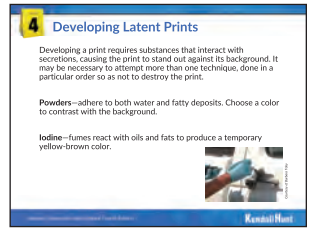
The fingerprints in the putty are outside; they could belong to the glazier. Even if matched to a suspect, they only put him at the scene, at some time, outside the house. However, a suspect's prints inside the house place him or her at the crime scene, although not necessarily at the time of the crime. If a suspect had never been inside the house before the crime . . . bingo!

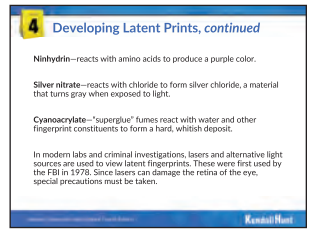
Visualizing Latent Prints

Background Note

Fuseo Matsumar was a hair and fiber expert examiner in a crime laboratory. He was working on a murder investigation. As he placed trace evidence (hairs) on glass slides using super glue, he saw that his own fingerprints had been applied to the slides. His lab partner Masato Soba saw what happened and was curious. So, he started an investigation of his own. Through his experiments, he learned that the vapors from the super glue are absorbed by human sweat and oils left behind by fingerprints. As a result, the fingerprints turn white.

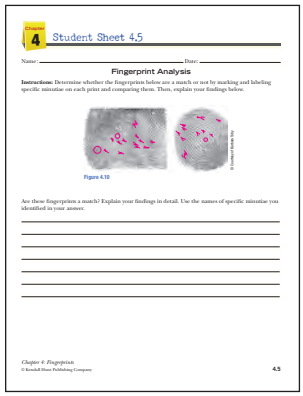






Slides

Consider displaying the Chapter 4 Slides as students read about latent prints. These slides can also serve as an introduction to what students will be investigating in Laboratory Activity 4.2.


Chapter 4 Student Sheet 4.5

Name: _____ Date: _____

Fingerprint Analysis

Instructions: Determine whether the fingerprints below are a match or not by marking and labeling specific minutiae on each print and comparing them. Then, explain your findings below.

Figure 4.10

Are these fingerprints a match? Explain your findings in detail. Use the names of specific minutiae you identified in your answer.

_____

_____

_____

_____

_____

_____

_____

Chapter 4: Fingerprints
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4.5

Teacher Tips

- Figure 4.10 shows an example of two fingerprints for comparison. The one on the left is the same as the one in Figure 4.8; note the red highlighted ridge characteristics. Do they match the digitized image on the right? Is the latent print on the right from the same finger? From the *Online Teacher Resources*, print and distribute **Student Sheet 4.5 *(Fingerprint Analysis)*** for students to mark and label specific minutiae for comparison.

- The eBook version of the Forensic Science book includes a brief video showing how to lift a print. Students can view this before participating in Laboratory Activity 4.2.

Laboratory Activity 4.2: Developing Latent Fingerprints

Time: 3 to 5 class periods

In this lab, students will practice several methods of collecting latent fingerprints.

Teacher Tips

- You may want to consider breaking up this lab so that students perform and analyze the physical methods during one class period and the four chemical methods during another class period using a jigsaw activity. Provide ample time for each group member to share their results from their investigation. If you choose to have all students try all the methods of developing latent prints, you will need 3–5 class periods.

- You may wish to set up a mock B & E in the classroom and ask the students to sketch the "crime scene," and locate where to look for fingerprints, and identify the best methods to use.

- If you use the fingerprint lab early in the school year, you might have the students make a latent print in some out-of-the-way place so that, at the end of the year, they can see if it still can be visualized. This will test the longevity of undisturbed fingerprints.

Student Instructions

One job of the crime scene investigator is to find latent fingerprints—those that are left by perspiration or grease and are not immediately visible to the naked eye—and develop them, that is, treat them so they can be seen and inspected. There are several physical and chemical methods of visualizing latent fingerprints. In this lab, you will obtain latent fingerprints using many of these techniques.

