Kendall Hunt

Chapter 5
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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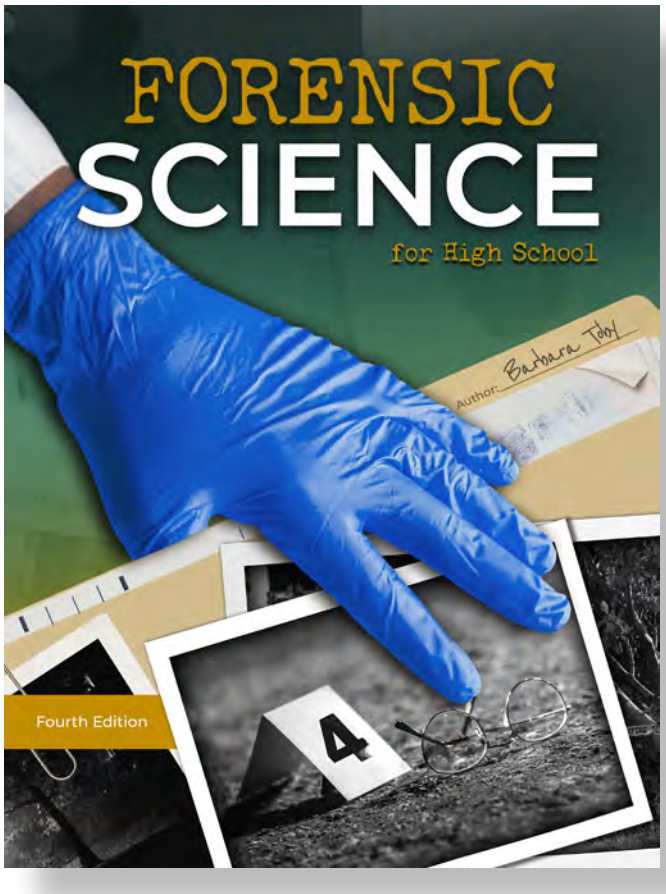


Chapter 5

Hair

STUDENT EDITION

Chapter

5 Hair

> **Everything is a self-portrait. A diary. Your whole drug history's in a strand of your hair. Your fingernails. The forensic details.**
>
> —Chuck Palahniuk, author

Objectives

- Explain why hair is class evidence.
- Describe how hair can be used to back up circumstantial evidence.
- Analyze how hair absorbs substances both from within the body and from the external environment.
- Successfully use a compound microscope.
- Describe the structure of hair.
- Identify the difference between human and animal hair.
- Recognize which characteristics of hair are important for forensic analysis.
- Assess the probative value of hair samples.
- Identify questions and ideas that guide scientific investigations.
- Communicate and defend a scientific argument.

Key Vocabulary

Locard Exchange Principle
morphology
polymer
cuticle
cortex
medulla
keratin
cortical fusi
undulation
micrometers (μm)
anagen phase
catagen phase
telogen phase
interference patterns
melanin
association
questioned
exemplar
metabolite
fasle positive

Hair as Evidence

Locard Exchange Principle

there is always a cross transfer of evidence between suspect and victim or locale

Investigators often find hair at the crime scene (remember the **Locard Exchange Principle**, introduced in Chapter 1). Hair is considered class evidence and is useful in backing up other circumstantial evidence, such as by placing someone at the crime scene. It can also be useful in eliminating suspects.

LABORATORY ACTIVITY 5.1: Observation of Hair

In this lab, you will be examining your own hair as well as hair from your lab partner(s) to look for similarities and differences.

Consider where you have hair on your body. Is the hair all the same?

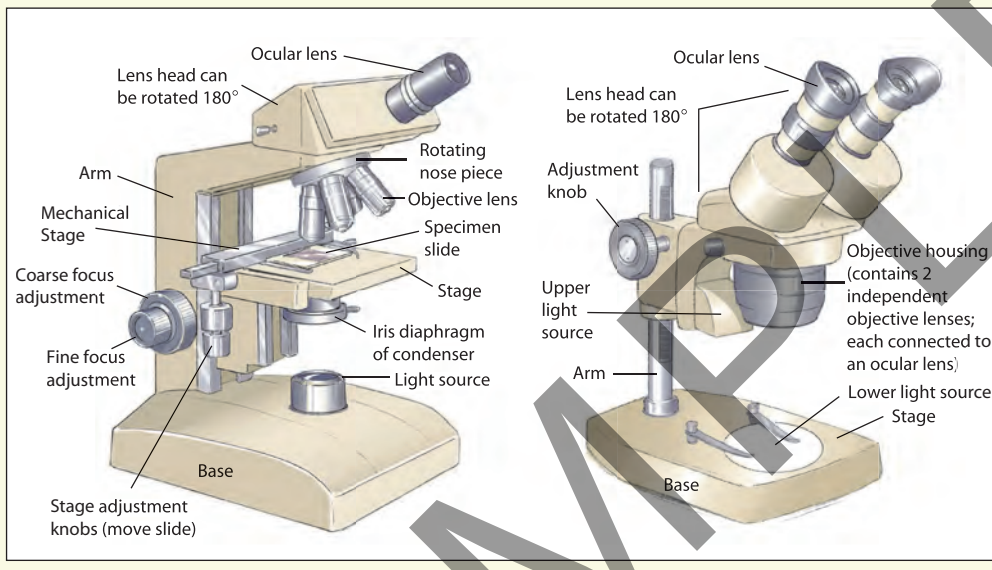
Materials

- magnifying glass or stereomicroscope
- embedding medium
- compound microscope
- set of animal hairs
- microscope slides
- cover glasses
- glycerin or mineral oil
- scissors
- ruler

Procedure

1. If you have long enough hair, run a comb or brush through it and collect three to five strands. If you cannot collect hair samples with a comb, then pull three to five strands of hair from your scalp. If your hair is too short, then have a friend cut three to five hairs close to the scalp.
2. Lay your samples out on a piece of white paper. Pull them taut and measure and record their length, in centimeters.
3. Record the hair color.
4. Borrow hair from some lab partners with different-colored hair and look at it under a magnifying glass or microscope. Sometimes playing with the amount of transmitted light will make the hair color more distinctive. Another trick is to place a hair on a black background and observe it in reflected light. Color is a very important characteristic for the forensic scientist. Save your hair samples by taping them in your notebook or placing them in an envelope. You will need them later.

5. You will be using a compound microscope to look at the hairs you have collected so far. Start with the lowest magnification, 40×.
6. Place the hair sample on a microscope slide and add a drop of glycerin or mineral oil. Anchor it with a cover glass. Adjust the light through the condenser for best viewing. Look at the entire length of your sample. Note the ends.
7. Cut a piece of your hair with sharp scissors and compare that end with the others.



Compound microscope Stereomicroscope

Most of us can grow only about three feet of hair before it stops getting any longer. The world's longest hair, according to Guinness World Records (www.guinnessworldrecords.com), with a length of more than 18 feet, belonged to Xie Quiping of China.

8. Repeat your observations with the other strands of your hair.
9. Draw a typical part of your hair and the ends. Make your drawing at least twice as large as what you see.
10. Pluck a hair from your eyebrow or eyelash or arm and compare it to your scalp hair. Examine and draw scalp hairs from at least three other students.

Analysis Questions

1. Are there any unusual features that set one sample apart from the others?
2. What characteristics do you think a forensic scientist would look for in describing hairs?
3. Record all observations and answer any questions in your lab notebook.

The Form and Structure of Hair

morphology
form and structure

polymers
a molecule consisting of many identical repeating units; polymers can be naturally occurring or synthetic

Neither hair nor fingernails continue to grow after death, contrary to some beliefs. The scalp shrinks and, with time, often slips off the skull in one piece, forming what is known as a hair mask. The skin merely shrinks on the fingers so the nails appear longer. See Chapter 13 for the details of death.

cuticle
tough, clear outside covering of the hair shaft

cortex
middle layer of the hair shaft that provides strength; comprises most of the hair mass

medulla
the spongy interior core of hair that gives it flexibility; appears as a canal in the middle of the shaft

You will need to understand the form and structure, or **morphology**, of hair before you can analyze it as evidence. The average human body has about 5 million hairs! Most of these are fine, downlike hairs that cover practically your entire body. Blonde people have the most hair on their head—about 120,000 strands. Redheads have at least 80,000. People with black and brown hair have about 100,000. Hairs are continuously shed and renewed at a rate of about 100 each 24-hour period from the scalp alone, so it's not surprising that hair is commonly found in our personal environment (again, remember the Locard Exchange Principle). When two people struggle physically, each is likely to leave his or her hair on the other.

Hair is made up mostly of complex cross-linked protein **polymers**. These polymers are very resistant to breaking down. Hair grows from a tubelike organ in the sublayer of skin (dermis) called a hair follicle (see Figure 5.1). The hair's root is embedded in the follicle. The follicle is linked to the body's blood supply, so whatever is taken into the body is distributed to the part of the hair growing at that time. This can be important in analyzing hair for drugs and poisons. The hair shaft extends out through the outermost layer of skin (epidermis) and ends at the tip.

The hair shaft is composed of three parts: the **cuticle**, the **cortex**, and the **medulla** (see Figure 5.2). The cuticle is the clear outside covering of the hair shaft (see Figure 5.3). It is made up of tough, overlapping scales, like those on a fish or like shingles on a roof. Humans have a much finer pattern of scales than

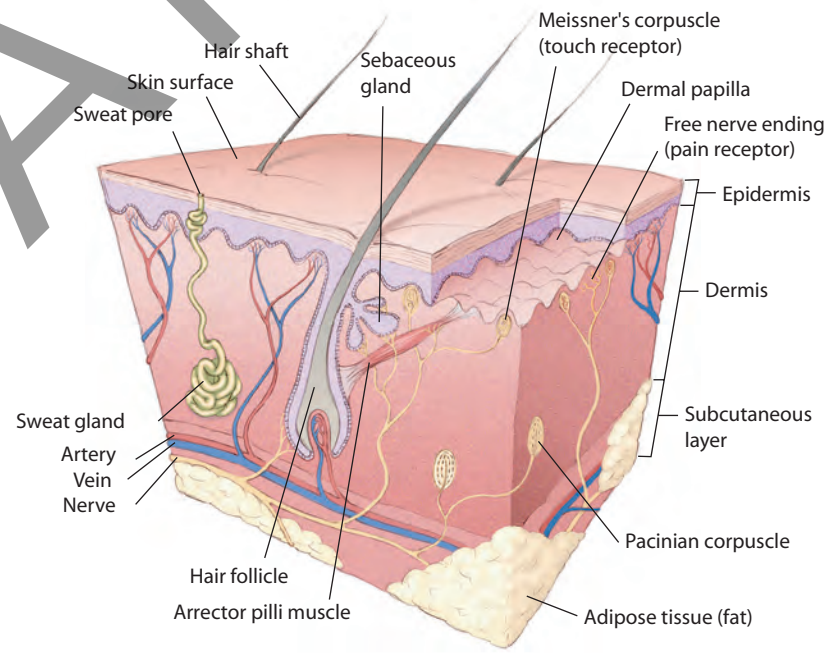


Figure 5.1 Cross section of human skin

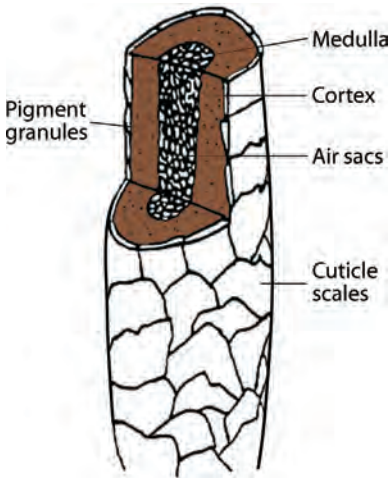


Figure 5.2 Hair shaft

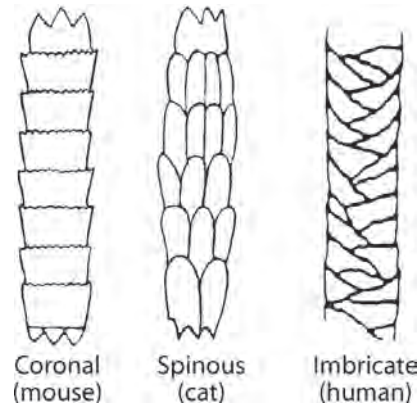


Figure 5.3 Cuticle scale patterns

animals have, and the scales don't show much variation. Differences in the cuticles of animal hairs can be used to identify species.

