Chapter Overview

Hair has been used in forensic analysis since the late 19th century. Hair regulates body temperature, reduces friction, protects the body from light, and is also a sense organ. It is made up of two parts: a follicle and a shaft. Hair varies in length and cross-sectional shape, depending on where on the body it originates. Some hair characteristics allow forensic experts to group hair evidence into general racial categories. Forensic experts examine hair using light and electron microscopy, and analyze hair chemically for drugs and toxins.

The Big Ideas

Hair is an important structure found on most mammals, including humans. While all hairs have the same basic structure, differences in the specific characteristics of an individual's hair can help an investigator determine general characteristics of that individual. Forensic investigators rely on their knowledge of hair structure, function, and variation when they use hair from a crime scene as evidence.

CHAPTER 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

CHAPTER 3

The Study of Hair

NEUTRON ACTIVATION ANALYSIS OF HAIR

In 1958, the body of 16-year-old Gaetane Bouchard was discovered in a gravel pit near her home in Edmundston, New Brunswick, across the Canadian–U.S. border from Maine. Numerous stab wounds were found on her body. Witnesses reported seeing Bouchard with her boyfriend John Vollman prior to her disappearance. Circumstantial evidence also linked Vollman with Bouchard. Paint flakes from the place where the couple had been seen together were found in Vollman's car. Lipstick that matched the color of Bouchard's lipstick was found on candy in Vollman's glove compartment.

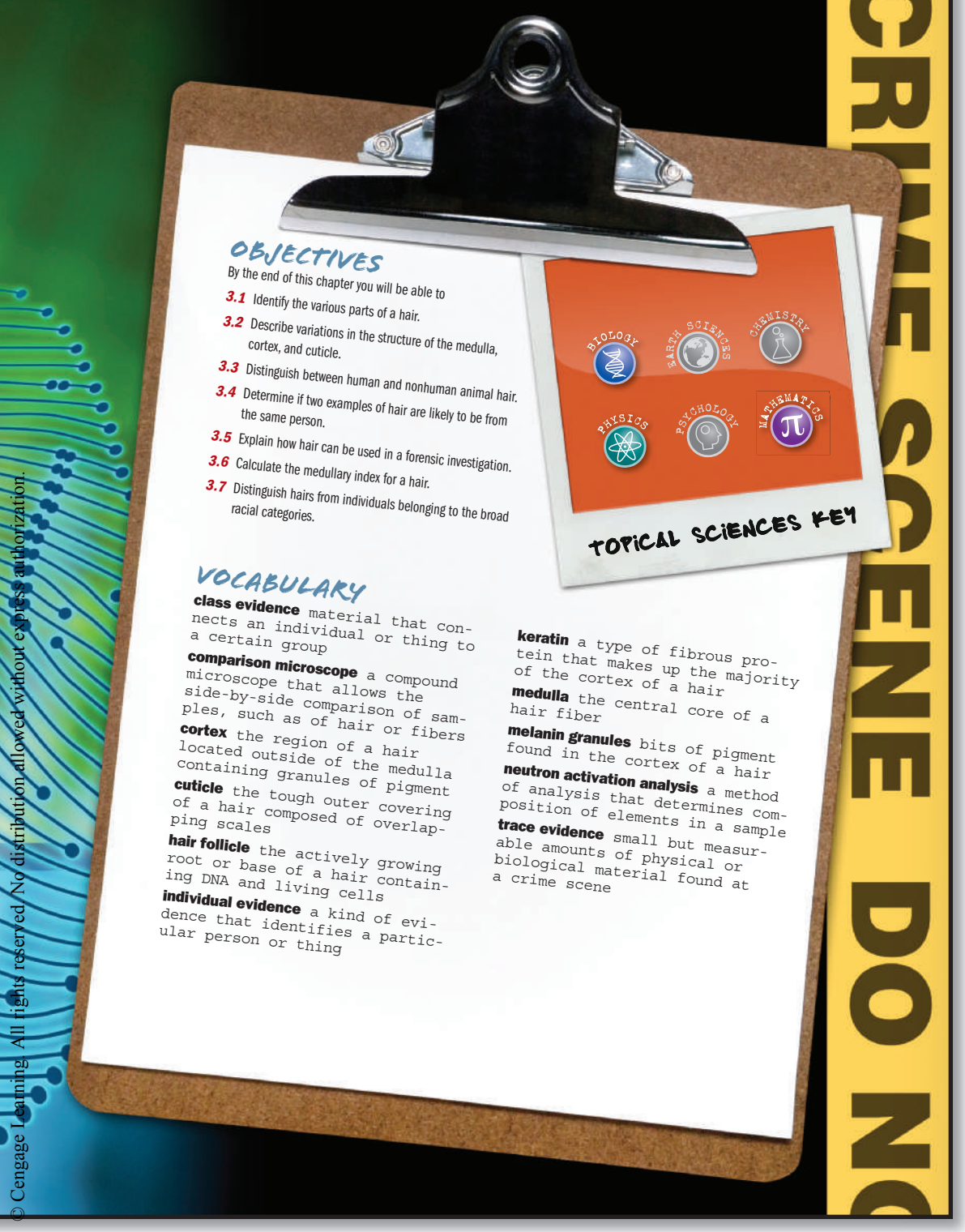
At Bouchard's autopsy, several strands of hair were found in her hand. This hair was tested using a process known as neutron activation analysis (NAA). NAA tests for the presence and concentration of various elements in a sample. In this case, NAA showed that the hair in Bouchard's hand contained a ratio of sulfur to phosphorus that was much closer to Vollman's hair than her own. At the trial, Vollman confessed to the murder in light of the hair analysis results. This was the first time NAA hair analysis was used to convict a criminal.

Investigators search for clues in a gravel pit similar to the one in which Gaetane Bouchard was buried.

48

SCENARIO

Read the scenario as a class. Then have the class discuss these questions:
What evidence was used in the investigation of Gaetane Bouchard's murder?
Describe the importance or usefulness of each kind of evidence. For example, could the evidence provided only by the paint flakes have been used to convict John Vollman? Why or why not?
What role did hair play in this investigation?



KEY SCIENCE CONCEPTS

Biology: the structure and function of human hair and hair of other mammals

Physics: using the properties of light and electron movement to analyze hair

Mathematics: calculating ratios and rates

Teaching Resources

- Instructor's Resource CD-ROM includes:
  - PowerPoint Presentation
  - Lesson Plan and extended Objective Sheets
  - Teacher Notes and Activities
  - Activity Forms
  - Rubric
- ExamView CD-ROM
- E-book on CD-ROM

Web site: school.cengage.com/forensicscience

Differentiated Learning

Teaching English-Language Learners

English-language learners (ELL) will benefit from strategies that make it easier to learn science vocabulary. One strategy is to help ELL students work with vocabulary terms that are composed of two simpler words. Ask students to write each of the following vocabulary terms on a separate index card: *class evidence, comparison microscope, individual evidence,* and *trace evidence*. Help students understand the meaning of these terms by discussing the meaning of each of the words that makes up the term. Often, ELL students will know the meaning of the words separately, but will need help understanding how they fit together in the vocabulary term.

Engage

One of the first cases in which hair was used was the murder of Germaine Bichon. In 1910, Rosella Rousseau confessed to the murder of Germaine Bichon. Rousseau only confessed after being confronted with hair evidence found at the murder scene.

Organize the class into four groups. Have each group discuss one of the following questions, and then share their thoughts with the rest of the class:

- What are the possible *limitations* of using hair as evidencein a crime investigation?
- What are the possible *advantages* of using hair as evidence?
- What reasons might have prevented investigators from using hair in investigations before 1910?
- What kinds of technological advances have made it possible for investigators to use hair as evidence?

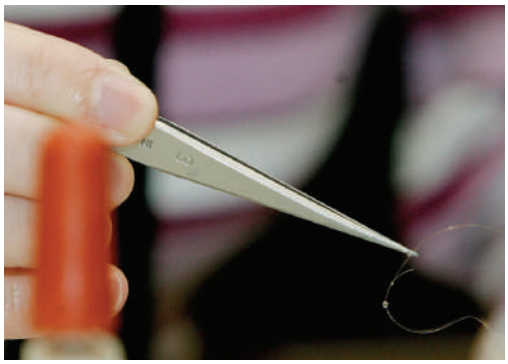
Teaching Tip

Students may have a difficult time distinguishing between class evidence and individual evidence. On the chalkboard or overhead projector, write the phrases *class evidence* and *individual evidence*. Ask students what the two phrases have in common. (They are both kinds of evidence.) Next, ask students how the two phrases are different by asking them what other meanings they associate with the words *class* and *individual*. Sample answer: The word *class* is used to describe a group of people, as in a science class. A class generally has one or more shared characteristics. For example, all members of a science class are students who are studying a similar subject. The word *individual* is used to describe one member of a group or class. An individual has many characteristics that are not shared by the group or class. For example, there may be only one student with green eyes in a science class.

INTRODUCTION

An investigator finds a blond hair at a crime scene. She thinks that it might help solve her case. What information could be gained from analysis of that hair (Figure 3-1)? What are the limitations of the information that hair can provide?

Figure 3-1. *A forensic scientist prepares a hair for analysis.*



©AP Photo/Ric Feld

Hair is considered **class evidence**. Alone (without follicle cells attached), it cannot be used to identify a specific individual. In the best case, an investigator can identify a group or class of people who share similar traits who might share a certain type of hair. For example, the investigator can fairly confidently exclude people with Asian and African ancestry as producers of the blond hair found at a crime scene. She could also compare the hair collected with hair from a blond suspect. However, even though the hairs may share characteristics, they may not necessarily be from the same source.

Hair can easily be left behind at a crime scene. It can also adhere to clothes, carpets, and many other surfaces and be transferred to other locations. This is called *secondary* transfer. Secondary transfer is particularly common with animal hair.

Because of its tough outer coating, hair does not easily decompose. Hair found at crime scenes or secondary locations can be analyzed. The physical characteristics of hair can offer clues to the broad racial background of an individual. Chemical tests can provide a history of the use of drugs and other toxins, indicate the presence of heavy metals, and provide an assessment of nutritional deficiencies. When the follicle of a hair is present, DNA evidence may be obtained. Results of DNA analysis is not considered class evidence. It is better, because it can lead to individual identification, thus it is **individual evidence**.

