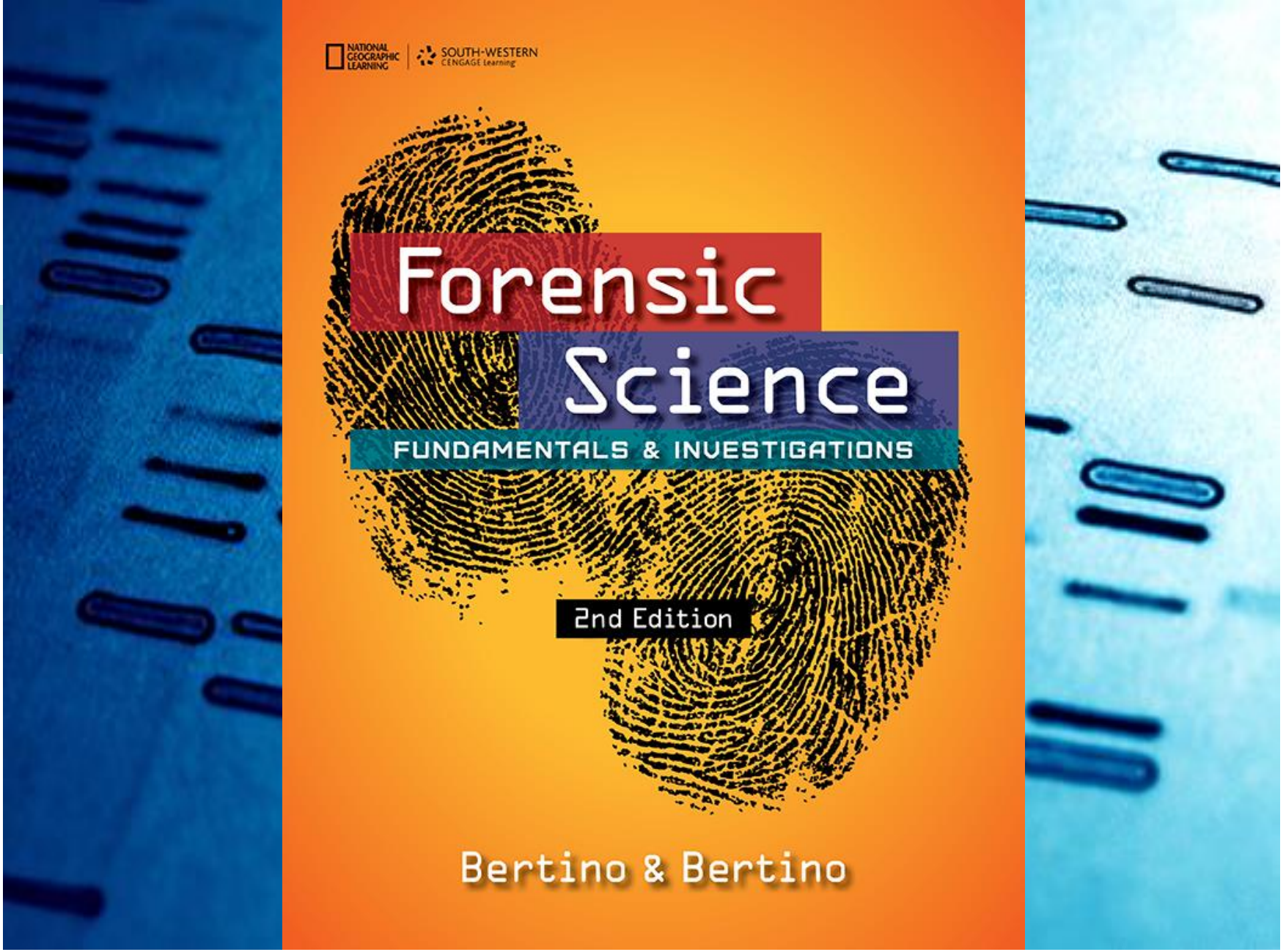


Unit 3 Section 1 *Hair Analysis*

By the end of this unit you will be able to:

3.1 Identify the various parts of a hair.

3.2 Describe variations in the structure of the medulla, cortex, and cuticle.

3.3 Distinguish between human and nonhuman animal hair.

3.4 Determine if two examples of hair are likely to be from the same person.

Unit 3 Section 1 *Hair Analysis*

By the end of this unit you will be able to:

3.5 Explain how hair can be used in a forensic investigation.

3.6 Calculate the medullary index for a hair.

3.7 Distinguish hairs from individuals belonging to broad racial categories.

Unit 3 Section 2 *A Study of Fibers and Textiles*

By the end of this chapter you will be able to:

3.8 Identify and describe common weave patterns of textile samples.

3.9 Compare and contrast various types of fibers through physical and chemical analysis.

3.10 Describe principal characteristics of common fibers used in their identification.

3.11 Apply forensic science techniques to analyze fibers.

Unit 3 Hair
Vocabulary

- comparison microscope
- cortex
- cuticle
- gas chromatography
- hair follicle
- hair shaft
- keratin
- medulla
- melanin granules
- mitochondrial DNA (mtDNA)
- nuclear DNA

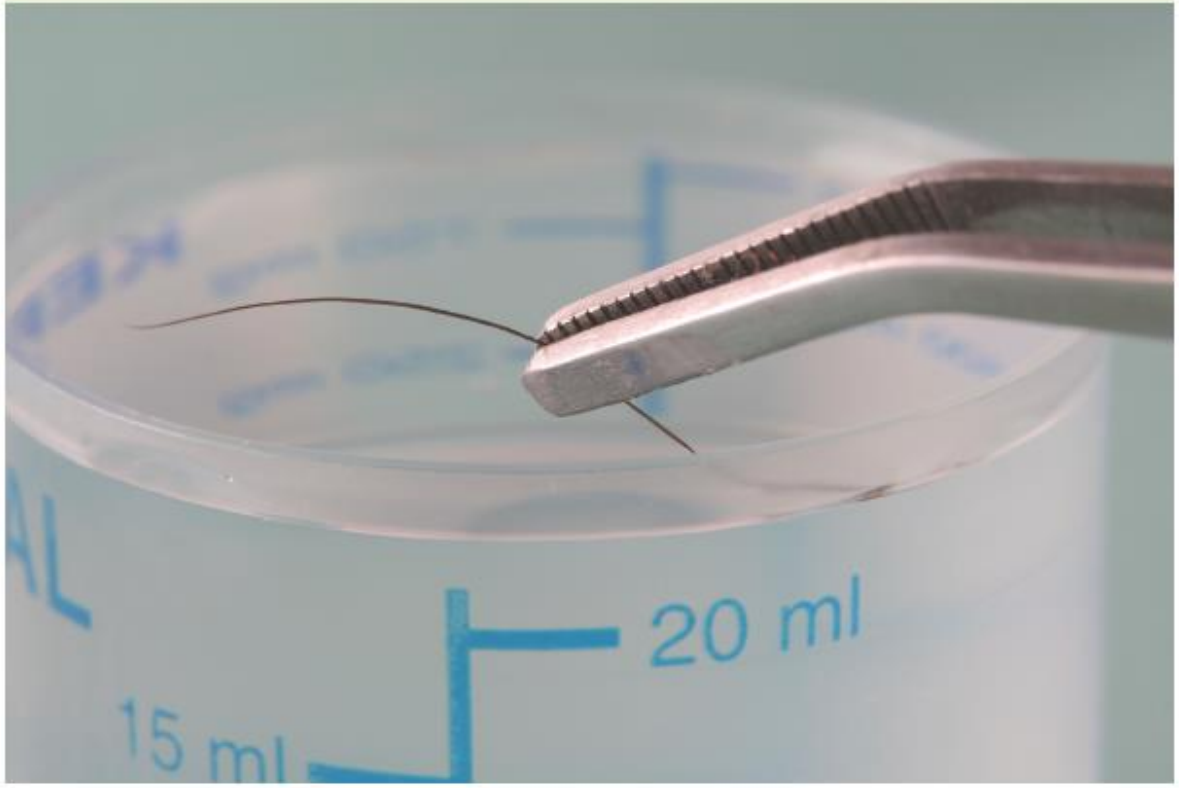
Unit 3 Fiber
Vocabulary

- Amorphous
- crystalline
- direct transfer
- fiber
- mineral fiber
- monomer
- natural fiber
- polymer
- synthetic fiber
- secondary transfer
- textile
- warp
- weft
- yard (thread)