The cortex is made up of **keratin** molecules aligned parallel to the length of the shaft (see Figure 5.4). In the cortex is the pigment that makes hair black, brown, yellow, or red. The absence of pigment makes hair gray or white. Little sacs of air called **cortical fusi** are also contained within the cortex; these come in different sizes and shapes, thus providing a possible class characteristic. These are best seen under the microscope at 100× or higher magnification.

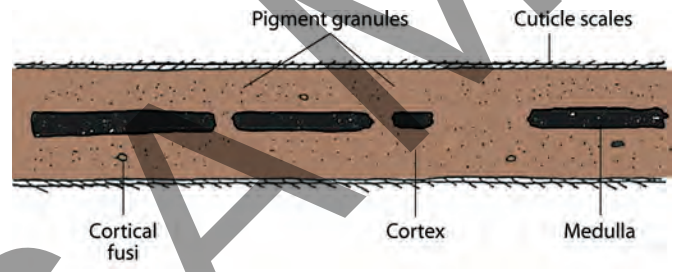
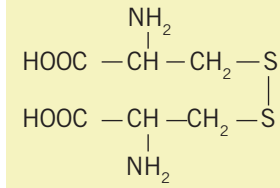


Figure 5.4 Lengthwise cross section of hair shaft

keratin

a tough protein polymer made up of about 20 different amino acids. The principal one is cystine, which allows strong disulfide bonds to form between protein chains.

This cross-linking is what makes hair so resistant to chemical and biological degradation. All that sulfur in keratin also accounts for the distinctive smell of burning hair.



cortical fusi

irregularly shaped air spaces in the cortex

The medulla is a row of cells like a canal running along the center of the cortex (see Figure 5.5). It may appear dark or translucent depending on whether there is air, liquid, or pigment within it, and it can be continuous, interrupted, or in pieces (fragmented). Human hairs generally have no medulla or one that is fragmented, except for the hairs of Native Americans and Asians, where the medulla is usually continuous.

Animal hairs show a wide variety of medullar patterns; investigators can use these patterns to identify some species.

undulation

in hair morphology, slight waviness

undulated

twisted

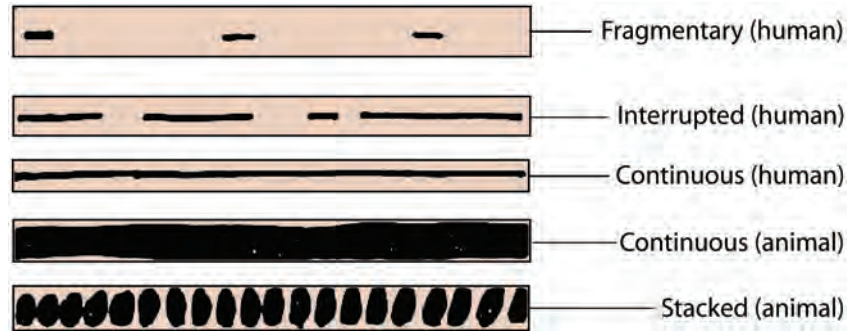
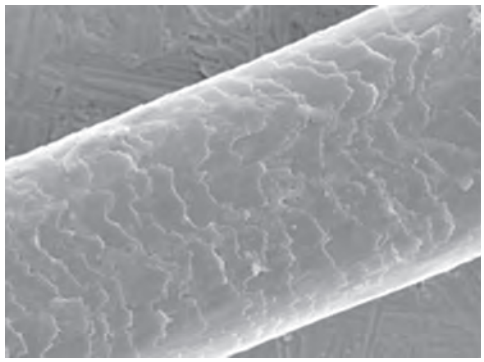
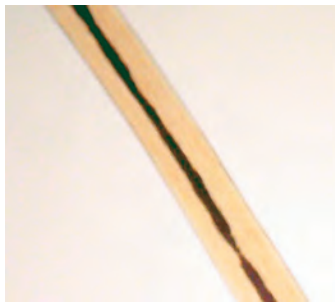


Figure 5.5 Medulla patterns



SEM photograph of human hair, ×2,800



Magnified human hair (blonde)

A scanning electron microscope (SEM) is a type of electron microscope that makes highresolution, blackand-white, almost three-dimensional images of a sample surface.

There are also several different possible shapes of hair. Hair can be straight, curly, or kinky, depending on whether the cross section of the shaft is round, oval, or crescent-shaped (see Figure 5.6). A cross section refers to a view or drawing that shows the shape of the inside of something after it has been cut across. It is risky to assign racial characteristics to hair evidence, but generally, hairs found in Asians and Native Americans have a round cross section and no twisting. The hairs of American and European whites, Mexicans, and people of Middle Eastern background show an oval cross section, rarely a twist or undulation, and evenly distributed pigmentation. People of African heritage have hair characteristics that include a flat to crescent-shaped cross section with a twist or undulation and dense, clumped pigmentation. Interestingly, hair from a beard is often coarse and triangular in cross section. How would hair with these characteristics look (straight, curly, or kinky)?

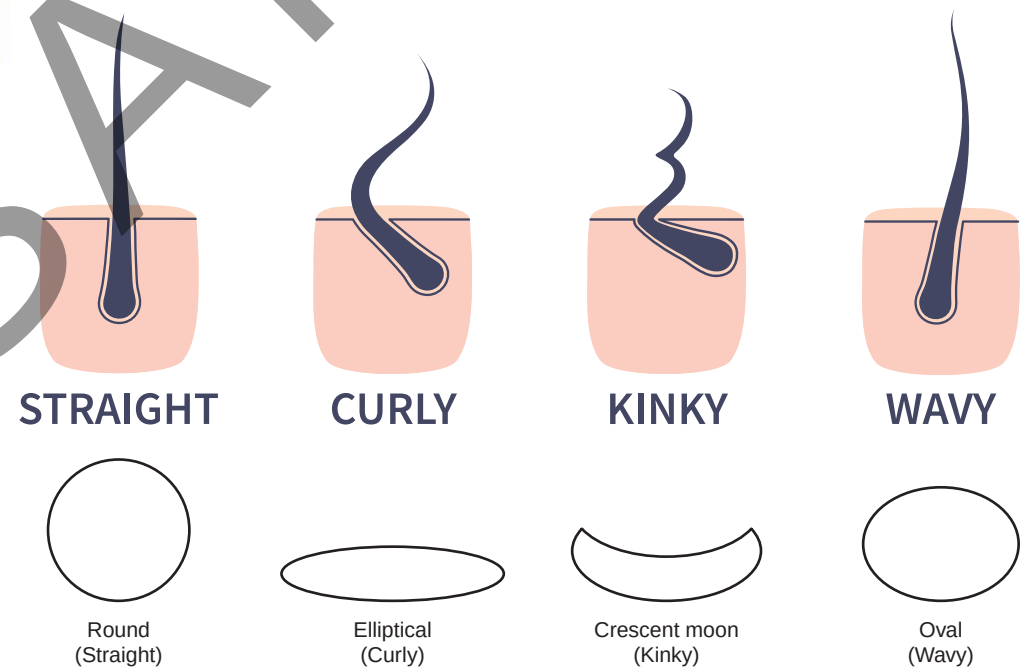


Figure 5.6 Hair types and cross sections of human hair

Human hair ranges in diameter from 25 to 125 **micrometers** (μm). Coarser hairs grow at a slower rate and fall out less frequently than finer hairs do.

The root can also be important in classifying hair (see Figure 5.7). Head hair grows about 1 cm per month and is replaced about every three to five years with new hair. There are three stages of growth: the **anagen phase**, lasting up to five years (this includes 80 to 90 percent of hair follicles at any one time); the **catagen phase**, which is an intermediate stage; and the **telogen phase** (8 to 10 percent of hair follicles), lasting two to six months, in which the follicle is ready to push out the mature hair. The hairs on your brush or comb are telogen hairs and should reflect that in the bulblike shape of the root, with few, if any, pigment granules near it. Hairs that have been pulled from the scalp in the anagen phase of growth may still have follicular tissue attached and may look stretched, and pigment granules may be seen because the hair was still growing. Animal hair roots can have different shapes but are generally spear-shaped.

micrometer (μm)
one-millionth of a meter, or one-thousandth of a millimeter (mm)

anagen phase
period of growth in the hair cycle, averaging three to five years

catagen phase
intermediate period of hair growth, lasting about three weeks

telogen phase
final phase in hair growth, resulting in the loss of hair over about three months

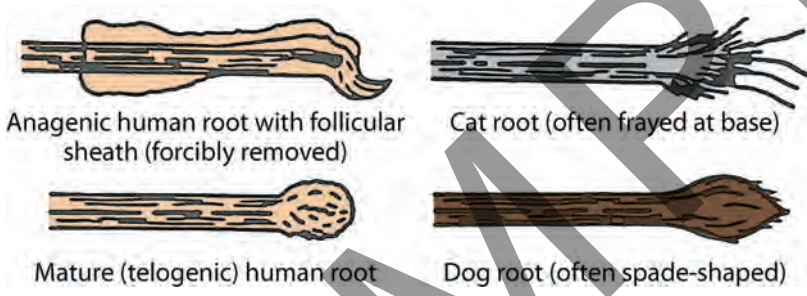


Figure 5.7 Hair roots

A mature human hair should have a bulb-shaped base. The length of the shaft can vary. The tip of a mature hair will taper to a point if it has not been cut or abused for a while. Recently cut hair is squared off at the tip, but within two to three weeks the tip becomes rounded. Frayed hair or split ends result from dryness and lack of care (no conditioners), harsh chemicals (bleaches, permanents, or straighteners), and overuse of a blow dryer (too hot); the effects of all of these are made worse by age.

A pencil can be a reasonable analogy for a hair. It has a length and a diameter that can be measured. The lead is like a continuous medulla; the surrounding wood, the cortex; the painted exterior, the cuticle. The shape of the pencil (round, hexagonal) is the cross section; the pencil point (rounded, sharp, broken), the tip; and the eraser, the root.

Pencil analogy for a hair

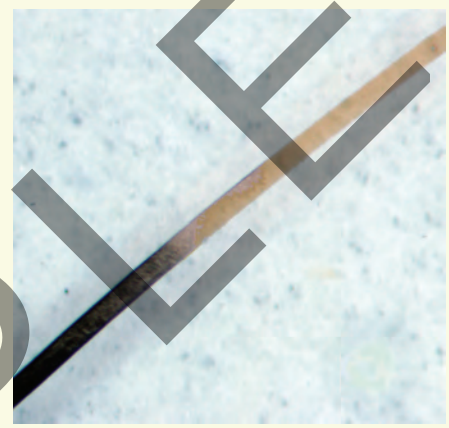
Hair from the mane of a horse is much coarser than the body hair. Porcupine quills are actually dense, fused hair, as is the horn of a rhinoceros.