HISTORY OF HAIR ANALYSIS

The history of prescription drug-use by Henri Paul was determined by analysis of his hair. Paul was the driver of the car in which he, Dodi Fayed, and Princess Diana died on August 31, 1997.

Investigators recognized the importance of analysis of hair as **trace evidence** in criminal investigations in the late 1800s. The case of the murder of the Duchesse de Praeslin in Paris in 1847 is said to have involved the investigation of hairs found at the scene.

A classic 1883 text on forensic science, *The Principles and Practice of Medical Jurisprudence* by Alfred Swaine Taylor and Thomas Stevenson, contains a chapter on using hair in forensic investigations. It includes drawings of human hairs under magnification. The various parts of human hair are identified. The book also references cases in which hair was used as evidence in England.

In 1910, a comprehensive study of hair titled *Le Poil de l'Homme et des Animaux (The Hair of Man and Animals)* was published by the French forensic scientists Victor Balthazard and Marcelle Lambert. This text includes numerous microscopic studies of hairs from most animals.

Differentiated Learning

Teaching Gifted Students

The murder of the Duchesse de Praslin occurred on August 18, 1847, in Paris, France. The Duchesse was thought to have been murdered by her husband, based on a great deal of evidence, including the discovery of bloodstained objects in his room as well as bruises and bite marks found on his body. Shortly before her husband was to go on trial, he committed suicide by poisoning himself. Ask students to investigate the collapse of the July monarchy, which this murder is thought to have sparked, and then present their findings to the entire class.

The use of the **comparison microscope** to perform side-by-side analysis of hairs collected from a crime scene and hairs from a suspect or victim first occurred in 1934 by Dr. Sydney Smith. This method of comparison helped solve the murder of an eight-year-old girl.

Further advances in hair analysis continued throughout the 20th century as technological advances allowed for comparison of hairs through chemical methods. Today, hair analysis includes neutron activation analysis and DNA fingerprinting and is considered a standard tool in trace evidence analysis.

THE FUNCTION OF HAIR

All mammals have hair. Its main purpose is to regulate body temperature—to keep the body warm by insulating it. It is also used to decrease friction, to protect against sunlight, and to act as a sense organ. In many mammals, hair can be very dense, and it is then referred to as fur.

Hair works as a temperature regulator in association with muscles in the skin. If the outside temperature is cold, these muscles pull the hair strands upright, creating pockets that trap air. This trapped air provides a warm, insulating layer next to the skin. If the temperature outside is warm, the muscles relax and the hair becomes flattened against the body, releasing the trapped air.

In humans, body hair is mostly reduced; it does not play as large a role in temperature regulation as it does in other animals. When humans are born, they have about 5 million hair follicles, only 2 percent of which are on the head. This is the largest number of hair follicles a human will ever have. As a human ages, the density of hair decreases.

All of the hair follicles in humans are formed when a fetus is five months old.

THE STRUCTURE OF HAIR

Obj. 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, and 3.7

A hair consists of two parts: a follicle and a shaft (Figure 3-2). The **follicle** is a club-shaped structure in the skin. At the end of the follicle is a network of blood vessels that supply nutrients to feed the hair and help it grow. This is called the *papilla*. Surrounding the papilla is a bulb. A sebaceous gland, which secretes oil that helps keep the hair conditioned, is associated with the bulb. The erector muscle that causes the hair to stand upright attaches to the bulb. Nerve cells wind around the follicle and stimulate the erector muscle in response to changing environmental conditions.

The hair shaft is composed of the protein **keratin**, which is produced in the skin. Keratin makes hair both strong and flexible. Like all proteins, keratin is made up of a chain of amino acids that forms a helical, or spiral, shape. These helices are connected by strong bonds between amino acids. These bonds make hair strong.

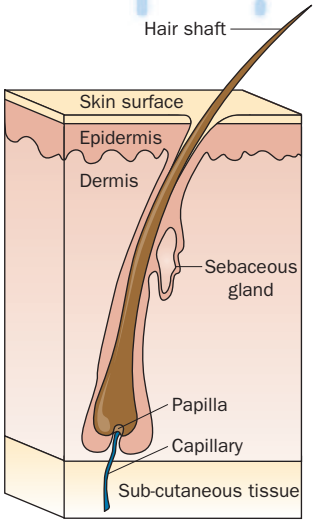


Figure 3-2. *This cross-section shows a hair shaft in a hair follicle in the skin. If the root of the hair is present, DNA may be extracted, amplified, and compared to known samples for identification. If no root is present, hair can be matched by other characteristics that can be viewed under a compound microscope.*

Science

Biology

Most mammals have hair. Hair serves important functions for mammals based on unique structures. Differences in a hair's structure can help a scientist determine if the hair came from a human or another mammal.

Science

Biology

Several overarching themes define the study of biology. One of these themes is the relationship between structure and function in a living organism. This theme reflects the fact that organisms and their parts have functions that reflect their structure. For example, the shape and composition (structure) of hair suit it to the roles it plays in temperature regulation and touch (functions) of mammals.

Teaching Tip

Explain to students that despite common belief, human hair does not continue to grow after a person dies. Any growth that appears to occur is a result of the shrinking of the skin, which begins to occur shortly after death.

Explore

The field of medicine concerned with the study of hair is called *tricology*. Organize the class into groups. Ask each group to research tricology and prepare a brochure that describes what tricologists do. The brochure might include a history of tricology, a description of how to become a tricologist, a list of the problems with which tricologists work, and an explanation of the techniques used by tricologists.

Evaluate

Understanding the basic structure of skin is important in a discussion of the structure and function of hair. Not only is skin the largest of all organs in the human being, but the functions of hair are possible because of the structure of skin, as well as the structure of hair itself. Organize students into small groups. Provide each group with an image of a cross section of human skin. Ask students to draw a model of a hair and label and describe the function of these parts: *epidermis, sebaceous glands, and sweat glands.* Epidermis is the outer layer of skin. Sebaceous glands are generally connected to hair follicles and secrete an oily substance. Sweat glands secrete a watery substance that is important in temperature regulation in mammals. Ask students to list the important role skin plays in hair formation and growth. Sample answer: Hair grows from skin. Hair roots are nourished by nutrients and oxygen present in blood vessels in the skin.

Explore

Remind students that humans are not the only animals to have structures made of the protein keratin. Tell students that birds, turtles, and other mammals, such as tigers and bears, have body structures made of keratin. Ask them what those body parts might be (e.g., beaks, shells, claws).

Explore

Ask students to study the image showing the hair shaft and cuticle in Figure 3-4. Then ask: Which side of the hair shaft shown is closer to the scalp? Cuticle scales always point toward the tips of your hair. Therefore, in Figure 3-4, the top of the photo is closer to the scalp.

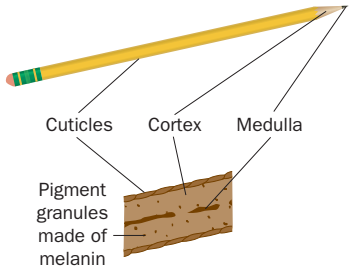
Teaching Tip

Students may notice that both fragmented and interrupted medullas are broken in appearance. Explain that interrupted medullas are also known as *intermittent* and are distinguished from fragmented because interrupted/intermittent medullas have breaks that occur at regular intervals, whereas the breaks in the fragmented medullas occur randomly and are of differing lengths.

Explore

Have students prepare a model of an animal hair and a human hair to compare and contrast the structures.

Figure 3-3. *The structure of a hair shaft is similar to that of a yellow pencil.*

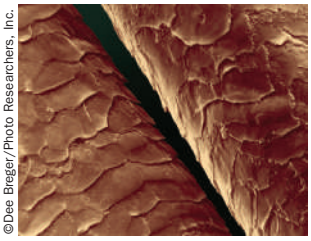


The hair shaft is made up of three layers: an inner **medulla**, a cortex, and an outer cuticle. A good analogy for the structure of a hair shaft is the structure of a pencil (Figure 3-3). The painted yellow exterior of the pencil is similar to the cuticle. The graphite in the middle of the pencil is similar to the medulla. The wood of the pencil is analogous to the cortex of a hair. Human hair has cuticle scales that are flattened and narrow, also called *imbricate*. Animal hair had different types of cuticles that is described and pictured later in the chapter under animal hair.

THE CUTICLE

The **cuticle** is a transparent outer layer of the hair shaft. It is made of scales that overlap one another and protect the inner layers of the hair (Figure 3-4). The scales point from the proximal end of the hair, which is closest to the scalp, to the distal end, which is farthest from the scalp. When examining a section of hair under a microscope, noticing the direction the scales point shows the younger and older ends of the hair. This information can be used when an investigator needs to analyze hair for the presence of different toxins, drugs, or metals at specific points in time. Human hair has cuticle scales that are flattened and narrow, also called imbricate. Animal hair has different types of cuticles that are described and pictured later in the chapter under animal hair.

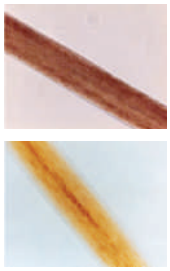
Figure 3-4. *This scanning electron photomicrograph shows the cuticle of a human hair with the overlapping scales.*



TYPES OF CORTEX

In humans, the **cortex** is the largest part of the hair shaft. The cortex is the part of the hair that contains most of the pigment granules (**melanin**) that give the hair its color (Figure 3-5). The pigment distribution varies from person to person. Some people have larger pigment granules within the cortex, giving the cortex an uneven color distribution when viewed under the compound microscope.

Figure 3-5. *The pigment granules in the red hair on the left are evenly distributed throughout the cortex. Commonly, the pigment is denser near the cuticle of human hairs, as shown on the right.*



TYPES OF MEDULLA

The center of the hair is called the medulla. It can be a hollow tube, or filled with cells. In some people the medulla is absent, in others it is fragmented, or segmented, and in others it is continuous or even doubled. The medulla can contain pigment granules or be unpigmented. Forensic investigators classify hair into five different groups depending on the appearance of the medulla, as illustrated in Figure 3-6.