Materials

For each group:

- ceramic tiles
- white powder
- fingerprint brushes
- 2-inch cellophane tape
- black or gray fingerprint powder
- white paper
- smooth black paper
- beaker and cover
- glossy white or photo paper
- iodine crystals
- forceps
- starch solution
- ninhydrin solution in atomizer

For each student:

- zinc chloride solution
- gloves
- heat gun
- UV lamp
- silver nitrate solution
- "fixer"
- paper towels
- microscope slides
- plastic bags
- Styrofoam cups
- fuming chamber and cover
- superglue
- copying machine
- clear acetate sheets
- red markers

PHYSICAL METHODS

Dusting and Lifting Latent Fingerprints Procedure

SAFETY ALERT	CHEMICALS USED
	• *Wear goggles when using the zinc chloride solution.* • *Wear gloves and apron.* • *Do not ingest or inhale. Iodine is toxic by inhalation and ingestion.*

Teacher Tips

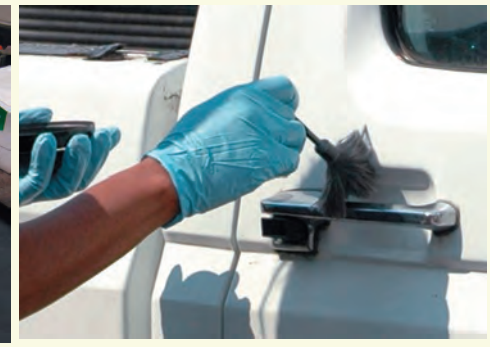
- The dusting activity is a messy one to clean up. You will find black powder everywhere. Fired, glossy kitchen/bathroom tiles (or pieces) make excellent substrates for practicing lifting, and your lab benches won't get as messy.

(continued)

- Black dusting powder can be purchased from companies that supply forensic science materials. A good substitute is toner from your copier. Be aware that some people are allergic to either or both powders. Fine charcoal can be used, as can soot, but these are messy to collect.
- Magnetic and fluorescent powders are also available. The former is not as messy, but is more expensive. For white dusting powder, talcum powder or chalk dust works well; gray powder can be made by mixing the black and white powders. About 1 percent of fine aluminum powder added to the mix increases adhesion
- There are brushes made specifically for fingerprint work. Good all-purpose brushes are about $4–10 each. Soft paint brushes or cosmetic brushes may work, but developing is difficult enough even with the right brush.
- Lifting tape can be a clear Scotch brand or similar tape; a 2-inch width works best.
- You will need white paper or card stock and black smooth paper (copier cartridges are wrapped in such paper).
- Local printers usually carry a black glossy paper. For skin, use glossy photo paper or a similar white, very glossy paper. See your local print shop.

1. Clean an area on a black tile.
2. Gently press your thumbprint on the edge.
3. Select a contrasting powder (white) and its brush. *Make sure you do not mix brushes*. When using the brush to apply powder, first fluff it up by rolling the handle rapidly between your fingers or palms.
4. Lightly touch the brush to the powder. Tap off any excess in a petri dish or on a newspaper.

Dusting technique



Dusting for fingerprints

5. Move the brush gently back and forth over the print surface. If a print begins to appear, continue brushing in the direction of the ridges. *If you brush too hard, the print will be wiped away or smeared and become useless*.
6. Gently blow off the excess powder from the print.
7. This takes practice; you may need to repeat several times before you get a good visible print. *Hint: If you are having difficulty getting enough oil on your fingers to make a latent print, run your fingers through your hair several times.* Once your print looks clear, move on to step 8.
8. Cut 3 inches of lifting tape.
9. Attach the tape to the base of the print. Holding the tape taut and beginning at the base of the print, gently begin pressing the tape down as you move upward and beyond the print. This should eliminate air bubbles and smearing.
10. Gently pull back the tape, lift the print, and place it on a 2-inch square of contrasting paper (black paper when using white powder or white paper when using black powder). Place the square with the print in your notebook and label which finger it came from and how you developed it. Keep in mind that you may have to develop and lift several prints to get one that is clear enough to identify characteristics.
11. Repeat steps 1–10 using the following materials: white tile with black powder; glass and metal with gray, white, or black powder.
12. Repeat steps 1–8 using porous surfaces such as white paper or an index card. Place the tape on the dusted print to protect it and place it in your notebook. Label your print.
13. A latent fingerprint on the surface of human skin can sometimes be lifted and developed. Try pressing several fingers on your wrist.
14. Press a 1-inch square of glossy photographic paper against the prints on your skin for 2 to 3 seconds. Try using a clean microscope slide if photographic paper is unavailable.
15. Develop with an appropriate powder. If using photographic paper, protect it with tape in your notebook. If using a microscope slide, lift the print using tape and place it on