LABORATORY ACTIVITY 5.2:
Microscopic Examination

In this lab, you will be taking a closer look at your hair samples to describe treatment, root, configuration, diameter and structure.

One of the forensic scientist's most useful tools is the microscope. A piece of evidence such as a hair can reveal important information when examined under the microscope.

Human hair, frayed end



Human hair, dyed

Materials

- magnifying glass or stereomicroscope
- fine wire with known diameter
- compound microscope
- samples of hair, human and animal
- lab tissue
- ruler
- alcohol
- clear nail polish

Procedure

Go back to the drawings you did earlier and label the different parts of the hair sample. Is the sample typical of your scalp hair?

1. *Treatment:* Describe the tips of your hair samples (recently cut, cut but rounded, split, narrowing to a point). Observe a hair strand that has been dyed, if one is available. The dye penetrates the cuticle and into the cortex. Bleached hair will appear light, even yellowish. Animal hair sometimes changes color along the hair shaft, such as with a skunk. Draw what you see in your notebook.
2. *Root:* If you didn't get a hair with a root, do so now and examine it. Sketch it.

Microscopic examination of hair from the mummy of Ramses II showed that the pharaoh was a natural redhead and that he used henna to accentuate his hair color. This analysis was possible despite the hair samples being 33 centuries old!

3. *Configuration:* When you stretched your hair in the earlier section of the lab, was it straight, curly, or kinky? It is difficult to prepare a cross section of hair to be analyzed under a microscope. Perhaps you can tell if it is round, oval, or crescent-shaped by twisting a strand back and forth on a microscope slide under low magnification. Comment on the configuration of your hair. Sketch what you see.

4. *Diameter:* The diameter of hair varies along its length, as you probably noticed; but individuals generally can have small variations within the larger range of fine, medium, and coarse. You can estimate the diameter of your hair by laying a piece of wire of known diameter next to it or comparing it to the field of view, if you know that. Some microscopes have a vernier, which is a scale in the eyepiece. Once calibrated, it can be used to accurately measure the diameter of your sample. Measure the diameter of your hair. Compare the diameter of your hair to the diameter of your lab partner's hair. Record your observations.

Human hair (brown)

5. *Structure*: Cuticle, Cortex, and Medulla

   a. The cuticle in human hair is close-packed, transparent, and fine; therefore, it is difficult to see. You can make the structure visible by making a cast of the hair. Clean a strand of your hair by pulling it through a folded tissue moistened with alcohol to remove grease and oil. Now coat a microscope slide with clear nail polish and press your hair into it. After the polish becomes sticky but not dry, remove the hair and examine the cuticle impression at 40 or 100×. Draw a picture of it. The cuticles of animal hairs can be quite varied and are generally much coarser than those of humans. Collect three or more different animal hairs for comparison. Compare your drawings to those shown in Figure 5.3.

Gray human hair—no pigmentation

(continued)

melanin

a natural pigment found in the skin. Ultraviolet rays in sunlight make it more concentrated, causing tanning.

LABORATORY ACTIVITY 5.2: Microscopic Examination (*continued*)

b. The cortex contains pigment granules composed of **melanin** or melaninlike molecules, fairly evenly spread out for Caucasians but often densely clumped in African American hair. Using 400× magnification, with your hair samples in glycerin or mineral oil, try to find similarities and differences in the pigment granules and cortical fusi of your hair and several hairs from other people. Be aware that sacs such as the fusi or medulla that contain air will look dark with transmitted light but bright in reflected light.

c. A principal difference between human and animal hair structure is the medulla. Not only does it look quite different, but it is much thicker relative to the diameter of the hair shaft in animals than in humans. The medullary index (M.I.) is a measure of the relative thickness and is determined by dividing the diameter (thickness) of the medulla by the diameter of the hair and multiplying by 100 (see Figure 5.8). Because the M.I. is a ratio between the two measurements, the units do not matter as long as they are consistent. Animal hair usually has an M.I. of more than 33. Measure or estimate the M.I. of your hair and that of at least three different animal hairs.

Record all observations, measurements, and calculations on the structure of your hair.

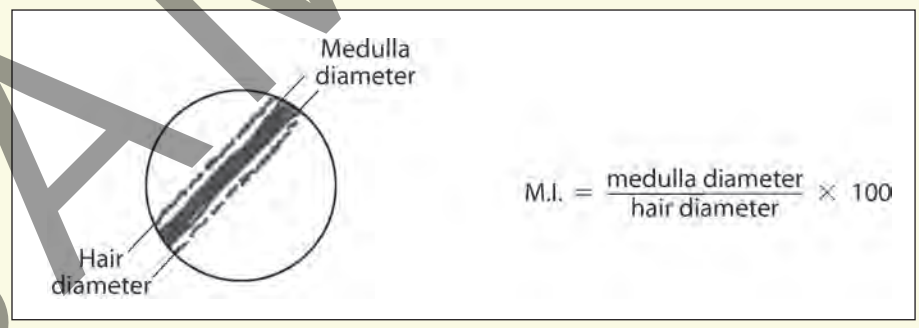
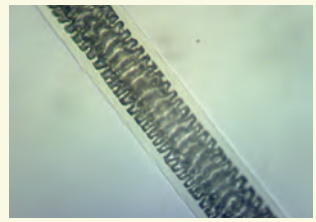
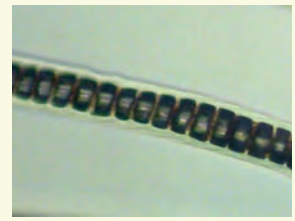


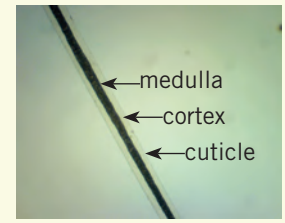
Figure 5.8 Medullary index calculation



Cat hair, M.I. = 85



Rabbit hair, M.I. = 71

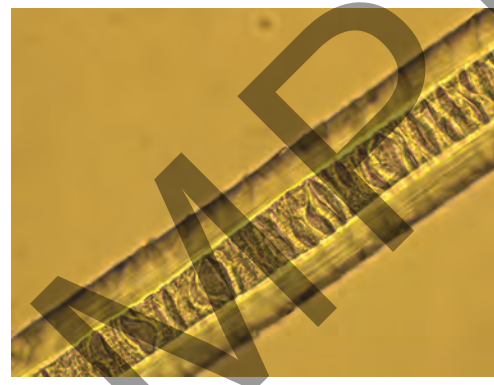


Raccoon hair, M.I. = 35

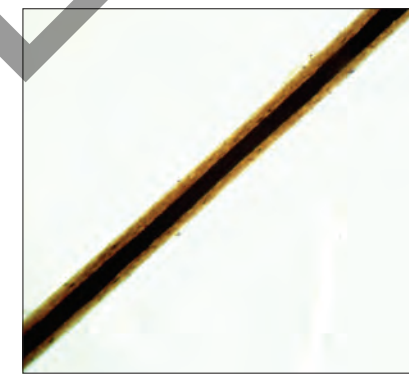
Analysis Questions

1. Does your root have a bulb? Is there tissue attached to it?
2. Does the diameter of your hair change along it's length?
3. Give a description of your cuticle and that of the three animal hairs you chose.
4. Describe what you saw in examining the cortex of your hair.
5. What is the medullary index (M.I.) of your hair? What is the M.I. of the three animals you chose?
6. Explain how a forensic scientist would determine if a hair is human or animal.

Polar bear hair



Dog hair



Sheep hair

ACTIVITY 5.1: Who Murdered Lily?

In this activity, you will read about a fictional crime. You will be tasked with analyzing hair evidence to determine the most likely culprit of a murder.

The victim in this case is Lily, the wife of a handsome real estate developer who flirted (and maybe more) with five women, all of whom were madly in love with him (or maybe with his money). Each was sure that if he were not married, she would be "the one" for him.

(continued)

ACTIVITY 5.1: Who Murdered Lily? (*continued*)

Lily went out riding one spring day, but her horse returned to the stables without her. Her body was found at the edge of a field. The autopsy revealed that her neck had been broken by a powerful blow with a blunt object. Evidence found in an examination of the crime scene suggested a struggle. Investigators sent Lily's clothing to the crime lab. They were especially interested in a wool sweater that yielded many hairs:

a. horse, brown
b. human, blonde
c. human, dark brown
d. cat, gray
e. cat, orange

Lily was a dark brunette with long hair, recently cut. She had two cats.

Suspects in the case include Lily's husband's five girlfriends:

- Violet is a computer programmer who works for the census bureau. She has long, blonde hair. She enjoys sports, especially horseback riding. She rents a stall in Lily's stable.

- Daisy is a redhead who dyes her hair. It was recently cut short. She is a nurse, and shares an apartment with Violet. Her cat is a thoroughbred Maine coon cat. She went to high school with Lily and Camellia.

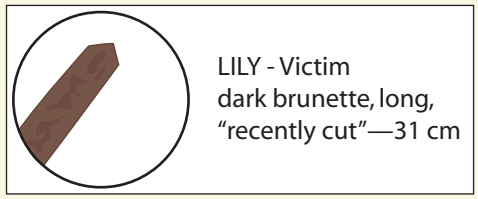
- Rose has long, kinky, dark brown hair. She lives with her golden retriever and keeps pretty much to herself. She is one of Lily's neighbors.

- Iris works for Lily's husband. She claims to be a natural blonde, and she very recently got her hair cut short a few days before Lily's murder.

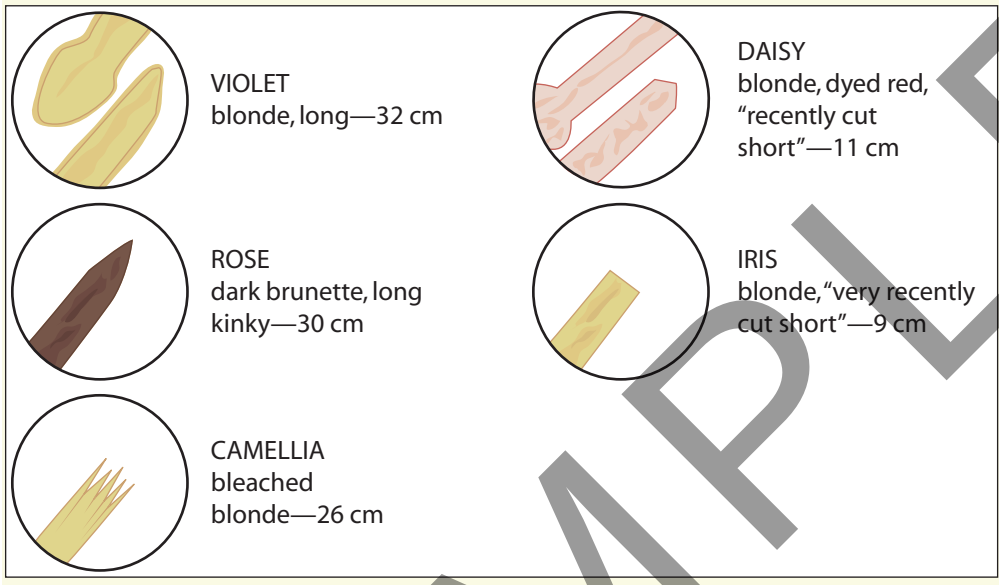
- Camellia is also a blonde who bleaches her hair, which causes split ends. She works as a real estate agent, which is how she met Lily's husband.

Drawings from a microscopic examination of the control and unknown hairs are shown in Figure 5.9. Be sure to notice whether the samples show the hair tip, root, or both.