TYPES OF HAIR

Hair can vary in shape, length, diameter, texture, and color. The cross section of the hair may be circular, triangular, irregular, or flattened, influencing the curl of the hair. The texture of hair can be coarse as it is in whiskers or fine as it is in younger children. Some furs are a mixture as in dog coats, which often have two layers: one fine and one coarse. Hair color varies depending on the distribution of pigment granules and on hair dyes

Differentiated Learning

Teaching At-Risk Students

At-risk students may benefit from having materials presented in a variety of ways. Engage at-risk students who are tactile or kinetic learners by asking them to create a model of a hair using modeling clay. Provide students with three different colors of clay. Ask them to refer to Figure 3-2 while they build their models.

Differentiated Learning

Teaching Gifted Students

Hair may curl as a result of natural or artificial causes. Have students research the processes involved in hair gaining a curly structure rather than a straight structure. Then ask them to explain how a perm mimics the natural processes that cause hair to be curly. Research why the heat of a hair dryer will straighten hair.

Figure 3-6. *Five different patterns of medulla are identified in forensic hair analysis.*

Medulla Pattern	Description	Diagram
Continuous	One unbroken line of color	
Interrupted (Intermittent)	Pigmented line broken at regular intervals	
Fragmented or Segmented	Pigmented line unevenly spaced	
Solid	Pigmented area filling both the medulla and the cortex	
None	No separate pigmentation in the medulla	

that might have been used (Figure 3-7). These attributes can all be used for identification or exclusion in forensic investigations.

In humans, hair varies from person to person. In addition, different hairs from one location on a person can vary. Not all hairs on someone's head are exactly the same. For example, a suspect may have a few gray hairs among brown hairs in a sample taken from his head. Because inconsistencies occur within each body region, 50 hairs are usually collected from a suspect's head. Typically, 25 hairs are collected from the pubic region.

Figure 3-7. *Hairs coming from a single area on one person can vary in characteristics.*

©Blend Images/Jupiter Images

HAIR FROM DIFFERENT PARTS OF THE BODY

Hair varies from region to region on the body of the same person (Figure 3-8). Forensic scientists distinguish six types of hair on the human body: (1) head hair, (2) eyebrows and eyelashes, (3) beard and mustache hair, (4) underarm hair, (5) auxiliary or body hair, and (6) pubic hair. Each hair type has its own shape and characteristics.

One of the ways in which hairs from the different parts of the body are distinguished is their cross-sectional shape. Head hair is generally circular or elliptical in cross section. Eyebrows and eyelashes are also circular but often have tapering ends. Beard hairs tend to be thick and triangular. Body hair can be oval or triangular, depending on whether the body region has been regularly shaved. Pubic hair tends to be oval or triangular.

Hairs from different parts of the body have other characteristic physical features. Hair from the arms and legs usually has a blunt tip, but may be frayed at the

Figure 3-8. *The physical characteristics of hairs provide information about which part of the body they came from.*

Courtesy, FBI; photos by Sandra Koch & Douglas W. Deedric

Pubic hair showing buckling

Beard hair with double medulla

Arm or leg hair with blunt, frayed end

Evaluate

Gray hair is often seen as a sign of aging in humans, but why does hair turn gray? Explain to students that hair is colored because melanocytes deposit pigments in the hair as it grows. *Melanocytes* are the same cells responsible for depositing pigment in skin. Although scientists do not know why this happens, the stem cells that produce melanocytes for hair follicles can die. When this happens, hair continues to grow but without pigment. Ask students why they think skin does not get lighter as a person ages. Ask them to compare going gray with balding.

Explore

Tell students that the shape of the root bulb from which hair grows changes over the course of a hair's life cycle. Because of this, hair that is pulled out of the head during the anagen stage is more likely to contain follicle cells than at other stages in the life cycle. Ask students to describe circumstances in which this might be an important fact in a criminal investigation. How might hair that contains follicle cells be used differently than other hair? Possible answer: Hair with follicle cells may have nuclear DNA, which can be analyzed to provide a DNA fingerprint of the owner of the hair.

Differentiated Learning

Teaching English-Language Learners

English-language learners often have little difficulty understanding content once they have mastered the important vocabulary. Teach English-language learners how to use the structure of the chapter to understand the important concepts being covered. Ask students to use the main headings to make a list of the most important topics in the chapter. Below each main heading, ask students to briefly predict what they expect to find in each section. After reading each section, students should evaluate whether their predictions were accurate. Also remind them to refer to the Glossary at the back of the book for the definitions of key terms.

Explore

Explain to students that not all crimes have human victims. At least one forensics lab in the United States investigates crimes involving or against wildlife, such as poaching or hunting endangered species. The National Fish and Wildlife Forensics Laboratory is located in Ashland, Oregon, and uses the same techniques and principles of forensic labs that investigate crimes against humans.

Teaching Tip

Ask students if they think insects and other organisms have hair. Explain that these organisms have structures that look like hair, but are not hair. For example, some caterpillars seem to have thin hairs covering their entire bodies. These structures are actually called *setae* and are structured much differently than hair. Challenge students to investigate how these structures differ from hairs.

Evaluate

Tell students that humans and dogs both have hairs with an imbricate cuticle. Ask them to draw a picture of what this means. Next, ask students what techniques forensic scientists would need to use to distinguish a dog hair from that of a human.

Teaching Tip

Point out to students that there is an even wider diversity of cuticle structures throughout the animal kingdom than those described in this chapter. Some students may be interested in finding images of these other structures. Direct these students to research the hair structure of deer (*Cervidae*) or related mammals. Ask students to prepare a drawing of their findings to show the class.

You lose approximately 100 hairs from your head each day. These end up on your clothes, in your hairbrush, on furniture, and at the places you visit.

ends from abrasion. Beard hair is usually coarse and may have a double medulla. The diameter of pubic hair may vary greatly, and buckling may be present.

THE LIFE CYCLE OF HAIR

Hair proceeds through three stages as it develops. The first stage is called the *anagen stage* and lasts approximately 1,000 days. Eighty to ninety percent of all human hair is in the anagen stage. This is the period of active growth when the cells around the follicle are rapidly dividing and depositing materials within the hair. The *catagen stage* follows as the hair grows and changes (perhaps turning gray). The catagen stage accounts for about 2 percent of all hair growth and development. The final stage is the *telogen stage*. During this stage the hair follicle is dormant or resting and hairs are easily lost. About 10 to 18 percent of all hairs are in the telogen stage. There is no pattern as to which hairs on the head are in a particular stage at any time.

TREATED HAIR

Hair can be treated in many different ways (Figure 3-9). Bleaching hair removes pigment granules and gives hair a yellowish color. It also makes hair brittle and can disturb the scales on the cuticle. Artificial bleaching shows a sharp demarcation along the hair, while bleaching from the sun leaves a more gradual mark. Dyeing hair changes the color of the hair shaft. An experienced forensic examiner can immediately recognize the color as unnatural. In addition, the cuticle and cortex both take on the color of the dye.

If an entire hair is recovered in an investigation, it is possible to estimate when the hair was last color-treated. The region near the root of the hair will be colored naturally. Human hair grows at a rate of about 1.3 cm per month (approximately 0.44 mm per day). Measuring the length of hair that is naturally colored and dividing by 1.3 cm provides an estimate of the number of months since the hair was colored. For example, if the unbleached root region measured 2.5 cm, then 2.5 cm divided by 1.3 cm per month equals approximately 1.9 months or about 7 weeks. This information can be used to identify hairs from different locations as belonging to an individual.

Courtesy, FBI; photos by Sandra Koch & Douglas W. Deedric

Figure 3-9. *Examples of dyed human hair.*

RACIAL DIFFERENCES

Hair examiners have identified some key physical characteristics that are associated with hair of different broad racial groups. These characteristics are only generalities and may not apply to individuals of certain races. In addition, a certain hair may be impossible to assign to a particular race because its characteristics are poorly defined or difficult to measure. The broad characteristics of hairs from different races are compared in Figure 3-10.

ANIMAL HAIR AND HUMAN HAIR

Animal hair and human hair have several differences, including the pattern of pigmentation, the medullary index, and the cuticle type. The pattern of the pigmentation can vary widely in different animals. While the pigmentation in human hair tends to be denser toward the cuticle, in animals it is denser toward the medulla. Animal pigments are often found in solid masses called *ovoid bodies*, especially in dogs and cattle. Human hairs are

Science

Biology

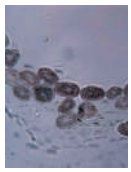
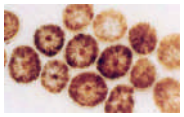
Point out to students that all living things have a life cycle, a series of changes that occur over the course of their lifetimes. The structures of living things also progress through a series of changes as they age. Students may be familiar with one of the most basic and important life cycles, the cell cycle. Briefly review the importance of the cell cycle with students.

Science

Math

Regardless of their specialty, scientists use mathematics to help describe the world around them. Forensic investigators use average growth rates of various structures in the human body, such as hair and fingernails, to decode clues left at a crime scene. When using average growth rates, it is important to pay close attention to the units of measurement being used.

Figure 3-10. *A comparison of some general physical characteristics of hair from different races.*

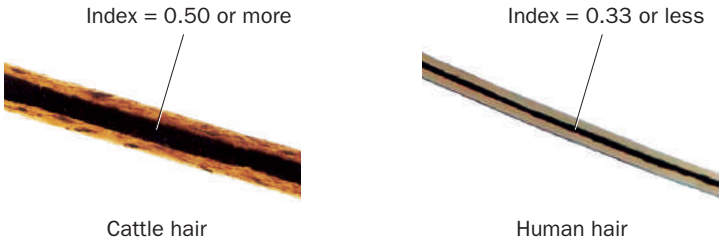
Race	Appearance	Pigment Granules	Cross Section	Other
European	Generally straight or wavy 	Small and evenly distributed	Oval or round of moderate diameter with minimal variation 	Color may be blond, red, brown, or black
Asian	Straight 	Densely distributed	Round with large diameter 	Shaft tends to be coarse and straight Thick cuticle Continuous medulla
African	Kinky, curly, or coiled 	Densely distributed, clumped, may differ in size and shape	Flattened with moderate to small diameter and considerable variation 	

Courtesy, FBI; photos by Sandra Koch & Douglas W. Deedric

usually one color along the length. Animal hairs can change color abruptly in a banded pattern.