(continued)

contrasting paper, then place it in your notebook. Most people find it very difficult to lift prints from skin; you may not be able to find very many ridge characteristics. Save one or more latents from your skin for subsequent chemical developing (below).

Analysis Questions

1. Which surfaces were easier to develop and lift prints from? Which surfaces are most difficult?
   It is easier to lift from smooth hard surfaces but more difficult with rough or flexible surfaces.
2. Choose your best developed print and identify ridge characteristics.
   Answers will vary.

CHEMICAL METHODS

Iodine Fuming Procedure

SAFETY ALERT — **CAUTION**

Iodine is toxic by ingestion or inhalation. This procedure should be performed under a hood.

Teacher Tips

- All the chemicals listed here are pretty standard; your chemistry department should have iodine crystals (I2). Note that iodine is toxic by inhalation and ingestion.
- For cornstarch or any starch product, make up a 2 percent solution by adding 2 g of starch to about 100 ml cold water and bringing to a boil while stirring. Cool. Sometimes it works better to put the starch in a spray bottle, than to dip the prints in a bowl of starch. Try both.

1. Place a fingerprint on two pieces of paper or index card.
2. Put each print in a beaker containing several crystals of iodine and cover the beaker. Solid iodine sublimes; that is, it passes directly from the solid phase to the vapor phase without going through the liquid phase. Both mothballs and dry ice also do this.

3. When the prints become visible, remove them with forceps or tweezers. Make sure you re-cover the beaker so fumes don't escape. Watch carefully as your prints develop. Leaving them in for too little time will not give enough detail; leaving them in for too much time will give you a big brown blotch.

Iodine fuming

4. Dip one of the prints in a starch solution. Allow to air dry.
5. Cover both prints with clear tape to preserve them.
6. Wash your hands thoroughly with soap and water.

Analysis Questions

1. What happened when you put the print in the starch solution? Why?
   The iodine reacted with the starch to make a darker, more permanent print.
2. Identify five ridge characteristics on each print. Place the prints in your notebook. Label. Check them in a day or two and note any changes. Explain.
   Individual answers will vary.

Ninhydrin Procedure

SAFETY ALERT	CAUTION
	Ninhydrin will stain skin and clothing. Wear gloves.

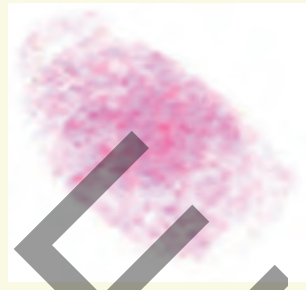
Teacher Tips

- Ninhydrin is available from most scientific supply houses. Make up a 5 percent solution in acetone or alcohol (stir 5 g of Ninhydrin into 95 ml acetone or alcohol).
- The hotplate speeds up the process so the lab can be completed in a class period.
- For zinc chloride solution, add 3 g zinc chloride ($ZnCl_2$), 25 ml ethyl alcohol, and 5 ml acetic acid to 70 ml of water.

(continued)

- A black light (ultraviolet lamp) positioned over a dark box eliminates the need for darkening the room and makes the procedure a lot safer.

1. Place several fingerprints on a piece of paper.
2. Hang the paper in a hood or well-ventilated place and spray it with the ninhydrin solution.
3. Wait 24 hours for the print to develop, or warm gently with a hot plate.