A. Known Hair Sample from Victim



B. Known Hair Samples from Suspects



C. Unknown Hair Samples from Victim's Sweater

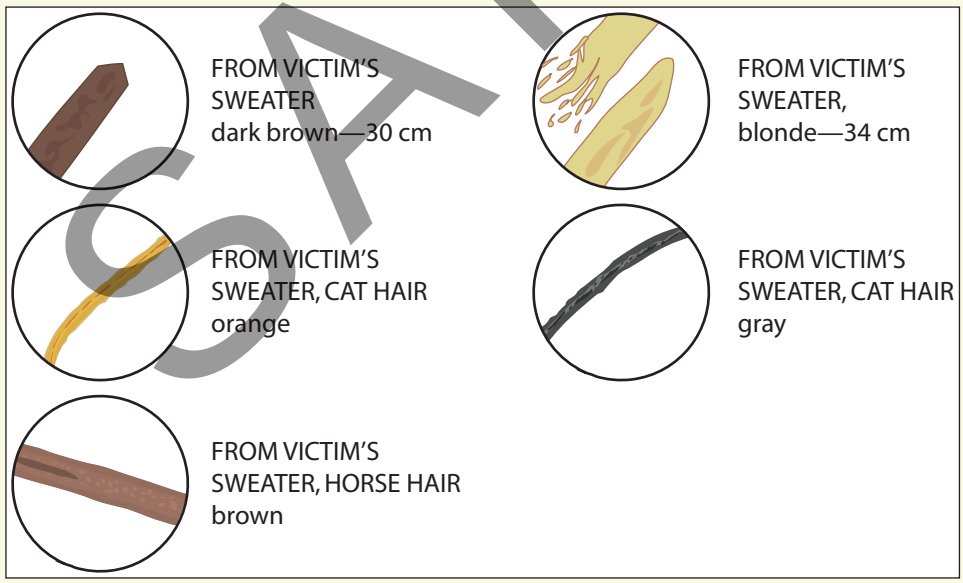


Figure 5.9 Hair from the victim, suspects, and crime scene

(continued)

ACTIVITY 5.1: Who Murdered Lily? (*continued*)

Analysis Questions

1. What motive do all of the women share as a possible reason to have murdered Lily?
2. Based on the hair evidence alone, are there any women that can likely be ruled out as suspects?
3. Based on the hair evidence alone, which women should still be considered suspects?
4. Which woman do you think is most likely to have committed the murder? Explain, using evidence to back up your answer.
5. What additional hair evidence and information should be gathered to build a stronger case?

The Value of Hair as Evidence

Investigators consider hair and fibers they find at the scene of a crime to be trace evidence. This type of physical evidence cannot by itself give positive identification; however, it can support other evidence developed during the course of an investigation. The forensic investigator's job is to compare different pieces of circumstantial evidence to reduce the possible sources to the smallest number they can obtain.

If hairs are collected at the scene of the crime, the investigator would first determine what species they came from. You now know how to differentiate between human and animal hair. If the hair is human, characteristics are compared to narrow the collected evidence to a group that includes the suspect.

As you have learned, each person can have hairs with different characteristics, while there may be many similarities from one person to another. This is why the more hair samples the investigator examines, the better. We cannot say that any two hairs from one person are identical and unique, as we can with fingerprints. Nevertheless, hair can be valuable evidence because it does have a wide range of class characteristics, it is persistent (ever try to remove a hair from a sweater?), it resists degradation, and it is commonly found at crime scenes.

An investigator may associate an unknown hair with an individual by comparing the characteristics you have observed here. The more characteristics that are similar, the greater the degree of probability of **association**. On the other hand, a *single significant difference* between unknown (**questioned**) and known (**exemplar**) hair would strongly suggest separate sources. For example, the questioned hairs found on the victim's body are all long, black, and round in cross section, with a continuous medulla. The suspect's hair samples are long, black, and round, but with no medulla. This difference means the investigator cannot say there is a direct association.

Careful examination of hair evidence cannot determine the age or sex of the individual (although DNA typing of the hair root can).

There are a number of things we can learn from hair samples:

- whether the source is animal or human
- racial origin (sometimes)
- location on the source's body
- whether the hair has been chemically treated (dyed, permed, straightened)
- color
- whether the hair was forcefully removed (usually)

The outcome of many cases was decided long before the advent of new scientific discoveries and modern forensic technology. In the case study you are about to read(Case Study 5.1: Colin Ross), DNA analysis from the root could have provided conclusive evidence of a link (or lack thereof) between Ross's blanket and the victim.

association

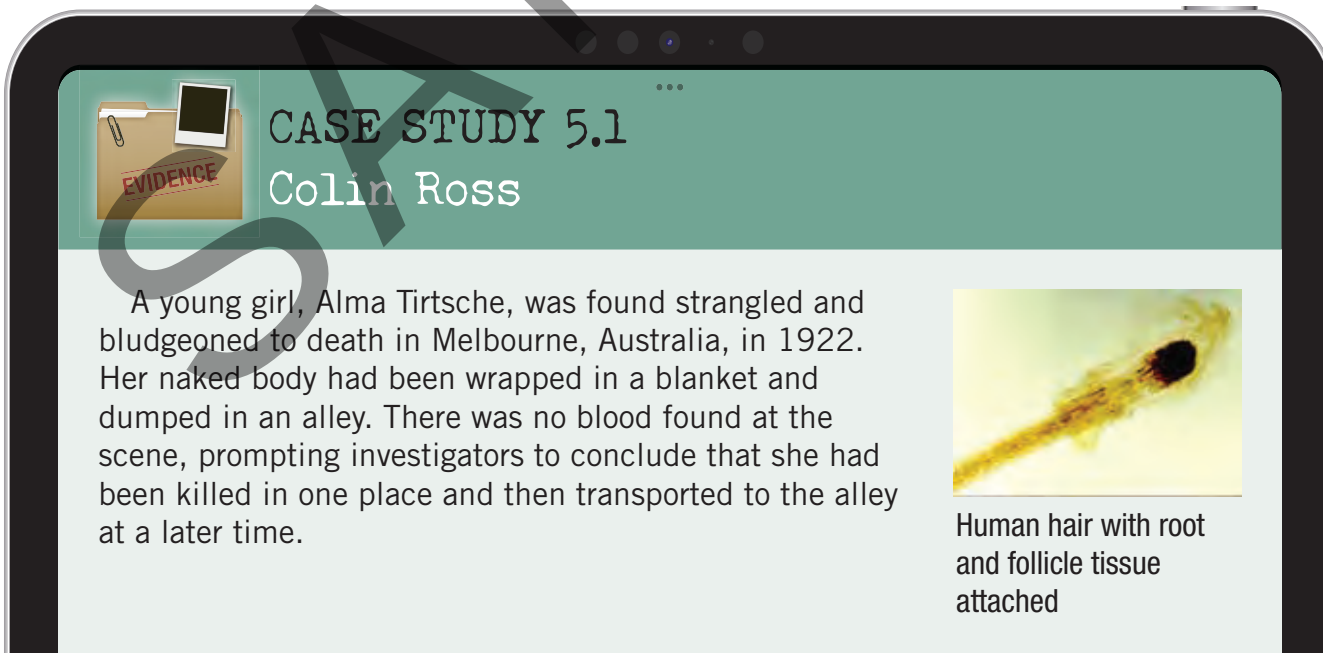
a link between an unknown sample and known evidence

questioned

term used in forensics to describe a sample of unknown origin; for example, a hair was found on a jacket, but we do not know whose head it came from

exemplar

term used in forensics to describe a sample of known origin; for example, we know that this hair was pulled out of so-and-so's scalp



Human hair with root and follicle tissue attached

As the investigation progressed, Colin Ross became a suspect. Police searched his home and obtained two more blankets that they sent to Dr. Charles Taylor for analysis. On one he found strands of reddish-gold hair, the same color as Alma's. Dr. Taylor determined that the hairs were indeed human and that they were most likely female (they were more than 12 inches long). He also concluded that because the hair had so much pigmentation, it must be from a young person. Some of the hairs had roots, suggesting that they were pulled out during a violent encounter. The hair evidence indicating that Alma had been in contact with the blanket found at Ross's home was enough to convict him.

Colin Ross was found guilty of murder and hanged four months later.

More than eighty years later, in his book *Gun Alley: Murder, Falsehood, and Failure of Justice*, Kevin Morgan proved that Ross was most probably innocent.

In 1993, Kevin Morgan, a former teacher, became interested in the case and did some research into it. He examined interview records and court transcripts. He discovered that five people stated that Ross had been in the saloon the entire afternoon of Alma's death. This information had not been introduced to the court.

In 1995, Morgan was able to obtain the hair samples from the Office of Public Prosecutions (Australia). In 1998, through DNA testing, he found that the hairs came from different sources.

In 2005, family members of both Alma and Ross submitted a petition of mercy. In 2007, a pardon was issued and in 2008 a verdict of miscarriage of justice was declared. Collin Ross's name was cleared.

Analysis Questions

1. Had this case occurred within the last decade or so, what test(s) could have been performed to determine guilt or innocence?
2. Should a prosecutor, judge or jury be able to convict on hair evidence alone? Why or why not?

Hair as a Chemical Indicator

metabolites
a specific product of a substance, formed by chemical processes in the body

Hair can collect chemicals that come into the body and are delivered by the blood to the hair root, where they are deposited in the cortex. As analytical testing methods have become more sensitive and efficient, many drugs and their **metabolites**, vitamins, and poisons can now be detected in just a few millimeters of hair.

Drug analysis of hair backs up standard blood and urine tests because drugs are typically gone from blood just a few hours after the last use. Analysis can generally detect drug metabolites in urine for a period of three to five days from last use. Hair, as you know, grows about 1 centimeter a month, so drug use can be traced over longer periods of time. By analyzing bits of hair, continuous or infrequent use can be discovered and even matched to an approximate timeline, such as every week, or three months ago (3 cm from the root). Think of drug testing of blood, then, as a snapshot of use; of urine tests as a time exposure; and of hair testing as a true album of use.

Scientists have had some success in using hair's metal content to diagnose dietary deficiencies and diseases. In forensics, chronic heavy metal poisoning (such as by arsenic, lead, or mercury) can be easily discovered.

A HAIRY MYSTERY

An interesting case of historical forensic investigation involved looking for arsenic in locks (pieces) of French military leader and emperor Napoleon Bonaparte's hair.

Napoleon died in 1821 while in exile on the island of St. Helena in the South Atlantic Ocean. The cause of his death has been debated, but it was originally believed to a stomach disorder.

During that period in history, it was common to collect locks of hair as a sign of affection or devotion, or as a way of remembering someone. When he died, much of Napoleon's hair was collected to give to his family and his many admirers. Some even made jewelry out of it!

Napoleon Bonaparte

In the 1990s, British scientists tested a lock and found the hair to have an unusually high level of arsenic in it. This led to many theories as to his cause of death. Was it accidental? Was it murder? Ever since, there have been a plethora of tests and theories about his true cause of death.

false positive

a test result that comes out positive when it should not; often caused by contamination or failure to run a control

A hair's cuticle is typically coated with scalp oils, so investigators can sometimes find traces of a person's environment. They have detected smoke from crack cocaine this way, as well as heavy metal industrial pollutants, such as cadmium. Because of this, someone who has not smoked crack or been deliberately poisoned may show a **false positive** in a hair analysis, just by having been exposed to incidental chemicals in the environment. Investigators should always take measures and perform tests to rule out false positives. Someone could be wrongly convicted on the basis of misleading test results. How would you try to avoid a false positive in such a case?

The small amount of DNA in the root of the hair can now be isolated and amplified; bits of DNA can be analyzed to provide more information that can be useful in identification. Mitochondrial DNA can be obtained from the hair's shaft. (See Chapter 11, "DNA Analysis.")