In animals, the medulla is much larger than it is in humans (Figure 3-11). The ratio of the diameter of the medulla to the diameter of the entire hair is known as the *medullary index*. If the medullary index is 0.5 or greater, the hair came from an animal. If the medullary index is 0.33 or less, the hair is from a human.

Figure 3-11. *The medulla of animal hair is much larger than in human hair, and it is always continuous.*



Cattle hair

Human hair

Courtesy, FBI; photos by Sandra Koch & Douglas W. Deedric

Differentiated Learning

Teaching Gifted Students

The material in this chapter may be extended by having students complete an investigation of the properties of a collection of scalp hair and nonhuman animal hair. Ask students to collect five scalp hairs from each of four different family members or friends. Tell students to also collect hair samples from family pets. Students should carefully place the collected hairs on an unlined white sheet of paper with a small piece of transparent tape and label the source of each hair. Ask students to create a table of hair characteristics similar to those used in a forensics lab and write out a procedure for observing those characteristics. Students should use the classroom microscopes to examine the properties of their hair collections.

Teaching Tip

Organize the class into three groups. Assign a portion of the hair life cycle to each group, and ask each group to make a short presentation to the class. In their presentations, they should include answers to the following questions:

- What does the hair look like at this stage?
- How long does this stage last?
- Are there any characteristics of a hair at this stage that would be helpful in a criminal investigation?

Evaluate

Ask students to refer to Figure 3-10 when answering the following questions:

- What is the most likely race of a person with dense, straight, black hair? Asian.
- What is the most likely race of a person with dense, curly, brown hair? Multiple answers possible. Use this question to discuss how difficult it is to use hair to define race.

Also, discuss how mixed-race individuals (people who belong to more than one race because of their family heritage) may not have hair that easily falls into one category.

Teaching Tip

Demonstrate the way bleach and hair interact with one another. Before class, prepare a dry mount of a short segment of human hair by placing the hair on a glass slide with a coverslip placed over the hair. In class, use a video microscope to examine the hair with the class. After you discuss the characteristics of the hair, place a drop of bleach next to the coverslip. As the bleach wicks across the slide, it will discolor the hair and then, after several minutes, begin to dissolve the hair. Discuss your observations with students.

Teaching Tip

Explain to students that while hair can be used as evidence to link suspects to a crime, hair is also commonly used to determine drug use or exposure to toxins. While there is debate about the use of hair to prove certain kinds of drug use, hair holds traces of drugs and other toxins far longer than any other body product, such as blood or urine.

Explore

Tell students that phase contrast microscopy is a technique that produces high-contrast images of transparent objects, such as living cells. Essentially, the technique amplifies small variations in the refraction of light to produce a high-contrast image. This technique has the distinct advantage of allowing living cells to be observed without staining or otherwise damaging or killing the cell.

Explore

Review the two main types of chemical bonds with students. Explain that when atoms are attracted to each other, they combine to form a new compound. This compound is held together by the chemical bond formed between the atoms. Sometimes one atom completely gives up some of its electrons to the other atom in the bond. This type of bond is called an *ionic bond*. Sometimes two atoms share some of their electrons when they form a chemical bond. This type of bond is called a *covalent bond*. Curly hair results from bonding between sulfur atoms on the protein molecules of hair.

The cuticle of the hair shaft can also help distinguish human hair from animal hair. There are different types cuticles in different mammal hair cuticles. Rodents and bats have a *coronal* cuticle with scales that give the appearance of a stack of crowns. Cats, seals, and mink have scales that are called *spinous* and resemble petals. Human hair has cuticle scales that are flattened and narrow, also called *imbricate*.

USING HAIR IN AN INVESTIGATION

Whenever two objects are in contact, some transfer of material will occur. This is known as Locard's exchange principle. It is the fundamental reasoning behind the use of trace evidence in forensic investigations. If a person is at a crime scene, he or she will leave some trace of his or her presence behind, or pick up some trace evidence from the crime scene. One of the major examples of trace evidence is hair.

When investigators enter a crime scene, they collect trace evidence, including hair. Hair can be collected from evidence by plucking, shaking, and scraping surfaces. It can also be collected by placing tape over a surface so that the hair adheres to it. When surfaces are large, they can be vacuumed. The material that is filtered into the canister can be examined for hair and other trace particles. Investigators are always careful to prevent cross-contamination of evidence by inadvertently transferring hair from one object to another.

If a large number of hairs are collected from a victim or a crime scene, an investigator will compare the sample with hair taken from the six major body regions of the victim or suspect(s). An initial analysis is performed using a low-power compound microscope to determine whether the hair is human or animal.

MICROSCOPY

Hair viewed for forensic investigations is studied both macroscopically and microscopically. Length, color, and curliness are macroscopic characteristics. Microscopic characteristics include the pattern of the medulla, pigmentation of the cortex, and types of scales on the cuticle (Figure 3-12). Medullary index can be measured. Typical magnification for viewing hair is between 40 times and 400 times. A particularly useful microscope for hair analysis is called a comparison microscope. It allows for simultaneous viewing of two different samples.

Several specialized microscopic techniques are also used in hair analysis. Phase contrast microscopy involves using a special objective lens and special condenser with a compound microscope. This configuration focuses light that passes through objects of different refractive indexes. The resulting image shows more contrast, especially when viewing translucent particles. Phase contrast microscopy in hair analysis is useful for observing fine detail in hair structure.

Many dyes and other hair treatments will fluoresce under a certain color (wavelength) of light. In a fluorescence microscope, a beam of light of a certain color is used. If the sample contains particular chemicals, it will absorb some of the light and then reemit light of a differ-

Figure 3-12. *Using microscopy, investigators might link dog hair to a dog owner or deer hair to a hunter.*

Courtesy, FBI; photos by Sandra Koch & Douglas W. Deedric

Dog hair 400×

Deer hair 400×

Science

Physics

Explain to students that light travels at different speeds through different materials. Refraction is the change in direction of a light ray when it changes speed as it travels from one material to another. For example, when light travels through glass, then it passes into water inside the glass, it changes speed. As it changes speed, the light ray bends.

Science

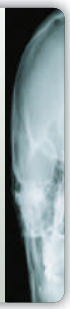
Physics

The refractive index of a material is a measure of how much a ray of light bends as it passes from one medium to another.

Digging Deeper

with Forensic Science e-Collection

Edmund Locard was a French criminalist who played a pivotal role in expanding the field of forensic science. Originally trained as a physician, Locard became fascinated with police work and using laboratory techniques to help solve crimes. Search the Gale Forensic Science eCollection on school.cengage.com/forensicscience and research Locard's life. Write a short biography of this great researcher explaining how his contributions affected forensic science. What ideas did he have that advanced the field? Who were his most important influences? How has forensics changed as a result of Locard's ideas?

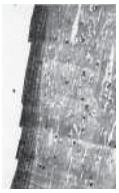


Forensic laboratories employ technicians to compare hair samples in preparation for presentation in hearings and trials. Their work involves the use of microscopes and digital imaging of evidence.

ent color. This is called *fluorescence.* A fluorescence microscope is equipped with filters to detect the fluoresced light, indicating the presence of a dye or other treatment.

Instead of using light to view a sample, electron microscopes direct a beam of electrons at a sample. Electron microscopes provide incredible detail of the surface or interior of the sample (Figure 3-13), magnifying the object 50,000 times or more.

Figure 3-13. *A transmission electron microscope produced this extremely detailed image of a long section of human hair. Notice the overlapping cuticle scales on the left side and the pigment granules in the cortex.*



Courtesy, FBI; photos by Sandra Koch & Douglas W. Deedric

TESTING FOR SUBSTANCES IN THE HAIR SHAFT

Because hair grows out of the skin, chemicals that the skin absorbs can become incorporated into hair. Ingested or absorbed toxins such as arsenic, lead, and drugs can be detected by chemical analyses of hair. During testing, the hair is dissolved in an organic solvent that breaks down the keratin and releases any substances that have been incorporated into the hair. A forensic chemist can perform chemical tests for the presence of various substances. In forensic investigations, this type of analysis can provide evidence of poisoning or drug use.

Because hair does not readily decompose, by testing different parts of the hair, it may be possible to establish a timeline for when exposure to poisons or other toxins might have occurred. The procedure for developing the timeline would be similar to the one used with hair color analysis discussed earlier in the chapter. Human hair grows at the rate of about 1.3 cm per month (approximately 0.44 mm per day). The hair can be analyzed in sections for the specific toxin. If the root is present to identify the base of the hair, these sections can be dated based on their distance from the root. If the toxin occurs 9 cm from the root, dividing this value by 1.3 cm per month provides an estimate of the number of months since the toxin was ingested. In this case, 9 cm divided by 1.3 cm per month equals approximately 7 months.

Neutron activation analysis (NAA) is a particularly useful technique that can identify up to 14 different elements in a single two-centimeter-long strand of human hair. The hair is placed in a nuclear reactor and bombarded with high-energy neutrons. Different elements will give off gamma radiation with different signals. These signals can be recorded and interpreted to determine concentrations of elements in the sample. Elements such as antimony, argon, bromine, copper, gold, manganese, silver, sodium, and zinc can be identified and quantified using NAA. The probability of the hairs of two individuals having the same concentration of nine different elements is about one in a million.

Differentiated Learning

Teaching Gifted Students

Explain to students that forensic scientists must understand many complex topics. One such topic, pathology, is the study of disease. Challenge students by asking them to conduct research on the causes, symptoms, and treatment of hair-related diseases, such as *hypertrichosis*, *telogen effluvium*, *alopecia*, and *anagen effluvium*.