Introduction

- **A hair without the follicle and its nuclear DNA cannot provide individual evidence.**
- **Hair can yield class evidence.**
- **Chemical tests performed on hair can reveal drugs, toxins, heavy metals and nutritional deficiencies.**
- mtDNA from hair can reveal some of a suspect's or victim's family relationships.

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



Ldf/Thinkstock/Getty Images

History of Hair Analysis

- 1883: Alfred Swaine Taylor and Thomas Stevenson covered hair in a forensic science text.
- 1910: Victor Balthazard and Marcelle Lambert published a comprehensive study of hair.
- 1934: Dr. Sydney Smith, analyzed hairs side by side using a comparison microscope.
- Today: Standard procedures of hair analysis include microscopic examination and DNA analysis.

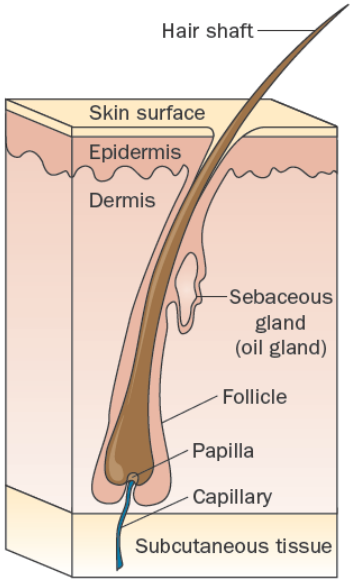
The Functions of Hair

- Regulates body temperature
- Decreases friction
- Protects against sunlight
- Acts as a sense organ
- Humans are born with about 5 million hair follicles.

The Structure of Human Hair

- Human hair consists of a 1) follicle and a 2) shaft.

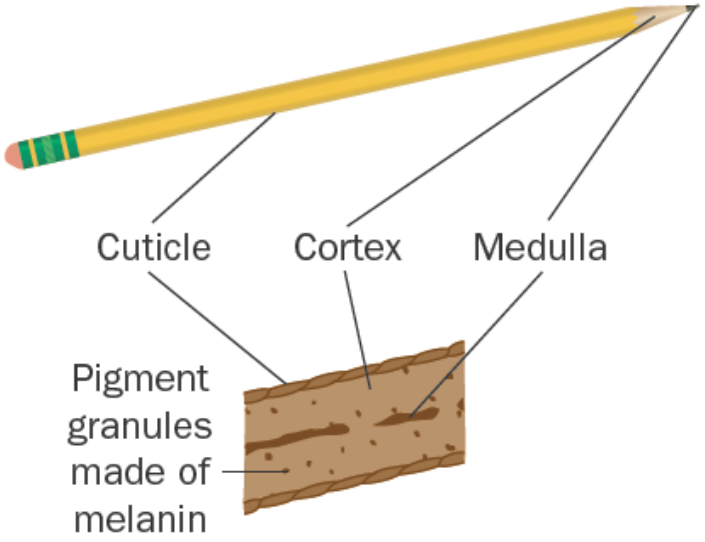
Figure 3-2 *This cross section shows a hair shaft in a hair follicle. If the follicle of the hair is present in evidence, nuclear DNA may be extracted, amplified, and analyzed for use as individual evidence. If no follicle is present, mitochondrial DNA or other characteristics may be analyzed for use as class evidence for comparison with crime-scene evidence.*



The Structure of Human Hair
(continued)

- The hair shaft is made up of three layers:
  - An inner medulla
  - A cortex
  - An outer cuticle