ACTIVITY 5.2: Hair Analysis

In this activity, you will analyze hair samples to help solve a crime.

A woman was attacked one evening on her way home from work. She swung her purse at the attacker, hitting him hard in the head. He fled. Later she was able to identify him from a police lineup. Police examined the purse and found some hair. The following samples were submitted to the crime lab for analysis:

Known/exemplar: suspect's hair

Known/exemplar: victim's hair

Unknown/questioned: hair from purse

Compare the unknown (questioned) hair with the known (exemplar) hair. Use the handout from your teacher to record your findings.

Analysis Questions

1. In your opinion, is there sufficient evidence to convict the suspect of assault? Why or why not?
2. What more could be done?

Career Feature: Forensic Hair Specialist

Trace evidence includes everything from fibers to soil to pollen, but probably one of the most common is hair. Because hair can be transferred between people or objects, it can serve as important physical evidence in an investigation.

As a **forensic hair specialist** or examiner working in a forensic laboratory, you would likely use two compound light microscopes to compare hair samples. An optical bridge connects these two microscopes so that hair sample evidence and known hairs can be viewed and compared at the same time. A forensic hair specialist can compare characteristics of the hair, such as color, thickness, and shape, to determine whether the hair belongs to a human or an animal. A forensic hair specialist can even do a DNA analysis of the hair sample. Even though hair samples do not always contain enough DNA to do an accurate analysis, DNA tests can provide information about the gender of the sample.

In addition to earning a bachelor's degree in chemistry, forensic science, or another science-related field, a candidate for a job as a forensic hair specialist will need to be trained and certified. The American Society of Trace Evidence Examiners offers training for forensic hair examiners. Certification is also offered by the American Board of Criminalistics (ABC). Training and work experience in hair microscopy and DNA analysis are key skills for a forensic hair specialist.

Other possible careers that are related to a forensic hair specialist include forensic hair analyst, forensic chemistry, forensic biology, trace evidence examiner, microbiologist, microscopist, and law enforcement. 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.

A forensic hair specialist examines a lock of hair

Checkpoint Questions

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

1. What characteristics make hair a useful forensic tool?

2. Is hair considered class or individual evidence? Why?

3. What is meant by the "morphology" of hair?

4. What is the medullary index (M.I.) of the polar bear hair shown in the text section "The Form and Structure of Hair"? Could such hair be confused with human hair? If so, how could it definitely be differentiated from human?

5. How many hairs fall out during an average day?

6. Where is the medulla found, and what might it look like?

7. Where is the cuticle found, and what might it look like?

8. Where in the hair are pigment granules found?

9. If the cross section of a hair is found to be oval in shape, would you expect the hair to be straight, curly, or kinky?

10. What is meant by the anagen phase, and how long does it last?

11. At any given time, approximately how many hairs are found to be in the anagen phase?

12. What is the telogen phase, and how long does it typically last?

13. What are a few advantages of using hair for drug testing over blood and urine tests?

14. Name a disadvantage of using hair for drug testing.

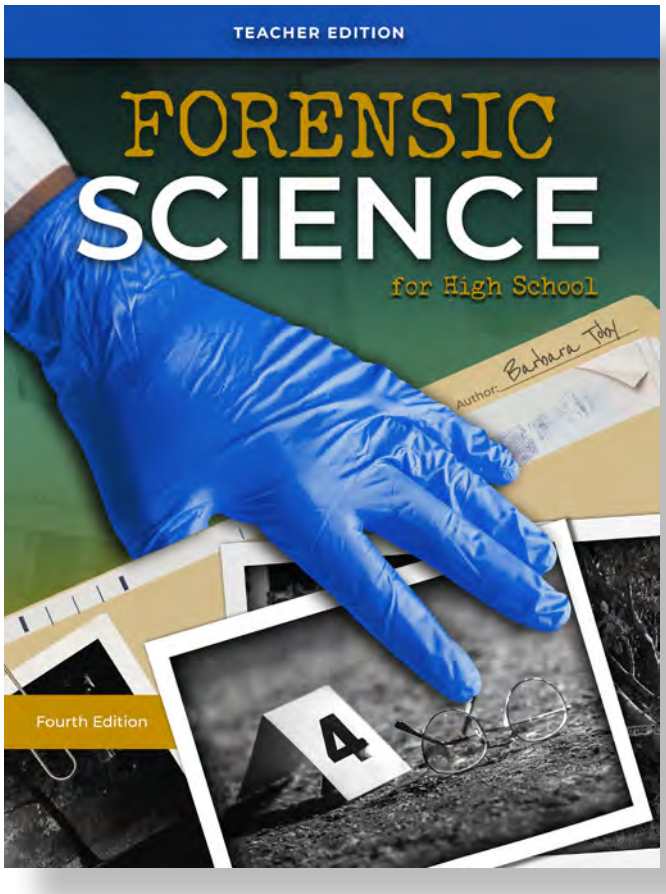
15. How would you decide approximately how long ago a hair sample was dyed?

Checkpoint Questions

16. If you were asked whether a particular hair sample were human or animal, what would you look for? Explain, using words and diagrams.

17. If you were asked to compare an unknown (questioned) sample to a known sample of human hair to match or identify origin, what would you look for? Would your observations give conclusive evidence? Explain, using words and drawings.

18. What fibers can also be considered hair?



Chapter 5

Hair

TEACHER EDITION

Chapter

5 Hair

> **Everything is a self-portrait. A diary. Your whole drug history's in a strand of your hair. Your fingernails. The forensic details.**
>
> —Chuck Palahniuk, author

Objectives

- Explain why hair is class evidence.
- Describe how hair can be used to back up circumstantial evidence.
- Analyze how hair absorbs substances both from within the body and from the external environment.
- Successfully use a compound microscope.
- Describe the structure of hair.
- Identify the difference between human and animal hair.
- Recognize which characteristics of hair are important for forensic analysis.
- Assess the probative value of hair samples.
- Identify questions and ideas that guide scientific investigations.
- Communicate and defend a scientific argument.

Key Vocabulary

Locard Exchange Principle
morphology
polymer
cuticle
cortex
medulla
keratin
cortical fusi
undulation
micrometer (μm)
anagen phase
catagen phase
telogen phase
interference patterns
melanin
association
questioned
exemplar
metabolite
false positive

Alignment to NGSS

Chapter 5: Hair	
Overarching Essential Questions	**Overarching Enduring Understandings**
• How is hair used in a criminal investigation? • How can hair be used to back up circumstantial evidence? • How can hair absorbing substances (like a sponge) or adsorbing (adhering to the surface) substances from the environment be a source of valuable information?	• Human hair is class evidence if no follicle is present. • Hair follicles contain DNA.

Student Learning Objectives	
After instruction, students should be able to:	**NGSS Standards**
Explain why hair is class evidence.	HS-LS1-2
Describe how hair can be used to back up circumstantial evidence.	HS-LS1-2
Analyze how hair absorbs substances both from within the body from the external environment.	HS-LS1-1
Successfully use a compound microscope.	HS-PS1-3 ETS1-2
Describe the structure of hair.	HS-ETS1-2 HS-PS1-1
Identify the difference between animal and human hair.	HS-LS3-3
Recognize which characteristics of hair are important for forensic analysis.	HS-LS1-2
Assess the probative value of hair evidence.	HS-LS1-1
Identify questions and ideas that guide scientific investigations.	HS-LS3-1 HS-ETS1-1
Communicate and defend a scientific argument.	HS-LS3-2

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 Academies 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.	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)** Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out essential functions of life through systems of specialized cells. **(HS-LS1-1)**	**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.

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.	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)** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. **(HS-PS1-1)** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. **(HS-LS3-3)**	**Structure and Function** • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way heir components are shaped and used, and the molecular substructures of their various materials. **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 *Hair Analysis* lesson, quiz, and lab activity on *Diablo Highway* online.

Student Sheets

Student Sheet 5.1 *(The Form and Structure of Hair)*

Student Sheet 5.1: Answer Key *(The Form and Structure of Hair)*

Student Sheet 5.2 *(Who Murdered Lily?)*

Student Sheet 5.2: Answer Key *(Who Murdered Lily?)*

Student Sheet 5.3 *(Hair Examination Form for ACTIVITY 5.2)*

Student Sheet 5.4 *(Crossword Puzzle)*

Student Sheet 5.4: Answer Key *(Crossword Puzzle)*

Additional Online Resources

- Chapter 5 Slides
- CASE STUDY 5.1: Colin Ross

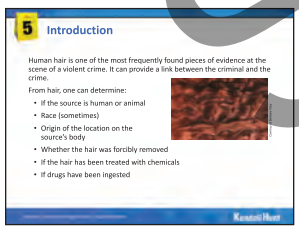
Warm-Up

> **Everything is a self-portrait. A diary. Your whole drug history's in a strand of your hair. Your fingernails. The forensic details.**
>
> ——Chuck Palahniuk, author

- Show students the quote on the chapter opener. Ask students if they know who Chuck Palahniuk is, and if they know that he is a writer, ask if they can recall any of the books he has written? *(Examples: Make Something Up: Stories You Can't Unread, Beautiful You, Diary: A Novel, Not Forever but for Now, Haunted, Choke, Survivor, Fight Club).* Explain to students that this quote comes from *Diary: A Novel.*
- Then ask students: What do you think it means? *(Possible answer: A person's diary is very personal and reveals a lot about a person, just like their hair does. Hair samples can reveal a person's race. Hair color—including whether it has been dyed or not—and hair style reveal more details about a person.)*
- Optional additional background: When Palahniuk was an adult, his parents divorced and his father started dating another woman. That woman's ex-husband then murdered both Palahniuk's father and the woman. This personal tragedy influenced the writing of his novel, *Lullaby.*

Hair as Evidence

Slides



Use this slide to introduce the chapter and to help students to better understand hair evidence.

LABORATORY ACTIVITY 5.1:
Observation of Hair

Time: 1 class period

In this lab, students will examine various hair samples.

Advance Preparation

You can prepare a permanent set of hair samples using an embedding medium such as Norlands NOA65, Paraplast (www1.fishersci.com), or Canadian balsam. The latter two are far more difficult to work with; Paraplast is messy and prone to bubble formation, while balsam must be heated just right, and bubbles may still result. Ask students to bring in pet hair samples in advance. Alternatively, consider contacting a pet store or zoo to obtain hair samples from a variety of animals.

Student Instructions

In this lab, you will be examining your own hair as well as hair from your lab partner(s) to look for similarities and differences.

Consider where you have hair on your body. Is the hair all the same?