Digging Deeper

Digging Deeper asks students to research the contributions of Edmund Locard. Students may be interested in researching the accomplishments and work of other famous criminologists, such as Cesare Beccaria, Sheldon and Eleanor Glueck, William Wilson, and Jane Addams.

Explore

Toxins and other substances can be detected in the hair. Morphine, tobacco, and alcohol are substances that leave traces. What is an example of a toxin that will not leave traces in the hair?

Teaching Tip

Point out to students that hairs provide other important clues to investigators. For example, investigators can tell if a hair has been burned or cut based on marks left on the ends of hair. Ask students to predict what the signs of burned or cut hair might be.

Explore

Explain to students that forensic scientists often use hair to determine a person's exposure to drugs and other toxins. This sometimes controversial use of hair operates on the principle that hair originates from cells imbedded in the skin and is nourished by nutrients and oxygen present in the blood. Once a person ingests a drug or other toxin, molecules of this substance circulate in the bloodstream until they are broken down by the liver. While traces of many drugs, such as THC—the active ingredient in marijuana—can be found in a person's urine, urine cannot show a history of exposure to drugs. Hair, if not cut, retains traces of some of the substances that were circulating through the bloodstream when the hair was formed.

Digging Deeper

In Digging Deeper, students are asked to research DNA testing. Tell students that DNA fingerprinting, or typing, has been used in criminal investigations since the mid-1980s. In 1985, Dr. Alec Jeffreys designed a process to perform human identity tests using DNA. Interested students may want to find out more about Dr. Jeffreys and the process he designed. For additional information, go to school.cengage.com/forensicscience.

Teaching Tip

Use the following questions to help students connect previous knowledge by leading them on a short review of DNA:

1. What is DNA? DNA is an organic compound found in all unicellular and multicellular organisms. It is a relatively large molecule known as a nucleic acid.
2. Where is it found? In multicellular and some unicellular organisms, DNA is found in the nuclei of almost all of the cells in the organism's body.
3. What function does DNA have in living things? DNA contains the genetic information of an organism. DNA is the molecule that is passed from parent to offspring during conception.
4. What is made from the instructions contained in DNA? The genetic information contained in DNA is used by the cell to construct proteins.
5. What is the relationship between the terms *DNA*, *gene*, and *chromosome*? DNA is the genetic information of an organism that is found in the nuclei of most of the cells in an organism's body. When condensed, all of the DNA in a single cell will form into chromosomes. Each chromosome can contain many genes, which are actually segments of DNA that contain the code for a protein.

Digging Deeper

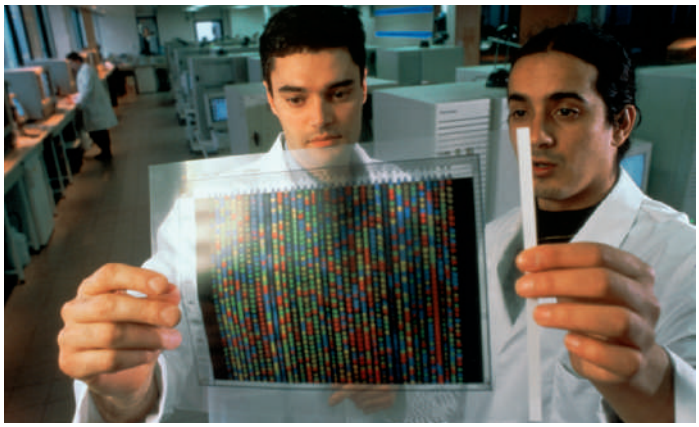
with Forensic Science e-Collection

How is DNA collected from hair follicles used in forensic investigations? What sorts of DNA testing are most often performed on hair follicles? What sorts of controversies surround these tests? Are errors ever made? What are the major problems with DNA testing of material associated with hair? Go to the Gale Forensic Science eCollection on school.cengage.com/forensicscience and enter the search terms "DNA hair analysis." Click on Academic Journals and read about some of the problems and successes associated with DNA analysis and hair. Write a brief essay describing your findings, and be sure to cite your resources.

TESTING THE HAIR FOLLICLE

If hair is forcibly removed from a victim, the entire hair follicle may be present. This is called a *follicular tag*. If this occurs, blood and tissue attached to the follicle may be analyzed. For example, blood proteins can be isolated to identify the blood type of a suspect. DNA analyses can also be performed on hair-follicle cells (Figure 3-14). DNA analysis of the hair follicle provides an identification with a high degree of confidence, whereas analysis of the hair shaft usually provides class evidence only. In many cases, a microscopic assessment of the hair is performed initially because it is more cost effective and rapid than blood protein and DNA testing. If a microscopic match between a suspect and a sample is found, then the samples will be forwarded for blood and DNA testing.

Figure 3-14. *DNA can be extracted from cells in the hair follicle for DNA analysis.*



SUMMARY

- Hair is a form of class evidence that has been used in forensic analysis since the late 19th century.
- Hair is a character shared by all mammals and functions in temperature regulation, reducing friction, protection from light, and as a sense organ.
- Hair consists of a follicle embedded in the skin that produces the shaft.
- The shaft is composed of the protein keratin and consists of the outer cuticle, a cortex, and an inner medulla, each of which varies among individuals or species.
- Hair varies in length and cross-sectional shape, depending on where on the body it originates.
- Hair development is broken into three developmental stages, called the anagen (growth), catagen (growth and change), and telogen (dormant) stages.
- Various hair treatments produce characteristic effects that are useful to forensic experts, and some hair characteristics allow them to be grouped into general racial categories.
- Forensic experts examine hair using light (phase contrast, fluorescence, comparing) and electron microscopy, and analyze hair chemically for drugs and toxins.
- Neutron activation analysis allows unique signatures of elements contained in hair to be identified, and the hair follicle can provide DNA for sequencing.

CASE STUDIES

Obj. 3.4, 3.5

Alma Tirtsche (1921)

Alma Tirtsche's beaten body was found wrapped in a blanket in what is known as Gun Alley in Melbourne, Australia. Because the body was relatively free of blood, the police deduced that she had been murdered elsewhere and brought to the alley. Her body had been washed before being wrapped in the blanket. A local bar owner, Colin Ross, was questioned. Ross admitted seeing Tirtsche in his bar earlier in the day.

Investigators collected blankets from Ross's home and found several strands of long, reddish blond hair on them. The length of the hair implied it had come from a female, and the concentration of pigment in the hair implied a younger woman. Some of the ends of the hair were irregular, implying the hair had been forcibly broken off. The physical similarity of the hair found on the blanket with that of Alma Tirtsche convinced the jury that Ross was the murderer. This was the first time that hair was used to secure a conviction in Australia. Unfortunately, analysis of the hairs 75 years later showed that two of the strands found on the blankets came from different individuals, which throws doubt on Ross's guilt.

Teaching Tip

Describe the meaning of the term *follicular tag* to students. A follicular tag is tissue from a hair follicle that is still attached to the root end of a hair. Often, this tissue appears colorless and clear. Explain to students that DNA may be extracted from a follicular tag. Ask students why a hair with a follicular tag might be able to be used as individual evidence instead of class evidence.

Teaching Tip

Ask students to rewrite *Little Red Riding Hood* in a forensic style. Tell them to include information about hair analysis, medullary index, and so forth to identify hair at the crime scene as Red's, Granny's, or the wolf in question.

Differentiated Learning

Teaching At-Risk Students

Students may struggle with calculating rates, such as the rate of hair growth. Discuss with these students other rates with which they may be familiar, such as the speed of a moving car measured in miles per hour. Using a time line, ask students to discuss the meaning of the following scenarios:

1. The speed of a car traveling at 60 miles per hour: How much time has passed when the car has traveled 60 miles? (1 hour) 120 miles? (2 hours) 90 miles? (1.5 hours)
2. A car traveling at an unknown speed: A car has traveled 30 miles in 1 hour. What is the speed of the car? (30 miles per hour) Another car has traveled 60 miles in 2 hours. What is the speed of this car? (30 miles per hour)
3. A car traveling at an unknown speed: It takes a car 3 hours to travel 90 miles. What is the speed of the car? (30 miles per hour)

Close

Draw an example of a hair on the board or overhead projector. Have students help you label the parts. As they name a part, ask them to explain what information can be gathered from that part. Then have students identify the six types of human hair and the key characteristics of each. Ask them to tell you what other information can be gathered from the hair shaft. Conclude by asking them how to distinguish human hair from animal hair.

Eva Shoen (1990)

In Telluride, Colorado, Eva Shoen was found dead from a single gunshot to her head. The police recovered the bullet and expected to solve the case using ballistics information. Unfortunately, they did not have any useful leads. Three years later, the police received a phone call from a man who believed that his brother, Frank Marquis, was responsible for Shoen's death. A gun was found on Marquis, but he had already tampered with its barrel, preventing a ballistic match.

From questioning a companion of Marquis's, police learned that Marquis had been in Telluride when Shoen was murdered. They also discovered that Marquis had thrown two bundles out of his car during his drive home to Arizona. Detectives searched the road until they found a bundle of clothing. One of the shirts in the bundle contained a single strand of hair. The color and structure of the hair matched that of Eva Shoen's hair. When confronted with the evidence, Marquis confessed to the murder and was imprisoned for 24 years.

Napoleon's Hair

Napoleon Bonaparte proclaimed himself emperor of France in 1804 after rising swiftly through the ranks of the French army. Following his defeat at Waterloo, he was exiled on the British island of St. Helena in the Atlantic Ocean. History books proclaim that he died in exile of stomach cancer.

In 2001, a Canadian Napoleon enthusiast, Ben Weider, challenged this theory. He had five strands of Napoleon's hair collected in 1805, 1814, and 1821 tested using neutron activation analysis. The results of the analysis showed that Napoleon's hair contained between 7 and 38 times more arsenic than normal, a fatal dose. In 2002, further analysis of Napoleon's hair showed extremely elevated levels of arsenic, leading researchers to joke that Napoleon should have died twice before his actual death, and suggesting that the hair must have been contaminated during storage.