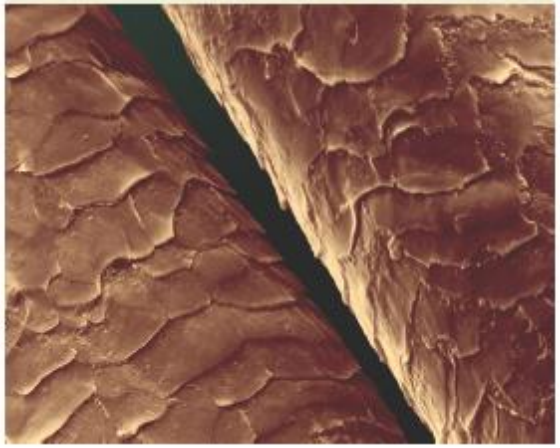
Figure 3-3 *The cross section of a hair shaft is similar to that of a round, wooden pencil.*



The Structure of Human Hair
(continued)

- The **cuticle is a transparent outer layer of the hair shaft**.

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



Dee Breger/Science Source

Types of Medulla

Figure 3-5 *Five different patterns of medulla pigmentation pattern 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	

Types of Hair

- In humans, hair varies from person to person, and even varies depending on its location on a particular person.
- For an individual person, **hair can vary based on its location on the body**.
- To compensate for inconsistencies that occur, **50 hairs are usually collected from a suspect's or victim's head.**

Hair from Different Parts of the Body

Figure 3-7 *The physical characteristics of a hair provide information about which part of the body it came from.*

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

Pubic hair showing buckling.

Beard hair with double medulla.

Arm or leg hair with blunt, frayed end.

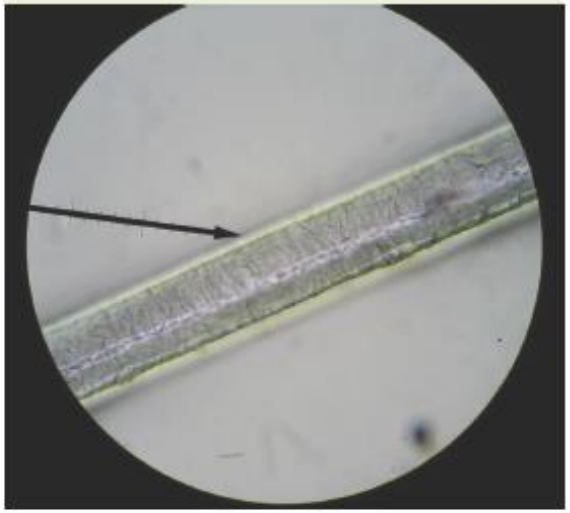
The Life Cycle of Hair

- Hair proceeds through three stages as it develops.
  - Anagen stage – growth and development
  - Lasts approximately 1000 days
- Catagen stage
  - The hair stops growing and the follicle recedes.
- Telogen stage
  - The hair follicle is dormant and hair is easily lost.

Treated Hair

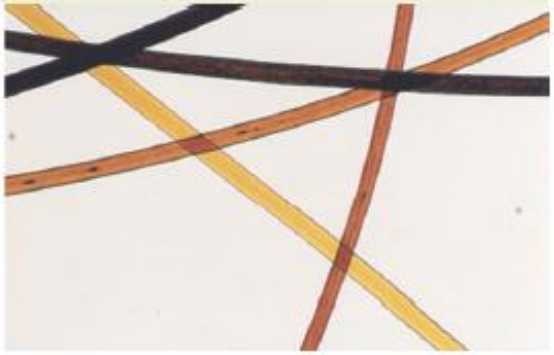
- Hair can be treated in many different ways.

Figure 3-8 *Bleached hair lacks pigment in the cortex and cuticle.*



© Cengage Learning®

Figure 3-9 *Examples of dyed human hair. Notice the dye stains the entire hair, including the cuticle and cortex.*

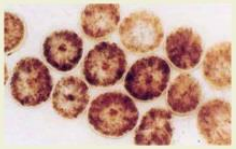
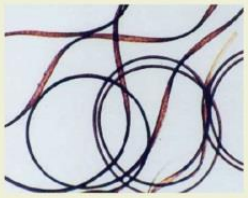


FBI; photos by Sandra Koch & Douglas W. Deedric

Ethnic or Ancestral Differences

- There are some key physical characteristics that are associated with hair of different ancestral groups.