Materials

- magnifying glass or stereomicroscope
- embedding medium
- compound microscope
- set of animal hairs
- microscope slides
- cover glasses
- glycerin or mineral oil
- scissors
- ruler

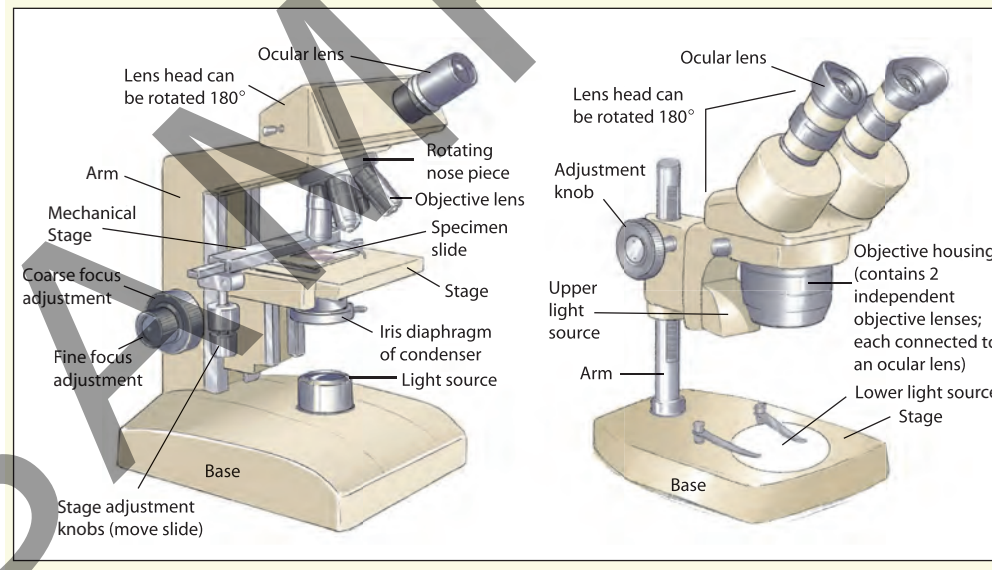
Procedure

1. If you have long enough hair, run a comb or brush through it and collect three to five strands. If you cannot collect hair samples with a comb, then pull three to five strands of hair from your scalp. If your hair is too short, then have a friend cut three to five hairs close to the scalp.
2. Lay your samples out on a piece of white paper. Pull them taut and measure and record their length, in centimeters.
3. Record the hair color.

(continued)

LAB ACTIVITY 5.1: Observation of Hair (*continued*)

4. Borrow hair from some lab partners with different-colored hair and look at it under a magnifying glass or microscope. Sometimes playing with the amount of transmitted light will make the hair color more distinctive. Another trick is to place a hair on a black background and observe it in reflected light. Color is a very important characteristic for the forensic scientist. Save your hair samples by taping them in your notebook or placing them in an envelope. You will need them later.
5. You will be using a compound microscope to look at the hairs you have collected so far. Start with the lowest magnification, 40×.
6. Place the hair sample on a microscope slide and add a drop of glycerin or mineral oil. Anchor it with a cover glass. Adjust the light through the condenser for best viewing. Look at the entire length of your sample. Note the ends.
7. Cut a piece of your hair with sharp scissors and compare that end with the others.



Compound microscope Stereomicroscope

8. Repeat your observations with the other strands of your hair.
9. Draw a typical part of your hair and the ends. Make your drawing at least twice as large as what you see.
10. Pluck a hair from your eyebrow or eyelash or arm and compare it to your scalp hair. Examine and draw scalp hairs from at least three other students.

Analysis Questions

1. Are there any unusual features that set one sample apart from the others?
   Answers will vary.
2. What characteristics do you think a forensic scientist would look for in describing hairs?
   Color; length; appearance of the tip; any hair treatment; curliness; diameter, perhaps; microscopic structure; smell; etc.
3. Record all observations and answer any questions in your lab notebook.
   Answers will vary.

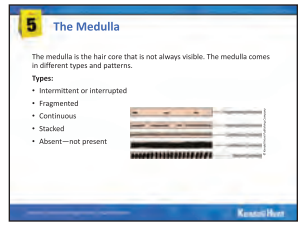
The Form and Structure of Hair

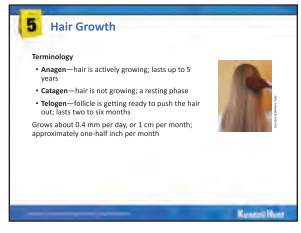
Teacher Tip

Have students fill in **Student Sheet 5.1** ***(The Form and Structure of Hair)*** with the correct labels for each figure as they read about the form and structure of hair. Answers can be found on **Student Sheet 5.1: Answer Key** ***(The Form and Structure of Hair)***. You can access the Student Sheets to print and distribute to students from the Online Teacher Resources.

Slides

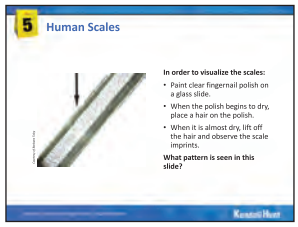
You may want to use the following slides to introduce the material that students will be investigating in this section.





Possible Discussion Questions

- Do you think the length of a strand of hair matters when collecting a hair sample? Why or why not?
  Most of its characteristics are not dependent on length so it should not matter. If all hairs are the same length it may add as another aspect of class evidence. length can be changed while other characteristics cannot.
- How can the stage of hair growth be a key factor in a forensics investigation?
  The growth phase can determine whether or not the hair was forcibly removed. If in the anagenic phase, it will likely have follicular tissue attached.



Slides

You may want to have students complete this short activity shown on the slide before they begin Laboratory Activity 5.2.

Possible Discussion Questions

- Why do you think that the scales of humans are similar to each other but those of animals are different?
  Scales on animal hair may be necessary for their protection and locomotory support.

- Does the pattern on the slide match the pattern shown in the image?
  They should match.

Cross-Curricular Connection

LABORATORY ACTIVITY 5.2:
Microscopic Examination

Time: 2 class periods

In this lab, students will further examine hair samples to describe treatment, root, configuration, diameter, and structure.

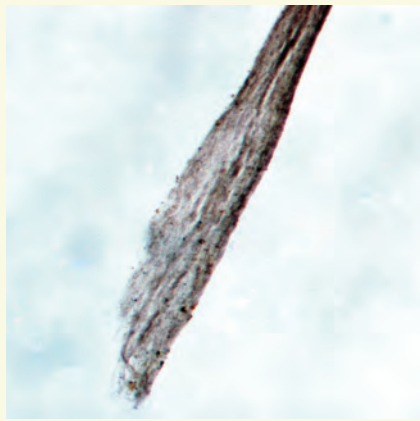
Advance Preparation

You can use a video or camera attachment to the microscope to project images of hair onto a monitor or screen; this is most helpful in the entire laboratory activity. You can point out features to the whole class, you can view prepared slides from many different animals, and the medullary index (M.I.) can easily be measured directly from the projected image. The scale won't matter, because M.I. is a ratio.

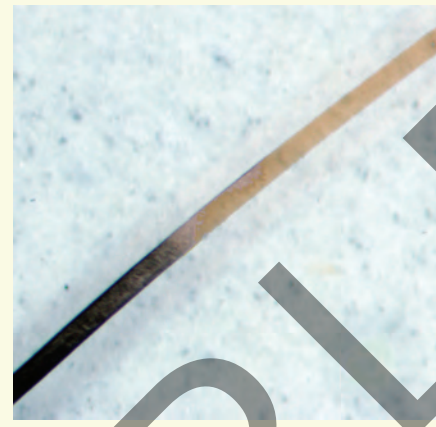
Student Instructions

In this lab, you will be taking a closer look at your hair samples to describe treatment, root, configuration, diameter and structure.

One of the forensic scientist's most useful tools is the microscope. A piece of evidence such as a hair can reveal important information when examined under the microscope.



Human hair, frayed end



Human hair, dyed

Materials

- magnifying glass or stereomicroscope
- fine wire with known diameter
- compound microscope
- samples of hair, human and animal
- lab tissue
- ruler
- alcohol
- clear nail polish

Procedure

Go back to the drawings you did earlier and label the different parts of the hair sample. Is the sample typical of your scalp hair?

1. *Treatment:* Describe the tips of your hair samples (recently cut, cut but rounded, split, narrowing to a point). Observe a hair strand that has been dyed, if one is available. The dye penetrates the cuticle and into the cortex. Bleached hair will appear light, even yellowish. Animal hair sometimes changes color along the hair shaft, such as with a skunk. Draw what you see in your notebook.
2. *Root:* If you didn't get a hair with a root, do so now and examine it. Sketch it.

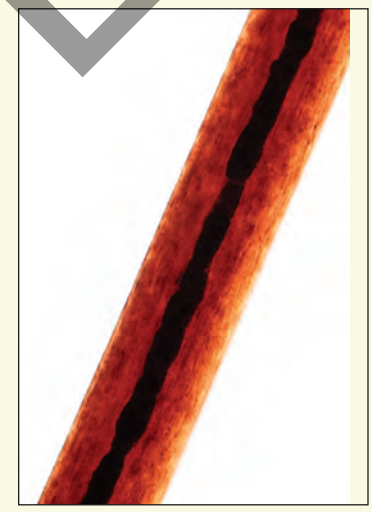
(continued)

3. *Configuration:* When you stretched your hair in the earlier section of the lab, was it straight, curly, or kinky? It is difficult to prepare a cross section of hair to be analyzed under a microscope. Perhaps you can tell if it is round, oval, or crescent-shaped by twisting a strand back and forth on a microscope slide under low magnification. Comment on the configuration of your hair. Sketch what you see.

Teacher Tip

The fine wires that come with a microsyringe are 100 µm in diameter. The shop in your school should have a fine wire or a synthetic bristle from a paintbrush that can be measured with a vernier micrometer. You may also have a microscope slide with a scale on it.

4. *Diameter:* The diameter of hair varies along its length, as you probably noticed; but individuals generally can have small variations within the larger range of fine, medium, and coarse. You can estimate the diameter of your hair by laying a piece of wire of known diameter next to it or comparing it to the field of view, if you know that. Some microscopes have a vernier, which is a scale in the eyepiece. Once calibrated, it can be used to accurately measure the diameter of your sample. Measure the diameter of your hair. Compare the diameter of your hair to the diameter of your lab partner's hair. Record your observations.



Human hair (brown)

5. *Structure*: Cuticle, Cortex, and Medulla

   a. The cuticle in human hair is close-packed, transparent, and fine; therefore, it is difficult to see. You can make the structure visible by making a cast of the hair. Clean a strand of your hair by pulling it through a folded tissue moistened with alcohol to remove grease and

Gray human hair—no pigmentation

oil. Now coat a microscope slide with clear nail polish and press your hair into it. After the polish becomes sticky but not dry, remove the hair and examine the cuticle impression at 40 or 100×. Draw a picture of it. The cuticles of animal hairs can be quite varied and are generally much coarser than those of humans. Collect three or more different animal hairs for comparison. Compare your drawings to those shown in Figure 5.3.

b. The cortex contains pigment granules composed of **melanin** or melaninlike molecules, fairly evenly spread out for Caucasians but often densely clumped in African American hair. Using 400× magnification, with your hair samples in glycerin or mineral oil, try to find similarities and differences in the pigment granules and cortical fusi of your hair and several hairs from other people. Be aware that sacs such as the fusi or medulla that contain air will look dark with transmitted light but bright in reflected light.

c. A principal difference between human and animal hair structure is the medulla. Not only does it look quite different, but it is much thicker relative to the diameter of the hair shaft in animals than in humans. The medullary index (M.I.) is a measure of the relative thickness and is determined by dividing the diameter (thickness) of the medulla by the diameter of the hair and multiplying by 100 (see Figure 5.8). Because the M.I. is a ratio between the two measurements, the units do not matter as long as they are consistent. Animal hair usually has an M.I. of more than 33. Measure or estimate the M.I. of your hair and that of at least three different animal hairs.

Record all observations, measurements, and calculations on the structure of your hair.