Eventually, the esteemed chemist, Walter McCrone, tested a sample of Napoleon's hair. His work contradicted the previous reports, stating that the levels of arsenic that had been incorporated into Napoleon's hair were much too low to have killed him. The story continues to cause controversy. Most chemists believe that McCrone's work is the final story, but Napoleon enthusiasts believe that the emperor's death is surrounded by too many questions to disregard the possibility of murder.

Think Critically **Do you consider hair evidence important in proving a crime? Explain your answer.**

CAREERS IN FORENSICS

William J. Walsh, Chemical Researcher

With a doctorate in chemical engineering and a research record that includes such illustrious laboratories as Atomic Research in Ames, Iowa, Los Alamos National Laboratory in New Mexico, and Argonne National Laboratory in Illinois, William Walsh has spent more than 30 years studying chemical processes involved in nuclear fuel production, liquid metal distillation, and electrochemistry. Dr. Walsh has authored more than 200 scientific articles and reports and made numerous presentations on his research. Dr. Walsh is the Chief Scientist of the Health Research Institute and Pfeiffer Treatment Center, both in Illinois.

©AP Photo/Ric Field

Scientist performing hair analysis.

Dr. Walsh's work in chemistry led to an interest in developing tools and chemical methods for extracting information from hair. Dr. Walsh and his colleagues collected known chemistry information from more than 100,000 people and synthesized it into the world's first standard of known hair composition. Walsh has served as an expert chemist in numerous forensic studies of hair samples in collaboration with medical examiners, coroners, and police groups. Some of the more famous, or infamous, people whose hair chemistry Walsh has studied include Charles Manson (Manson Family murders), Henry Lee Lucas (20th-century serial killer), James Hubeity (McDonald's massacre), William Sherrill (Oklahoma post office slayings), and other notorious criminals. In addition, while volunteering at the Stateville Penitentiary in Joliet, Illinois, Walsh became interested in the way that chemicals can affect behavior. These combined interests—hair forensics and the influence of biochemicals on behavior—made Walsh the perfect candidate to head up one of the most famous hair investigations: that of composer Ludwig van Beethoven.

Walsh was the chief scientist on the Beethoven Research Project in 2000. The goal of the project was to understand whether chemical toxins may have played a role in Beethoven's death. Beethoven developed an illness in his twenties that involved abdominal distress, irritation, and eventually depression. By the age of 31, he began to lose his hearing, and by 42, he was completely deaf. He died of liver and kidney failure. Using highly sensitive techniques—scanning electron microscope energy dispersion spectrometry (SEM/EDS) and scanning ion microscope mass spectrometry (SIMS)—Walsh verified that Beethoven's hair contained extremely high concentrations of lead, which almost certainly contributed to his death.

Learn More About It
To learn more about forensics hair analysis, go to school.cengage.com/forensicscience.

CAREERS

Many famous criminologists specialized in different subject areas when in school. Topics of study that are important for criminologists and forensic scientists include molecular biology, genetics, sociology, psychology, organic chemistry, and biochemistry.

Chapter 3 Review

True or False

1. True
2. False
3. False
4. True

Multiple Choice

5. a
6. d
7. a
8. a
9. a
10. a

CHAPTER 3 REVIEW

True or False

1. The shaft of the hair is considered class evidence in a trial. *Obj. 3.5*
2. Hair is composed of a protein called cellulose. *Obj. 3.1 and 3.2*
3. All hairs on the head of a person are identical. *Obj. 3.2*
4. The cortex may contain pigment granules. *Obj. 3.2*

Multiple Choice

5. The hair shaft is composed of the cuticle, cortex, and *Obj. 3.1 and 3.2*
   a) medulla
   b) root
   c) crown
   d) granules
6. Which factors are used to calculate the medullary index of the hair? *Obj. 3.6*
   a) scale diameter of cuticle and the length of the hair
   b) width of cortex and the width of the medulla
   c) length of entire hair and the pattern of pigmentation
   d) width of medulla and the width of the hair
7. Which of the following characteristics is found in typical Asian hair? *Obj. 3.7*
   a) dark medulla
   b) sparsely distributed pigment granules
   c) flattened cross section
   d) hair is curly
8. Human hair has which type(s) of cuticle? *Obj. 3.3*
   a) imbricate
   b) spinous
   c) coronal
   d) pigmented
9. Neutron activation analysis can check hair for the presence of *Obj. 3.5*
   a) silver
   b) DNA
   c) water content
   d) hair dye
10. Which part(s) of a hair can be analyzed for DNA? *Obj. 3.5*
    a) root
    b) cuticle
    c) medulla
    d) cortex

11. The cuticle scales of the hair always point toward the *Obj. 3.2 and 3.5*
    a) root
    b) medulla
    c) tip of the hair
    d) follicle

12. The period of active hair growth is called the _____ stage. *Obj. 3.1*
    a) catagen
    b) telogen
    c) anagen
    d) imagen

13. Although variations can occur, which of the following best describes northern European hair? *Obj. 3.7*
    a) kinky with dense, unevenly distributed pigment
    b) straight with evenly distributed granules
    c) round cross section with a large diameter
    d) coarse with a thick cuticle and a continuous medulla

14. Which of the following is most likely a result of hair bleaching? *Obj. 3.5*
    a) increased number of disulfide bonds
    b) a yellowish tint to the hair
    c) a more triangular cross section
    d) thickened scales on the cuticle

Short Answer

15. Why is hair considered class evidence? *Obj. 3.5*

_____

_____

_____

_____

16. Describe the structure of hair. Include in your answer the terms *follicle*, *medulla*, *cortex*, and *cuticle*. *Obj. 3.1 and 3.2*

_____

_____

_____

_____

11. c
12. c
13. b
14. b

Short Answer

15. Hair is considered class evidence when no source of DNA, such as skin cells, is attached to the hair. Without DNA, hair can only indicate what racial group an individual may belong to.
16. Sample answer: Hair grows from a follicle found in the skin. It is composed of an inner medulla, surrounded by the cortex, and protected on the outside by the cuticle.

17. Sample answer: Animal hairs have different medulla patterns and a different cuticle pattern.

18. Hair grows 0.44 mm/day. The woman's hair grew 4 mm since August 1, 2004.

    4 mm ÷ 0.44 mm/day ≈ 9 days. 9 days from August 1 would be August 10. The woman died approximately on August 10, 2004.

19. Medullary index = diameter of medulla / diameter of hair = 58 microns/110 microns = 0.527 ≈ 0.53. This is most likely animal hair.

17. Crime-scene investigators collected hair from a dead person's body. One of the first things that needs to be established is if this hair is human or animal. Describe two ways that animal hair differs from human hair. *Obj. 3.3*

_____

_____

_____

_____

18. The body of a woman was found in the woods. Some hair fibers found on the body were sent to the crime lab for analysis. The ends of the hair attached to the body were gray, but the tips of the hair showed that it had been dyed. The distance from the root of the hair to the beginning of the dyed area measured 8 mm. Investigators determined that the victim's hair had last been dyed on August 1, 2004. Assuming the hair grows at the rate of 0.44 mm per day, on approximately what date did the woman die? Explain your answer. *Obj. 3.5*

_____

_____

_____

_____

19. Calculate the medullary index of a hair whose diameter is 110 microns wide and whose medulla measures 58 microns. Is this a human or animal hair? *Obj. 3.3 and 3.6*

_____

_____

_____

_____

20. A woman with long hair is a suspect in a burglary case. At the crime scene, several long hairs were found attached to a broken lock of the safe. The police obtain a warrant and request a sample of 25 to 50 hairs from this woman. They tell the woman it is important that they pull the hairs from her head rather than to merely cut the hairs. The police suspect that the woman was stealing to help support a drug habit. *Obj. 3.4, 3.5, and 3.7*
    a. Why is it important that the police pull the hairs from her head rather than cut her hair?
    b. Why is it necessary to obtain 25 to 50 hairs from this woman?
    c. The woman denies that she is currently taking drugs and states that she stopped using drugs a year ago. Explain how the police can determine if the woman has been off drugs for over one year.
    d. Suppose the hairs of the woman match the hairs found at the crime scene. Why does this not necessarily prove that she was the guilty party?

Bibliography

Books and Journals

Baden, Michael, and Marion Roach. *Dead Reckoning.* London: Arrow Books, 2002.

Lee, Henry. *Physical Evidence in Forensic Science.* Tucson, AZ: Lawyers & Judges Publishing, 2000.

Saferstein, Richard. *Criminalistics: Introduction to Forensic Science*, 7th ed. Englewood Cliffs, NJ: Prentice Hall, 2000

Taylor, Alfred Swaine. *The Principles and Practice of Medical Jurisprudence.* London: Churchill Livingstone, 2007

Watkins, Ronald J. *Birthright: Murder, Greed, and Power in the U-Haul Family Dynasty.* New York: William Morrow & Company, 1993

Web sites

"Alma Tirtsche." http://www.history.com/this-day-in-history.do?printable=true&action=tdihArticlePrint&id=982

Deedrick, Douglas W. "Hair, Fibers, Crime and Evidence." Quantico, VA: FBI. http://www.fbi.gov/hq/lab/fsc/backissu/july2000/deedric1.htm.

Deedrick, Douglas W., and Sandra L. Koch. "Microscopy of Hair. Part 1: A Practical Guide and Manual for Human Hairs." Quantico, VA: FBI.

Deedrick, Douglas W., and Sandra L. Koch. "Microscopy of Hair. Part 2: A Practical Guide and Manual for Human Hairs." Quantico, VA: FBI. http://www.fbi.gov/hq/lab/fsc/backissu/jan2004/research/2004_01_research01b.htm

Gale Forensic Sciences eCollection, school.cengage.com/forensicscience.

"Thread of Evidence." The Discovery Channel, Netherlands, Forensic Institute. http://www.forensischinstituut.nl/NFI/en/Typen+onderzoek/Items/Forensic+examination+of+hair.htm.

"Thin Blue Line." http://www.policensw.com/info/forensic/forensic7a.html.

20. a. The police need to pull the hair so they will have hairs with the follicle still on them. When the follicle is present, DNA analysis can be performed that might identify an individual.
    b. Obtaining multiple hairs from the woman will give a more accurate picture of the woman's exposure to drugs and other toxins, because the hairs of a single individual vary significantly. This is especially true of hair color that may contain a mix of gray and brown hair.
    c. If the woman has been off drugs for over a year, traces of the drugs will appear in her hair only after roughly 16 cm.
    d. If the hairs at the crime scene do not contain DNA, they cannot be used to determine the identity of an individual.