Ninhydrin print

Analysis Question

1. Identify five ridge characteristics. Place the print in your notebook. Label.

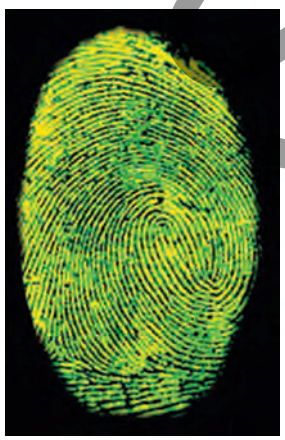
Further Development with the Ninhydrin Print Procedure (*optional*)

SAFETY ALERT

CAUTION

- *Do not look directly into a black light; the UV radiation can harm your eyes.*
- *You should wear gloves because zinc chloride solution is a skin irritant.*

1. Dip your ninhydrin prints in a zinc chloride solution. This should turn the print orange, making it easier to visualize. Caution: Zinc chloride solution is a skin irritant; you may wish to wear gloves.
2. Place the print under a black light (ultraviolet [UV] lamp).
3. Allow the print to dry and place it in your notebook. Label the print and describe what you saw under the black light. The zinc chloride treatment causes the prints to fluoresce. Basically, **fluorescence** occurs when a material absorbs light



Fluorescent print

Prints developed by fuming

Lifting prints from a can

and reemits it at wavelengths longer than those of the light source.Substances are added to textiles and papers to cause them to fluoresce white (optical brighteners). Many fingerprint powders now contain fluorescent agents.

Superglue (Cyanoacrylate) Fuming Procedure

SAFETY ALERT

CAUTION

- *Do not get superglue on your skin and do not breathe the fumes, because they irritate the mucous membranes.*
- *Keep your face away from the top of the developing chamber when you slowly remove the lid. Open the lid towards the back of the hood.*

Teacher Tip

A superglue developing tank can be made from an aquarium, even one with cracked sides (tape them with duct tape). Line three sides with aluminum foil to prevent eventual clouding by cyanoacrylate polymer (superglue) and insert a 40-watt lightbulb and socket, covered by a tin can with a few holes punched in it. Place aluminum foil or a bottle cap on top of the can. Insert a small container of water in the tank (this catalyzes faster development of prints) and a rack to hold objects to be fumed. Use a cover for the aquarium (a piece of cardboard will do) because the fumes are quite irritating to the eyes and throat. Place the chamber in a hood or where there is good ventilation.

1. Wipe clean a microscope slide, a portion of a plastic bag, or a piece of Styrofoam cup. Write your initials on the sample.
2. Add fingerprints.
3. Place in the developing chamber.
4. Squeeze three or four drops of superglue on the aluminum foil or tin can that rests upon the heater (a lightbulb with a can over it).
5. Replace the lid on the chamber and turn on the light.

(continued)

6. Prints should be visible after five to ten minutes. Carefully remove the item from the chamber. Be sure you do not breathe the fumes or allow them to get in your eyes as you lift up the lid.
7. You can enhance the prints even more with powder.

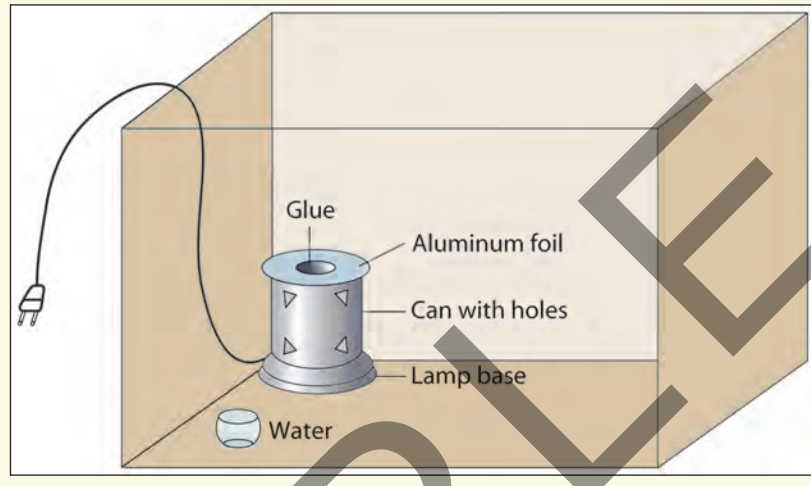


Figure 4.11 Superglue developing tank

Analysis Questions

1. Using a magnifying glass, identify ridge characteristics.
2. Label each print and how it was developed. Place in your notebook.