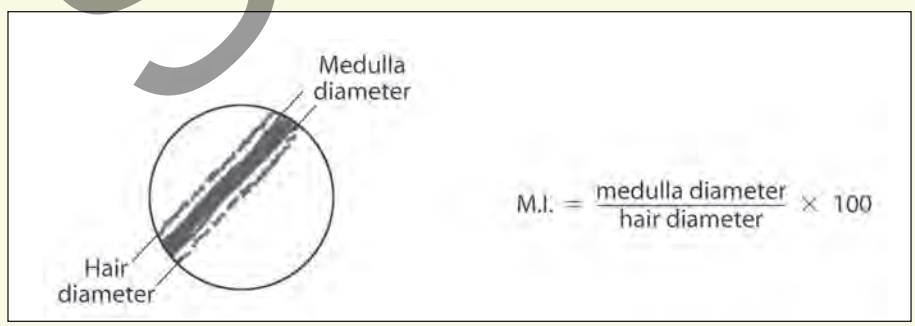
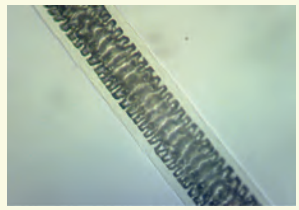


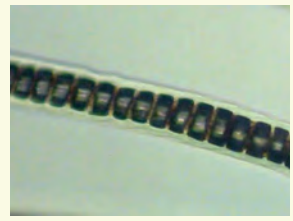
Figure 5.8 Medullary index calculation

(continued)

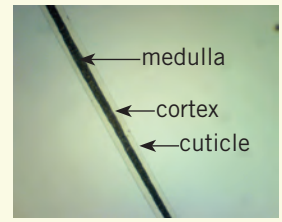
LAB ACTIVITY 5.2: Microscopic Examination (*continued*)



Cat hair,
M.I. = 85



Rabbit hair,
M.I. = 71



Raccoon hair,
M.I. = 35

Analysis Questions

1. Does your root have a bulb? Is there tissue attached to it?
   Answers will vary.
2. Does the diameter of your hair change along its length?
   Answers will vary.
3. Give a description of your cuticle and that of the three animal hairs you chose.
   Answers will vary.
4. Describe what you saw in examining the cortex of your hair.
   Answers will vary.
5. What is the medullary index (M.I.) of your hair? What is the M.I. of the three animals you chose?
   Answers will vary.
6. Explain how a forensic scientist would determine if a hair is human or animal.
   Answers will vary.

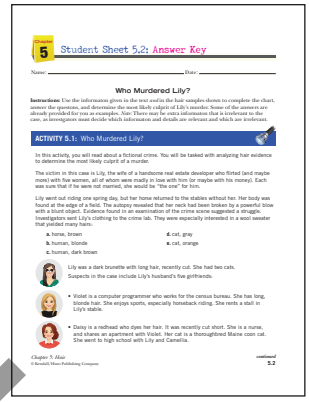
ACTIVITY 5.1: Who Murdered Lily?

Time: 1 class period

In this activity, students will apply the knowledge they have learned about hair analysis to try to narrow down the field of suspects in a crime. Students may work independently or in pairs to read the activity and answer the questions.

Student Sheets

- Student Sheet 5.2 *(Who Murdered Lily?)*


5 Student Sheet 5.2: Answer Key

Name: _____ Date: _____

Who Murdered Lily?

Instructions: Use the information given in the text and in the hair samples shown to complete the chart, answer the questions, and determine the most likely culprit of Lily's murder. Some of the answers are already provided for you as examples. *Note:* There may be extra information that is irrelevant to the case, as investigators must decide which information and details are relevant and which are irrelevant.

ACTIVITY 5.1: Who Murdered Lily?

In this activity, you will read about a fictional crime. You will be tasked with analyzing hair evidence to determine the most likely culprit of a murder.

The victim in this case is Lily, the wife of a handsome real estate developer who flirted (and maybe more) with five women, all of whom were madly in love with him (or maybe with his money). Each was sure that if he were not married, she would be "the one" for him.

Lily went out riding one spring day, but her horse returned to the stables without her. Her body was found at the edge of a field. The autopsy revealed that her neck had been broken by a powerful blow with a blunt object. Evidence found in an examination of the crime scene suggested a struggle. Investigators sent Lily's clothing to the crime lab. They were especially interested in a wool sweater that yielded many hairs:

a. horse, brown
b. human, blonde
c. human, dark brown
d. cat, gray
e. cat, orange

Lily was a dark brunette with long hair, recently cut. She had two cats.

Suspects in the case include Lily's husband's five girlfriends:

- Violet is a computer programmer who works for the census bureau. She has long, blonde hair. She enjoys sports, especially horseback riding. She rents a stall in Lily's stable.
- Daisy is a redhead who dyes her hair. It was recently cut short. She is a nurse, and shares an apartment with Violet. Her cat is a thoroughbred Maine coon cat. She went to high school with Lily and Camellia.

Chapter 5: Hair
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continued
5.2

Teacher Tip

Print and distribute **Student Sheet 5.2** ***(Who Murdered Lily?)*** to guide students through this activity. The students will complete a grid of information using the known facts and hair samples given. The evidence and probing questions provided should lead them to a conclusion of the most likely culprit. Some of the information included in the text is not relevant, but let the students figure that out. **Student Sheet 5.2: Answer Key** ***(Who Murdered Lily?)*** provides the answers.

Student Instructions

In this activity, you will read about a fictional crime. You will be tasked with analyzing hair evidence to determine the most likely culprit of a murder.

The victim in this case is Lily, the wife of a handsome real estate developer who flirted (and maybe more) with five women, all of whom were madly in love with him (or maybe with his money). Each was sure that if he were not married, she would be "the one" for him.

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Lily was a dark brunette with long hair, recently cut. She had two cats.

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- Violet is a computer programmer who works for the census bureau. She has long, blonde hair. She enjoys sports, especially horseback riding. She rents a stall in Lily's stable.

- Daisy is a redhead who dyes her hair. It was recently cut short. She is a nurse, and shares an apartment with Violet. Her cat is a thoroughbred Maine coon cat. She went to high school with Lily and Camellia.

(continued)

ACTIVITY 5.1: Who Murdered Lily? (*continued*)

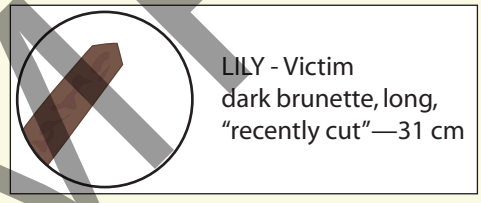
- Rose has long, kinky, dark brown hair. She lives with her golden retriever and keeps pretty much to herself. She is one of Lily's neighbors.

- Iris works for Lily's husband. She claims to be a natural blonde, and she very recently got her hair cut short a few days before Lily's murder.

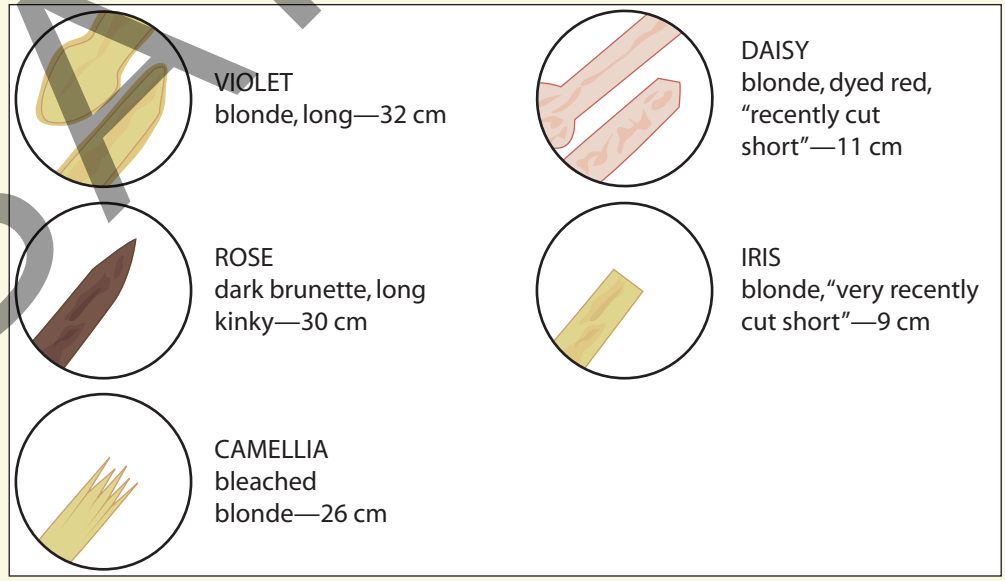
- Camellia is also a blonde who bleaches her hair, which causes split ends. She works as a real estate agent, which is how she met Lily's husband.

Drawings from a microscopic examination of the control and unknown hairs are shown in Figure 5.9. Be sure to notice whether the samples show the hair tip, root, or both.

A. Known Hair Sample from Victim



B. Known Hair Samples from Suspects



C. Unknown Hair Samples from Victim's Sweater

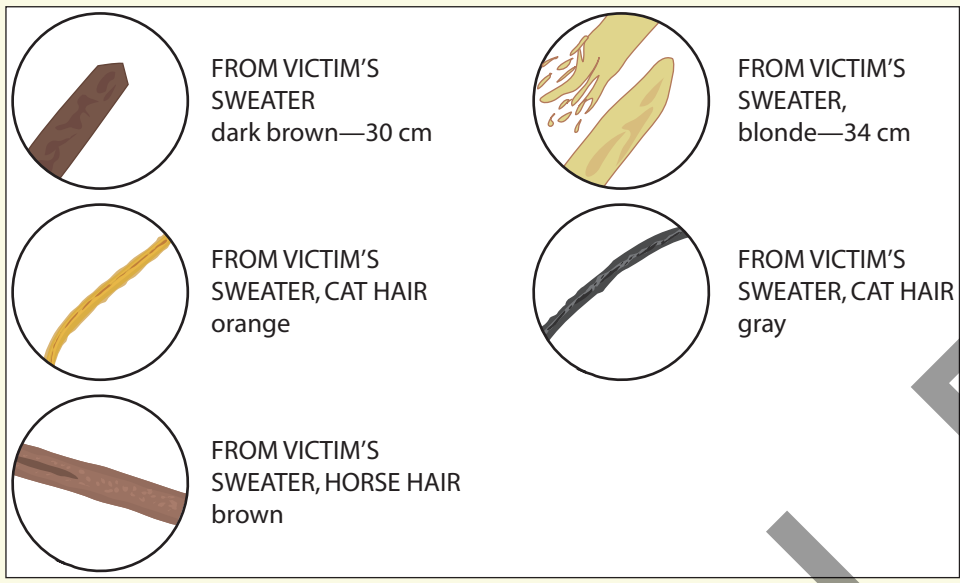
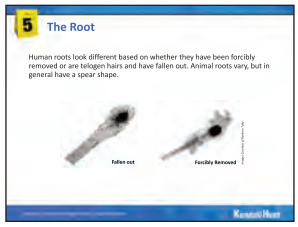


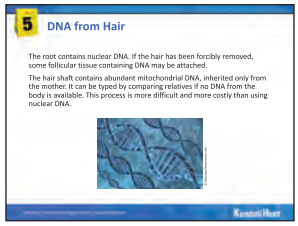
Figure 5.9 Hair from the victim, suspects, and crime scene

Analysis Questions

1. What motive do all of the women share as a possible reason to have murdered Lily?
   They were having an afair with Lily's husband and wanted her out of the picture.
2. Based on the hair evidence alone, are there any women that can likely be ruled out as suspects?
   Iris and Camellia can likely be ruled out, as neither their hair nor any animal hair that is connected to them was found at the crime scene. Though it can't be seen in the sample provided, it is stated earlier that Rose has kinky hair, while Lily has straight hair. This would mean that the hair samples found on the purse would not match and Rose could also likely be ruled out.
3. Based on the hair evidence alone, which women should still be considered suspects?
   Violet and Daisy are the most likely suspects, based on the hair evidence found. Both women have animal hair at the scene possibly linking them to the crime. The human hair found at the scene is possibly matched to Violet.
4. Which woman do you think is most likely to have committed the murder? Explain, using evidence to back up your answer.
   Violet is the most likely to have commited the murder based on the evidence. A human hair sample that seems to match her hair was found on Lily's sweater, and there is also horse and cat hair evidence that may link her to the scene, too.