Background

Transfer of hair from a suspect to the victim is a good example of Locard's exchange principle. Although hair is not unique to a person, it can be used to identify a class of individuals. (The exception to this occurs if the hair follicle containing DNA is present. DNA is unique to a particular individual.)

Students will examine one of their hairs and a cuticle impression of their hair using a microscope. After reviewing characteristics such as cuticle type and medulla types, students will investigate a crime by trying to link a suspect to a crime scene through trace evidence analysis of hair.

Safety Precautions

Remind students to always carry a microscope with two hands. This prevents students from dropping an expensive and heavy piece of equipment on their toes. Be sure that students do not place a slide containing nail polish under the microscope unless they have added a cover slip to the slide.

ACTIVITY 3-1 *Ch. Obj. 3.1, 3.2, 3.4, 3.5, 3.6, and 3.7*

TRACE EVIDENCE: HAIR

Objectives:

By the end of this activity, you will be able to:

1. Describe the external structure of hair.
2. Distinguish between different hair samples based on color, medulla types, cuticle types, thickness, and length.
3. Compare a suspect's hair with the hair found at a crime scene.
4. Form a hypothesis as to which suspect could have been present at a crime scene.
5. Justify whether or not a suspect's hair sample matches the hair sample left at a crime scene.

Time Required to Complete Activity: 60 minutes

Introduction:

In this laboratory exercise, you will work with hair evidence that was collected at a crime scene. Your task is to try to match the hair evidence that was collected at the crime scene with hair collected from four suspects.

Materials:

Activity 3-1 Lab Sheet
plastic microscope slides
clear plastic tape
compound microscope
prepared slides of hair samples
2 glass slides
glass cover slips
scissors
clear nail polish

Safety Precautions:

Always carry a microscope using both hands.
Do not get nail polish on the lens.

Scenario:

A murder was committed. To dispose of the body, the suspect(s) tossed the body from the car into a ditch. When crime-scene investigators arrived, they photographed the crime scene and drew sketches of the body. Hair evidence was found on the victim. Hair samples were collected from the four suspects, as well as a sample of hair taken from the victims head. At the crime lab, a comparison microscope was used to examine each of the hair samples. Your task is to examine all hair samples under the compound microscope and record your observations. After reviewing all samples, determine if any of the suspects' hair matches the hair found at the crime scene. You will need to justify your decision.

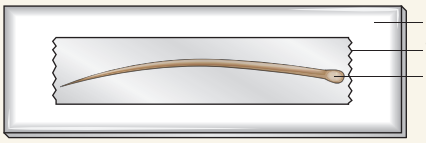
Procedure:

Part 1: Cuticle Impression

1. Obtain a clean glass slide.
2. Place the slide along the edge of the desk.
3. Wipe a thin layer of nail polish on the slide the length and width of a cover slip.
4. Either pull out or cut a hair from your head.
5. While holding onto the hair between two fingers in front of the slide, slowly lower the hair onto the slide being careful not to wiggle the hair back and forth. Pull the hair down into the nail polish and let go of the hair.
6. Wait 10 minutes to remove the hair.
7. After 10 minutes, grasp the lose end of the hair and pull straight up to completely remove the hair from the nail polish.
8. Observe the slide under 100×. Sketch your cuticle.

Part 2: Observation of Your Own Hair

1. Obtain a plastic slide. Write your initials on the end of the slide.
2. Remove a hair from your head, preferably a hair that contains a root. You may pull it out or use scissors to cut it.
3. Place the hair on your desk.
4. Fold the tape with the sticky side facing the hair on the table. Hold the tape near the hair, but do not touch the hair. The hair should be attracted to the sticky surface of the tape.
5. Place the tape with the attached hair to the plastic slide. Use your finger to press down on the tape to squeeze out any air pockets. Cut off the excess tape. You now have a permanent slide.



The finished slide.

6. Label the slide with your name using a permanent marking pen.
7. Focus the hair using 100× magnification.
   a. Draw your hair in the space provided on Data Table 1.
   b. Identify the type of medulla, cuticle, color, and any other distinguishing features.

Data Table 1

Source of Hair	Sketch	Color	Medulla	Cuticle	Straight or Curly	Other Characteristics
Your name						

Procedures

Prior to the lab, the teacher should complete the following:

1. Print, copy and distribute Activity Sheet 3-1 from the IRCD.
2. Instead of plastic slides, you can cut overhead transparency (acetate) sheets into pieces approximately 1" × 2½" (about the size of a glass microscope slide). Cut about 100 slides.
3. Obtain hair samples from five students having different hair color or textures and place them in six separate envelopes.
4. Label four of these hair samples suspect 1, 2, 3, and 4.
5. Label a fifth hair sample as "Victim's Own Hair." Do not allow students to observe which hair you place in which envelope.
6. Choose one of the four suspects' hair to also be used as your crime scene hair sample. Place some of this hair in an envelope labeled "Crime Scene Hair."
7. Prepare at least 10 slides of suspects 1, 2, 3, and 4, Victim's Hair, and Crime Scene Hair.
8. Stress to students the importance of taking only one slide at a time to examine.

Answers

Check students' data tables.

Final Analysis

1. Answers may vary.
2. Possible answer: Three characteristics of hair that forensic scientists use in investigations are hair color, texture, and whether or not the hair is curly. Also, scientists examine the structure of the hair's medulla.

Part 3: Comparative Analysis of Suspect and Crime Scene Hair

1. Obtain a slide of the victim's hair from the envelope prepared by your instructor. Draw a sketch of the victim's hair, and record all of the information in Data Table 2. Return the slide to the envelope as soon as you are finished so that someone else can use the slide.
2. Look at each of the four suspects' hairs. Draw sketches and record all required information in Data Table 2. Please take only one slide at a time!
3. You will need to rule out that the hair found on the victim did not come from the victim's own head. You will need to examine the sample entitled "Victim's Own Hair."
4. Compare your results with another classmate. If you find you have different answers, it might be necessary to examine more than one hair sample from any individual. Recall that not all hairs are exactly alike.
5. Is it possible to match any of the suspects' hair with the evidence hair that was found on the victim? Be prepared to justify your answer using forensic evidence.
6. Record your results in Final Analysis.

Final Analysis:

1. Does your crime scene hair match any of the suspects' hairs? If yes, which particular suspect?
2. Cite three different characteristics of hair that can be used to support your answer to question number 1. Use complete sentences and correct terminology.

Data Table 2

Source of Hair	Sketch	Color	Medulla	Cuticle	Straight or Curly	Other Characteristics
Crime Scene Hair						
Suspect 1						
Suspect 2						
Suspect 3						
Suspect 4						
Victim's Own Hair						

Further Research and Extensions

Pose one or more of the following questions to students. Ask them to form hypotheses, and then have the students design experiments to test their hypotheses.

1. Can hairspray, gels, and other hair treatments be noted under a microscope?
2. Does eyebrow hair differ from head hair?
3. Is it possible to detect if a person had his or her hair cut with scissors or a razor?
4. Is it possible to tell if hair was burned, or if someone was near a fire?
5. Is there a difference in the structure of hair in a dog's winter coat versus his summer coat?
6. Do all blonds have the same type of medulla?
7. Does using hair conditioner on one's hair make a difference in the appearance of hair under a microscope?

Background

Hair is an important kind of evidence that may be left at a crime scene by any person involved in the crime. In this activity, students will examine their own hair under a microscope and record the following data: color of cortex, type of medulla, type of cuticle, width of hair in micrometers, and whether the hair is straight, curly, or kinky. Then they will use the same techniques to examine hair found at a crime scene, and hair from a suspect, and try to conclude whether the samples match.

Safety Precautions

It is important for students to carry microscopes with two hands.

ACTIVITY 3-2 *Ch. Obj. 3.2, 3.4, 3.5, and 3.6*

HAIR MEASUREMENT AND MATCH

Objectives:

By the end of this activity, you will be able to:

1. Describe how to measure the diameter of a hair that is viewed under a compound microscope.
2. Measure hair samples and determine if the diameter of the hair samples from different sources are the same.

Time Required to Complete Activity: 60 minutes

Introduction:

Hair is an example of trace evidence that can be left at a crime scene or removed from a crime scene (Locard's exchange principle). Although hair is not unique to a specific person, it can be used to identify a class of individuals. (The exception to this occurs if the root of the hair is present and DNA can be extracted and a match made with a crime-scene sample.)

Materials:

(per group of 2 students)
Activity 3-4 Lab Sheet
compound microscope
clear plastic mm ruler
2 glass slides
dropper of fresh water
pencil
pre-made slide of crime scene hair
pre-made slide of the victim's hair
pre-made slide of suspect #1 hair
pre-made slide of suspect #2 hair
pre-made slide of suspect #3 hair

Safety Precautions:

Always carry the microscope with both hands.
No special safety concerns

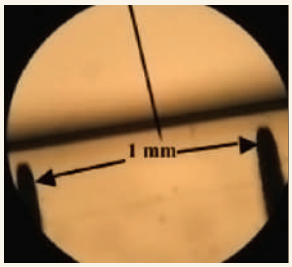
Scenario

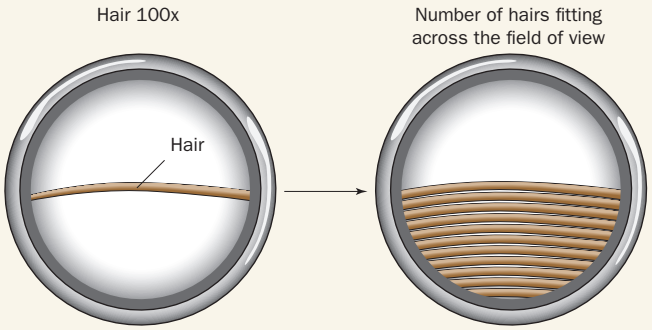
You might say that some people's hair is very fine. Others may have hair that is very coarse. The diameter of the hair provides us with another way to compare a suspect's hair to the crime scene hair. In this lab activity, you will compare the crime scene hair with three suspect's hairs by comparing their medulla, cortex, and cuticle types, as well as compare the diameter of the hair samples.