Silver Nitrate Procedure (*Optional*)

SAFETY ALERT

CAUTION

- *Wear gloves because silver nitrate will darken your skin when it is exposed to sunlight.*
- *Do not look directly at the UV light. UV radiation can harm your eyes.*
- *Sodium bisulfate is a corrosive solid. Avoid skin contact, inhalation, and ingestion.*

Teacher Tip

On step 6 for a fixer, use 20 g of sodium thiosulfate ("hypo") plus 14 g of sodium bisulfite per 100 g of water.

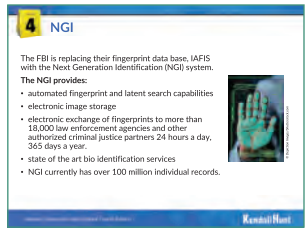
1. Place a fingerprint on a piece of paper.
2. Using forceps, immerse it in the silver nitrate solution for 5 to 10 minutes.

3. Remove the paper with forceps and drain the excess liquid. You may want to wear gloves for this one because silver nitrate will darken your skin when it is exposed to sunlight.
4. Sandwich the fingerprint paper between paper towels and dry it. Then expose the print to bright sunlight or long-wave UV light. Place a fingerprint on a piece of paper.
5. Watch the development carefully so that it does not become overexposed.
6. To develop or "fix" the print, immerse it in the fixer solution for 15 to 20 minutes.
7. Remove and blot dry with paper towels.
8. Place in your notebook, label, and identify five ridge characteristics. This is a good method to use on older fingerprints. The silver nitrate reacts with the sodium chloride that is left after other materials from the print have evaporated or deteriorated. It also works well with fingerprint impressions on wood. Try it on a Popsicle stick, wood splint, or some other small piece of wood.

Other Methods

Slides

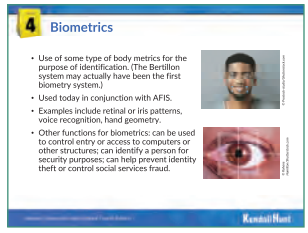
Use this slide to support students' understanding or a review of NGI after students have read the section. Have students work with a partner to create a Venn diagram to compare the IAFIS and NGI systems.



Other Biometrics

Slides

Use this slide to support students' understanding or as a review of biometrics after students have read the section.

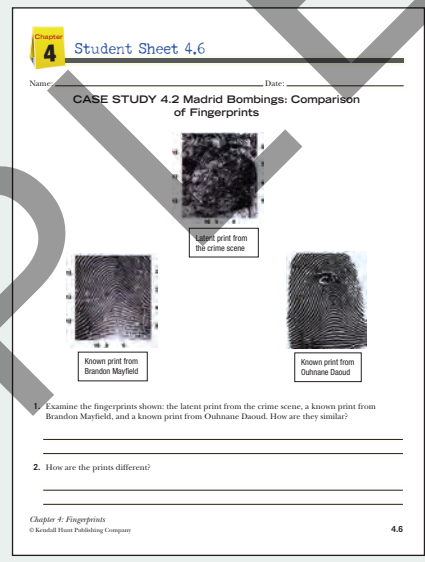


CASE STUDY 4.2
Madrid Bombings

For the full case study, see the student text. Have students compare the fingerprints of the suspects in this case using enlarged images of the fingerprints in the student book on **Student Sheet 4.6** ***(CASE STUDY 4.2 Madrid Bombings: Comparison of Fingerprints)***. This can be found in the *Online Teacher Resources* to print and distribute to students. A reduced image is shown.