5. What additional hair evidence and information should be gathered to build a stronger case?
Additonal hair samples from Lily's horse, Violet's horse, Daisy's cat, and Lily's two cats are needed to determine which animals the hairs on Lily's sweater came from. Then, it can be determined whether the animal hair connects any of the women to the crime scene. Investigators should also confirm for how long Daisy has dyed her naturally blonde hair red. They should also confirm when her "recent" hair cut occurred—was it before or after Lily's murder? The answers to these questions could either rule her out or make her a prime suspect.





The Value of Hair as Evidence

Slides

Consider displaying these slides as students read about hair as evidence.

CASE STUDY 5.1
Colin Ross

For the full case study, see the student text.

Analysis Questions

1. Had the Colin Ross case occurred within the last decade or so, what test(s) could have been performed to determine guilt or innocence?
Comparing DNA from the root of the hair found on Ross's blanket to that of the victim

2. Should a prosecutor, judge or jury be able to convict on hair evidence alone? Why or why not?
Answers will vary. The Innocence Project provides a number of these cases on its website.

Hair as a Chemical Indicator

Background Note

In the late 18th century arsenic was commonly used as a "cure-all" medicine. It was used to preserve food and appeared as a key ingredient to produce bright colors of green in pigments (paint). Some researchers believe that the wallpaper on the walls of the home where Napoleon lived at the end of his life contained this arsenic-laced pigment. Others argue that arsenic was a common element in so many products (including face powder, which Napoleon likely applied for clearer skin) that Napoleon and others of the time period used. They contend that his continued exposure to arsenic over his lifetime likely contributed to his ill health and death.

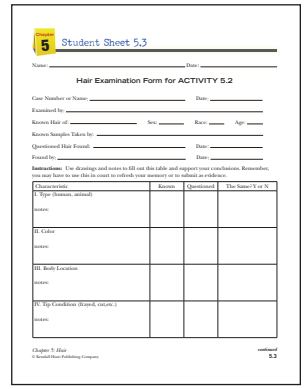
ACTIVITY 5.2: Hair Analysis

Time: 1 class periods

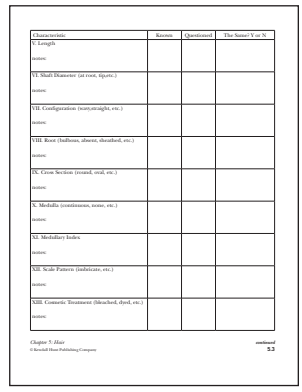
Students may work in small groups to read the activity and answer the questions.

Student Sheets

Student Sheet 5.3 *(Hair Examination Form for ACTIVITY 5.2)*


Student Sheet 5.3

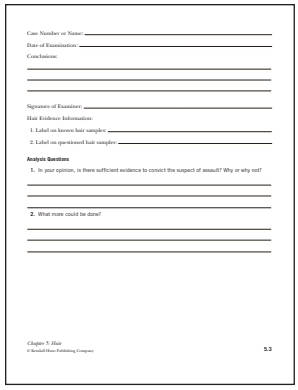
Hair Examination Form for ACTIVITY 5.2



Advance Preparation

Before this activity, collect hair samples from three people: one from the suspect (known), one from the purse (questioned), and one from the victim (known). The one on the purse should be forcibly removed. Then you can set up the outcome any way you want. The questioned hair can match the known hair, and you have possibly identified the perpetrator. Or, if it doesn't match, you hope the students will ask for the victim's hair to compare to the known hair. Other evidence to look for might include blood or skin on the purse. The hair evidence alone is probably not enough to convict, however it could support her ID of the perp.

Print and distribute **Student Sheet 5.3** ***(Hair Examination Form for Activity 5.2)*** from the *Online Teacher Resources* for students to record their findings of the following characteristics: type (animal or human), color, body location (maybe), tip condition, length, shaft diameter, configuration (kinky, straight, curly), root, pigment density and distribution (maybe), medulla, cuticle scale pattern, cortical fusi abundance (maybe), and cosmetic treatment.



Case Number or Name: _____
Date of Examination: _____
Conclusion:
_____
_____
_____
Signature of Examiner: _____
Hair Evidence Information:
1. Label on known hair sample: _____
2. Label on questioned hair sample: _____
Analysis Questions
1. In your opinion, is there sufficient evidence to convict the suspect of assault? Why or why not?
_____
_____
_____
2. What more could be done?
_____
_____
_____
Chapter 5: *Hair*
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5.3

Student Instructions

In this activity, you will analyze hair samples to help solve a crime.

A woman was attacked one evening on her way home from work. She swung her purse at the attacker, hitting him hard in the head. He fled. Later she was able to identify him from a police lineup. Police examined the purse and found some hair. The following samples were submitted to the crime lab for analysis:

Known/exemplar: suspect's hair

Known/exemplar: victim's hair

Unknown/questioned: hair from purse

Compare the unknown (questioned) hair with the known (exemplar) hair. Use the handout from your teacher to record your findings.

Analysis Questions

1. In your opinion, is there sufficient evidence to convict the suspect of assault? Why or why not?
   Answers will vary.
2. What more could be done?
   Answers will vary.

Career Connection: Forensic Hair Specialist

Other possible careers that are related to a forensic hair specialist include forensic hair analyst, forensic chemistry, forensic biology, trace evidence examiner, microbiologist, microscopist, and law enforcement.

Optional: You may want to assign students the task of choosing one career and researching it to find out more. Provide opportunities for students to share their findings.

Checkpoint Questions

1. What characteristics make hair a useful forensic tool?
   The body is constantly losing hair, more so in violent situations. Hair is persistent; it catches on and clings to clothing, rugs, dust balls, and the like. Hair is resistant to chemical and biological degradation. It absorbs chemicals ingested by the source.

2. Is hair considered class or individual evidence? Why?
   class evidence because each person's hairs may have many different characteristics, and there may be similarities between individuals

3. What is meant by the "morphology" of hair?
   structural characteristics

4. What is the medullary index (M.I.) of the polar bear hair shown in the text section "The Form and Structure of Hair"? Could such hair be confused with human hair? If so, how could it definitely be differentiated from human?
   The polar bear hair has an M.I. of 30. Usually animal hair has an M.I. greater than 33, so this could be construed as human; it can be differentiated by the cuticle.

5. How many hairs fall out during an average day?
   100

6. Where is the medulla found, and what might it look like?
   The medulla is found on the interior of the hair; it may be continuous, fragmented, or absent.

7. Where is the cuticle found, and what might it look like?
   The cuticle is found on the outside of the hair shaft; it has a scale pattern.

8. Where in the hair are pigment granules found?
   in the cortex

9. If the cross section of a hair is found to be oval in shape, would you expect the hair to be straight, curly, or kinky?
   curly

10. What is meant by the anagen phase, and how long does it last?
    The anagen phase is the active growth stage that lasts up to five years.

11. At any given time, approximately how many hairs are found to be in the anagen phase?
    80–90 percent

Checkpoint Questions

12. What is the telogen phase, and how long does it typically last?
The follicle gets the hair ready to fall out; this phase lasts from two to six months.

13. What are a few advantages of using hair for drug testing over blood and urine tests?
Hair is very durable. It will last a long time, and it can give a history or timeline of drug use or poisoning.

14. Name a disadvantage of using hair for drug testing.
Hair may pick up environmental pollutants, giving false positives, or a person may cut his or her hair, removing the evidence.

15. How would you decide approximately how long ago a hair sample was dyed?
Measure the distance from the line where the dye begins to the root and divide by the growth rate of 1 cm per month.

16. If you were asked whether a particular hair sample were human or animal, what would you look for? Explain, using words and diagrams.
The investigator would primarily study the medullary index; he or she would also examine the cuticle, thickness, and color banding.

17. If you were asked to compare an unknown (questioned) sample to a known sample of human hair to match or identify origin, what would you look for? Would your observations give conclusive evidence? Explain, using words and drawings.
The investigator would look at the length, color, tip condition, diameter, configuration, cross section, medulla type, and any cosmetic treatment.

18. What fibers can also be considered hair?
Fibers that are also hair include wool, mohair, cashmere, and, more rarely, llama, alpaca, and camel.

Additional Activities

1. Treat hair samples with a variety of dyes and note changes in morphology. You will be able to compare them more easily by dipping only part of the hair strands into the dye. Also try Grecian Formula, depilatories, and other products that are used on hair. Are there distinctive characteristics to use as class evidence? As individual evidence?
   Answers will vary.

2. Note daily changes in the tips of your hair from when they are freshly cut to three or four weeks later.
   Tip should change from flat to rounded. Dull scissors can cause fraying.

3. Invent a test to measure the effects of weathering (specifically, ultraviolet radiation) on hair. What makes hair eventually decompose?
   Tape hair on a board and expose it directly to sunlight (not through a window). Cover a portion with paper or plastic; this will be the control. You can repeat exposure through window glass, in a hot area, or under an infrared bulb. What happens in a microwave?

4. Investigate the legal aspects of taking a hair sample from a suspect, as you did in identifying issues around fingerprinting. Is taking a suspect's hair a violation of the Fifth Amendment?
   Answers will vary with the degree of searching. Students should review both sides and offer an opinion.

5. Research the effect of hair treatment (including dyeing, bleaching, washing, and the like) on the detection of drugs and poisons.
   Answers will vary with the degree of searching.

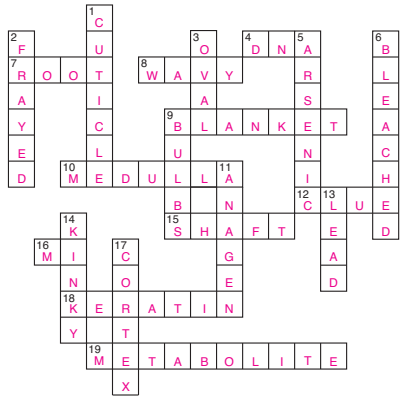
6. Review articles written about the use of hair analysis for medical diagnosis or in environmental chemistry.
   Answers will vary with the degree of searching.

7. Investigate the Colin Ross case and his alleged innocence. What do you think?
   Answers will vary.

8. There are many cases over the years where someone was convicted on hair evidence, only to be exonerated later by DNA testing. Research and report on one of these cases.
Answers will vary. The Innocence Project provides a number of these cases on its website.

Chapter 5 Student Sheet 5.4: Answer Key

Crossword Puzzle



ACROSS

4 found in hair root
7 the part of the hair in the follicle
8 a hair configuration
9 key to solving the Ross case
10 the inner portion of a hair
12 possible evidence
15 hair from epidermis to top
16 important property of animal hairs
18 protein polymer common to hair
19 chemical by-product in the body

DOWN

1 tough outer layer of hair shaft
2 a tip condition
3 a cross section
5 found in Napoleon's hair
6 cosmetic treatment
9 telogen hair ends
11 commonest stage of hair growth
13 possible cause of deafness
14 a hair configuration
17 that part of a hair containing fusi

Teacher Tip

Now is a good time to assess your students' learning by having them complete **Student Sheet 5.4** ***(Crossword Puzzle)***, which can be found in the Online Teacher Resources to print and distribute to students. **Student Sheet 5.4: Answer Key** ***(Crossword Puzzle)*** provides the answers.

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www.ojp.gov/ncjrs/virtual-library/abstracts/microscopy-hair-part-ii-practical-guide-and-manual-animal-hairs; Microscopy of Hair, Part II: A Practical Guide and Manual for Animal Hairs

www.keratin.com/; everything you ever wanted to know about the biology of hair and then some