Procedure:

1. Measure the size of the diameter of the microscope under 100×.
   a. If an ocular micrometer is available, measure the diameter of the field of view. (Most microscopes have a field of view of approximately 1.2 mm.)
   b. If an ocular micrometer is not available:
      - Place a small, clear plastic ruler under the microscope under 100×.
      - Focus on the metric side of the ruler.
      - Measure the diameter of the field of view to the nearest tenth of a millimeter.
      - Record your answer in Data Table 1.
2. Pull out one of your hairs and place it in a drop of water on a microscope slide.
3. Place a cover slip over the hair and view under LOW power (100×).
4. Note the following characteristics of your hair and record the information in Data Table 2:
   - Color of cortex
   - Type of medulla (e.g., continuous, interrupted, fragmented, solid, none)
   - Type of cuticle (e.g., spinous, coronal, or imbricate)
5. Measure or estimate the width of the hair using the diameter of your field of view as a reference. Record your answer in Data Table 2. For example: Center your hair so that it is in the middle of the field of view. Estimate how many hairs would fit across the field of view (100×).

Plastic ruler viewed under 100×.





It appears that about 10.5 hairs fit across half of the diameter of the field of view (100×). Therefore, it would take about twice as many hairs (or 2 × 10.5 = 21 hairs) to fit across the field of view.

The diameter of the single hair is 1/21 of the diameter of the field of view.

If the diameter is 1.2 mm, or 1200 microns, then the size of a single hair is:

Diameter = 1/21 *of 1.2 mm* = 0.05 × 1.2 mm = 0.06 mm

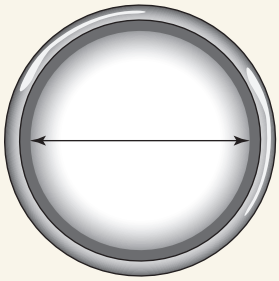
Diameter = 1/21 *of 1200 microns* = 0.05 × 1200 microns = 60 microns

Procedures

1. Print, copy, and distribute Activity Sheet 3-2 from the IRCD.
2. Students need to review what is meant by the diameter of the field of view.
3. Students will also need to know how to measure in millimeters using a metric ruler. Review with them how to convert from millimeters to micrometers.
4. Review with the students how to prepare a wet-mount slide using a coverslip.
5. Go over the different parts of hair found in this chapter.
6. For a further explanation of field of view, teachers could present the example of placing a quarter in a petri dish. The petri dish is the field of view, and the quarter is the specimen to be measured. Ask students to estimate the number of quarters that fit across the dish. From that information and the size of the dish, have them determine the size of one quarter.
7. Tell students that their own hair will serve as "victim hair" in Step 2.
8. Designate one-third of the class as Suspect 1, one-third as Suspect 2, and one-third as Suspect 3. Students will be sharing data.

6. Focus your hair under 400×. Draw a sketch of your hair. Record your answer in Data Table 2.
7. The diameter of the high-power (400×) field of view is ¼ of the diameter of the field of view under 100×, or approximately 300 microns. Calculate the diameter of your field of view under 400× in microns. Record your answer in Data Table 3.
8. Obtain a pre-made slide of a hair sample from the crime scene from your teacher. Measure (or estimate) the diameter of the hair in microns. Record your observations and sketch the hair sample in Data Table 4.
   You will need to record the following information:
   - Sample number
   - Width of the hair in microns
   - Color of cortex
   - Type of medulla
   - Type of cuticle
   - Straight, curly, or kinky
9. Obtain a premade slide of a suspect's hair sample from your instructor. Measure (or estimate) the diameter of the hair in microns. Record your observations and sketch the hair sample in Data Table 4.
   You will need to record the following information:
   - Sample number
   - Width of the hair in microns
   - Color of cortex
   - Type of medulla
   - Type of cuticle
   - Straight, curly, or kinky
10. Based on the forensic analysis of hair and the size of the hair's diameter, would you consider the suspect's hair to match the evidence or crime scene hair? Justify your answer using the information recorded in your Data Table 4.
11. Check with your classmates regarding the other suspects' hair sample analysis. Did anyone find a hair sample that did seem to match the hair evidence left at the crime scene? Does more than one hair sample match the hair sample left at the crime scene?
12. Record the data obtained from your classmates regarding the other suspects' hair samples to Data Table 5. You do not need to view these slides under the microscope since your team of classmates is sharing their data with you. Indicate whether these two other suspects' hair matches the crime-scene hair and justify your answer.

Diameter of the field of view at high power = (¼) × diameter at low power.



Bonus:

Describe how you can determine that the hair sample left at the crime scene is definitely a human hair and not an animal's hair. Include calculations in your answer. Record your answer on the last page of the data sheet.

Data Table 1: Size of Field of View Under 100×

Diameter of Field of View under 100×	
(millimeters)	(microns)

Data Table 2: Your Own Hair

Your Name	Color Cuticle	Type of Medulla	Type of Cuticle	Straight, Curly, or Kinky	Width in Microns	Sketch

Data Table 3: Size of Microscope Diameter under 400×

Diameter of Field of View 100× in Microns	Calculations ¼ Diameter of Field of View under 100×	Diameter of Field of View under 400× Microns

Data Table 4: Whose Hair Matches the Crime-Scene Hair?

Hair Sample	Color Cuticle	Type of Medulla	Type of Cuticle	Straight, Curly, or Kinky	Width in Microns	Sketch
Crime Scene						

Hair Sample #	Match? or Not a Match	Justification

Answers

Check students' data tables.

Thought Questions

1. Yes, there could easily be a different suspect.
2. Yes, it is possible that more than one person's hair matches. Remember that hair is considered to be class evidence, and more than one person can have the same type of hair.
3. No, there is not a way to determine if a hair was transferred. It is possible the hair was transferred earlier. It is not possible to tell when that hair was left on the crime-scene victim.
4. If the hair is a match, then further evidence is needed. If the hair sample has some cells on it from the hair follicle, then a DNA analysis could be conducted. It would then be necessary to get a warrant to request DNA from the suspect. DNA can be obtained from hair, interior cheek cells, blood, semen, or any cell from the body.

Data Table 5: Check with Two Other Classmates

Hair Sample #	Match? or Not a Match?	Justification
Sample # ———		
Sample # ———		

Thought Questions:

Explain each of your answers.

1. Is it possible that none of the hair samples matches the hair found at the crime scene?
2. Is it possible that more than one person's hair matches the crime scene?
3. If someone's hair does match the crime-scene evidence, does that mean that he or she committed the crime?
4. If someone's hair did match the crime scene, what type of evidence could be obtained to indicate that the DNA at the crime scene is a match to their DNA and not to anyone else's DNA?

Return all materials, complete this sheet, and hand it in during your lab. Explore further information at links on the Forensic Fundamentals and Investigations web site at school.cengage.com/forensicscience.

Bonus:

Is the last sample animal hair or human hair? Explain your answer.

Further Research and Extensions

Interested students may be curious about what images of hair from different kinds of microscopes look like. Have these students create a poster or slideshow presentation that shows how the same structure looks using different kinds of microscopes.

ACTIVITY 3-3 *Ch. Obj. 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, and 3.7*

HAIR TESTIMONY ESSAY

Objectives:

By the end of this activity, you will be able to:

1. Write a clear and organized essay.
2. Describe the basics of forensic hair analysis.
3. Explain why hair is considered class evidence.
4. Write a convincing argument stating your case that the suspect's hair either matches the hair found at the crime scene or that the hair does not match hair found at a crime scene

Time Required to Complete Activity: 1.5 to 2 hours

Background:

Your task is to write an essay. You are an expert witness called on to testify in a court case. You are asked to prepare a presentation to the jury that will demonstrate that a particular suspect can be linked to the crime scene. You should assume that the jury knows nothing about hair. Your paper should be typed (double-spaced), with paragraphs separating major ideas. Use spellcheck to correct any spelling errors.

Procedure:

You should prepare:

1. An introductory paragraph addressing the following questions:
   a. Who are you?
   b. Why are you here?
   c. Remember: do not cite specific information about hair within your opening statement to the jury.
2. A body paragraph in which you educate the jury about hair.
   a. Include a graphic or visual aid. Cite the source of your picture.
   b. Define all terms.
   c. Describe what characteristics or traits to look for when analyzing hair.
      - Macroscopically
      - Microscopically
3. Another body paragraph in which you convince the jury why you believe a particular suspect is a match to the hair found at the crime scene.
   a. Recall that hair is class evidence, and describe how it pertains to your argument.
   b. Recall that the hair could have been left at the crime scene prior to the murder.
   c. Your job is to convince the jury that the crime-scene hair evidence is a match to a particular suspect.
4. A concluding paragraph in which you:
   a. Summarize your findings.
   b. Remind them you are an expert.
   c. Restate your conclusion about the evidence hair and the crime-scene hair.
   d. Remember: do not introduce any new information in your conclusion.

ACTIVITY 3-3

Background

When experts testify in court, they must not only address the specific topics relevant to the case, but they must also educate the jury about the subject of their testimony. In this activity, students must prepare a typed, formal presentation to a jury about hair analysis, hair evidence, and why hair from a particular suspect matches hair found at a crime scene. It might be helpful if students know the names of local forensics labs and schools.

Safety Precautions

No safety precautions for this lab.

Procedures

Emphasize how important it is that students answer each of the questions needed to complete this essay. Also remind them to assume that members of the jury know nothing about hair analysis.

Answers

Based on the number of points you would like to reward your students, you may benefit from preparing a rubric for this assignment. A rubric, which can also be passed out to students, not only helps you clarify what is most important in a complete essay, but also makes grading much faster once the essays have been turned in. See the IRCD for sample rubrics.

Further Research and Extensions

Students may be able to find transcripts from real court cases. Also, students may be interested in attending a court case that is open to the public to see another, less common, aspect of a forensic scientist's career.