Analysis Questions

1. Examine the fingerprints shown: the latent print from the crime scene, a known print from Brandon Mayfield, and a known print from Ouhnane Daoud. How are they similar?
   They are all loops.
2. How are the prints different?
   Answers will vary. Students can find minutiae that match Daoud's to the crime scene or find minutiae on Mayfield's that do not match the crime scene.
3. What is the significance of this case?
   Even though IAFIS found 20 possible matches, an individual needs to examine the prints to positively confirm a match.


Chapter 4 Student Sheet 4.6

Name: _____ Date: _____

CASE STUDY 4.2 Madrid Bombings: Comparison of Fingerprints

Latent print from the crime scene

Known print from Brandon Mayfield

Known print from Ouhnane Daoud

1. Examine the fingerprints shown: the latent print from the crime scene, a known print from Brandon Mayfield, and a known print from Ouhnane Daoud. How are they similar?

2. How are the prints different?

Chapter 4: Fingerprints
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4.6

Career Connection: Biometric Forensics Specialist

Other possible careers that are related to a forensic fingerprint **biometric forensics specialist** include: fingerprint analyst, fingerprint technician, latent print examiner, biometric fingerprint technician, biometric specialist, or law enforcement.

Optional: You may want to assign students the task of choosing one career and answering a list of generic questions about the career, such as general job duties, salary, who do you work for, who do you work with, and required education.

Checkpoint Questions

From the 25 impressions in Figure 4.12, match the ones that are made by the same finger. Write your answers in the 11 answer spaces listed. There are a total of 10 fingerprint matches, and one print that has no match. In some cases, one print may appear two, three, or even four times. An example has been given.
A copy of Figure 4.12 is provided in the *Online Teacher Resources* as **Student Sheet 4.7 *(Matching Fingerprints)***. You can print it and distribute it to students. Answers (shown) can be found on **Student Sheet 4.7: Answer Key *(Matching Fingerprints)*.**

Note: Matching can be facilitated by digitally enlarging and comparing cropped areas, or by enlarging the image with a copier and using a transparency overlay.

1. A = N = V = Y
2. B = K
3. C = X = Q = R
4. D = T
5. E = U
6. F = L
7. G = H
8. I = P
9. J = W
10. M = O
11. S = No Match/Unreadable

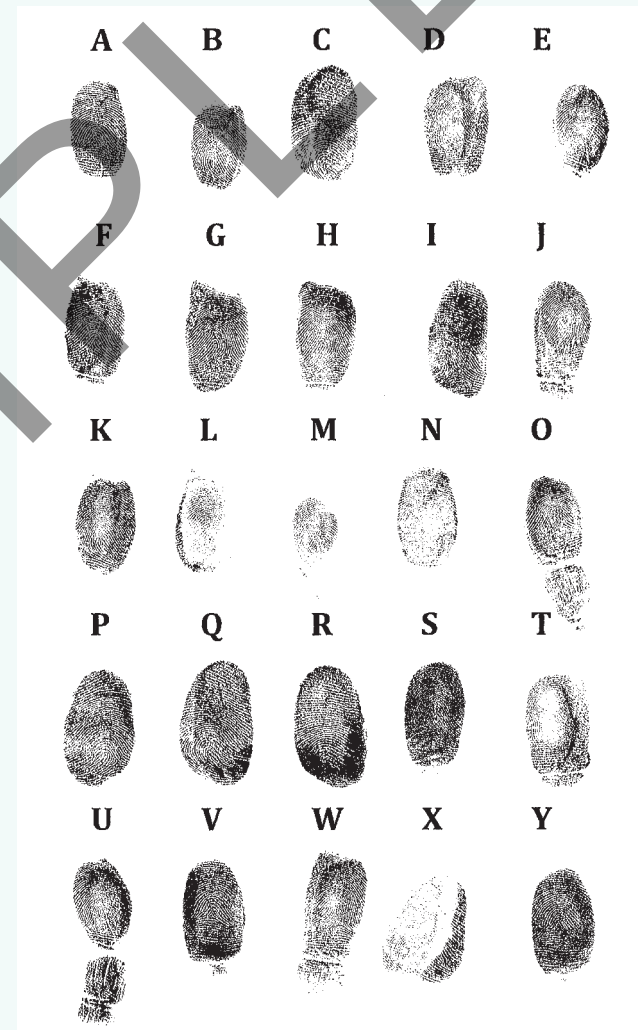


Figure 4.12 Match fingerprints

Checkpoint Questions

12. All fingerprints have class characteristics such as loops, whorls, arches, cores, deltas, bifurcations, ridges, spurs, and the like. Why, then, are fingerprints considered individual rather than class evidence?
The relative locations of the class characteristics make the pattern unique.

13. What are fingerprints composed of, and how are they deposited?
water, salts, organic compounds; deposited by touching or handling an object

14. What is the difference between a fingerprint pattern and a ridge characteristic?
Loops, whorls, and arches are patterns; the minutiae are the ridge characteristics.

15. How can fingerprint patterns be changed?
Patterns cannot be changed.

16. The most common type of fingerprint pattern is _____.
loop

17. The least common type of fingerprint pattern is _____.
arch

18. A loop pattern that opens toward the thumb is known as a _____.
radial loop

19. All whorl patterns have _____ deltas.
at least two

20. What is meant by a latent print, and how can one be developed?
A latent print is invisible; it can be developed by various physical and chemical means.

21. Explain what IAFIS is and how it is used.
the Integrated Automated Fingerprint Identification System

22. How is the "final verification" made using the IAFIS system?
through examination by an expert

Checkpoint Questions

23. What type of fingerprint (plastic, visible, latent) would be likely to be found in, on, or by means of the following materials?

a. blood

visible

b. mud

plastic

c. wood tabletop

latent

d. windowpane

latent

e. Romano cheese

possibly plastic, but Romano cheese is very hard, so maybe latent

f. chalk

visible

g. skin

latent

h. polyethylene bag

latent

i. fudge

plastic

j. dust

visible

k. newspaper

latent

l. leather jacket

latent

m. gun barrel

latent

n. snow

plastic

Checkpoint Questions

24. In the crime scene presented at the beginning of the chapter, what would be the best way to develop the latent prints at each area? How would you preserve them? How would you preserve those in the putty?

latch, windowsill—dusting; putty—photograph; bedroom—dusting and perhaps fuming particular small, portable objects that may have been picked up and examined; cheese—dusting, photography; the note—iodine and/or ninhydrin fuming; back door—dusting.

25. What would be the best way to visualize latent fingerprints on the following materials?

a. matchbook cover

ninhydrin or iodine

b. Popsicle stick

silver chloride

c. vinyl upholstery

superglue and/or dusting

d. cigarette butt

ninhydrin

e. broken bottle

superglue fuming

f. handkerchief

very difficult to visualize prints from textiles, possibly iodine

g. toilet seat

dusting

h. lightbulb

superglue fuming and/or dusting

Additional Activities

Note: The list below includes optional projects that can be assigned to students.

1. Investigate the use of "eye prints" (retinal or iris scans) as a means of identification.
   Is this a valid method of identification? What are the advantages and disadvantages as compared to the use of fingerprints?

2. Are ears different enough to be a useful class of identification? How could a person devise a method of recording and classifying an individual's ear? See, for example, Kurland, Chapter 6.

3. Although not often used, lip prints can provide a means of identification because, like fingerprints, they are unique and do not change during a person's lifetime. Transfer a lip print to a folded piece of paper by means of a dark, washable lipstick or lip gloss with subsequent powder dusting. You can then work out a method to classify the resulting prints. See Chapter 9.
   See Chapter 9, "Trace Evidence," for activities. Students could even write a short mystery in which lip prints aid in the solution of the crime.

4. Explore the social issues around fingerprinting and other means the government uses to confirm individual identity, considering issues such as too much government, "Big Brother" watchdog, and the like.

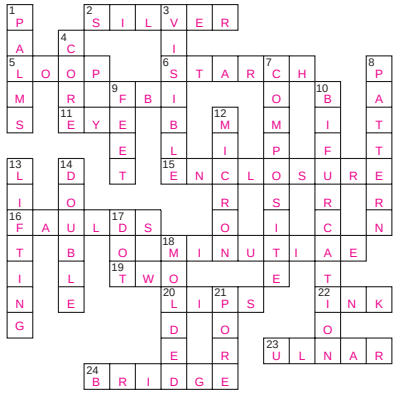
5. Biometrics uses biological information to verify identity. The basic idea behind biometrics is that our bodies contain unique properties that can be used to distinguish each of us from all other human beings. Discuss the latest technology in identification techniques. How are some related to historical bases? You might ask students to review testimonial evidence in Chapter 2. Techniques that could be explored include facial features, eye scans, voice verification, ear classification, and hand recognition. The principles are related to Bertillon's work of 100 years ago. Identity theft and terrorism have increased the importance of biometric identification. Examples abound: "keys" to unlocking computer files, airport security, etc.

6. Explore the role tattoos may have in identification. Look for actual examples.

7. You may want to share the following with students and then ask students what other markings on the body besides fingerprints are relatively permanent and would help identify a subject. Point out that Tatt-E, or Tattoo Recognition Technology-Evaluation and the Tattoo Recognition Database are two tools that investigators use to identify suspects. Have students work in small groups or pairs to research how investigators have used these tools and the outcomes.

Chapter 4 Student Sheet 4.8: Answer Key

Crossword Puzzle



ACROSS

2 _____ nitrate for use in developing prints on wood
5 a fingerprint pattern
6 reacts with iodine to form a blue color
9 a government agency
11 a minutia
15 a minutia
16 early pioneer in use of fingerprints
18 fine structure of ridge characteristics
19 number of types of arch
20 area of body with distinctive patterns
22 used to record fingerprints
23 type of loop pattern
24 a minutia

DOWN

1 area of body with ridge patterns
3 type of fingerprint
4 area of a fingerprint
7 subgroup of whorls
8 a map of friction ridges
9 area of body with ridge patterns
10 a minutia
12 one-millionth of an inch
13 removing a fingerprint from an object
14 _____ loop, a whorl
17 a minutia
18 type of fingerprint
21 area of the epidermis

Chapter 4: Fingerprints

4.8

Teacher Tip

Now is a good time to assess your students' learning by having them complete **Student Sheet 4.8** ***(Crossword Puzzle)***, which can be found in the *Online Teacher Resources*. **Student Sheet 4.8: Answer Key** ***(Crossword Puzzle)*** is shown.

References

Books and Articles

Beavan, C. *Fingerprints: The Origins of Crime Detection and the Murder Case that Launched Forensic Science.* New York: Hyperion Books, 2001.

Evans, C. *The Casebook of Forensic Detection.* New York: John Wiley, 1966.

Fisher, D. Chapter 5 of *Hard Evidence.* New York: Dell, 1995.

Kurland, M. Chapter 5 of *How to Solve a Murder.* New York: MacMillan, 1995.

Lee, H. C., and Gaensslen, R. E., eds. *Advances in Fingerprint Technology* (2nd ed.). Boca Raton, FL: CRC Press, 2001.

Noble, D. "The Disappearing Fingerprints," *Chem Matters,* February 1997, pp. 9–12.

Ragle, Larry. *Crime Scene.* New York: Avon Books, 2002.

Films and Videos

Nova Video, "Hunt for the Serial Arsonist." Suspicious fires were breaking out all over greater Los Angeles. 60 min on one DVD. http://shop.wgbh.org/product/search?terms=serial+arsonist

Websites

www.crimelibrary.com/forensics/fingerprints; the "Night Stalker" case

www.crimeandclues.com; good general links

http://whyfiles.org/133crime_lab/3.html; the criminal justice system and fingerprints

www.fbi.gov/hq/lab/org/systems.htm; forensic systems, including AFIS

www.fbi.gov/hq/lab/fsc/backissu/jan2001/lpu.pdf; FBI manual on processing latent prints

www.fbi.gov/hq/cjisd/takingfps.html; a good reference for taking fingerprints

www.ridgesandfurrows.homestead.com/index; everything you ever wanted to know about fingerprints, including history, anatomy, developing, classification, and the like