Figure 3-10 *A comparison of general characteristics of hair from people of different ancestries.*

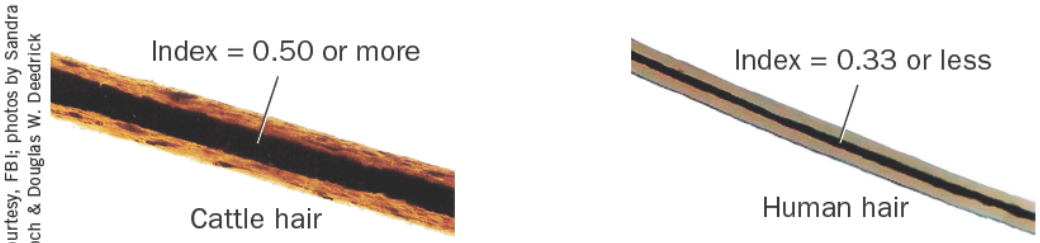
Ancestry	Appearance	Pigment Granules	Cross Section	Other
European	Generally straight or wavy 	Small and evenly distributed	Oval or round of moderate diameter with minimal variation 	Color may be blond, red, brown, or black
Asian	Straight 	Densely distributed	Round with large diameter 	Shaft tends to be coarse and straight; thick cuticle; continuous medulla; color black
African	Kinky, curly, or coiled; shaft may be buckled 	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. Deedrick

Animal hair and Human Hair

- Animal hair and human hair have several differences including:
  - The pattern of pigmentation
  - The **medullary index** – width of medulla divided by the width of the entire hair.
  - The cuticle type

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

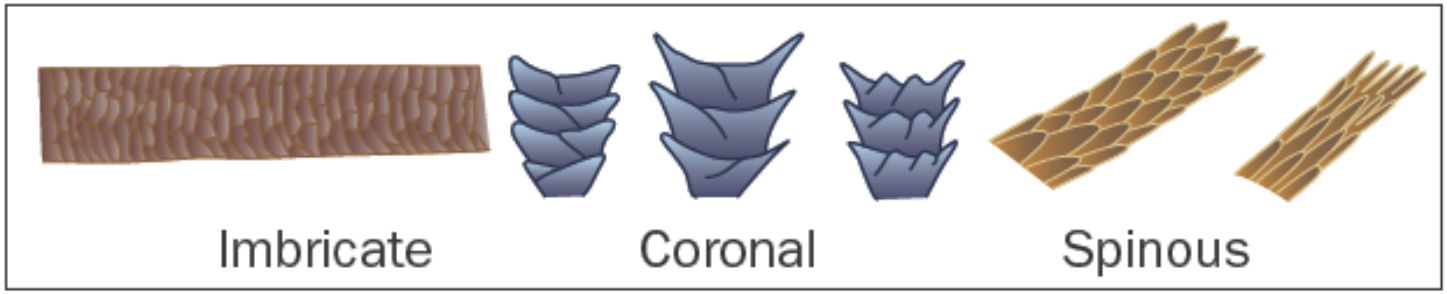


Courtesy, FBI; photos by Sandra Koch & Douglas W. Deedrick

Hair Cuticles

- The cuticle of the hair shaft can help distinguish human hair from other animal hair.

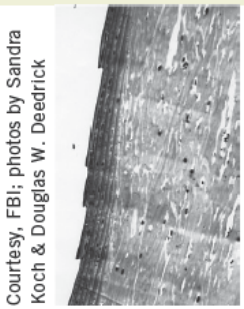
Figure 3-12 *Imbricate (human), coronal (mouse), and spinous (cat) cuticles.*



Electron Microscopes

- Electron microscopes direct a beam of electrons at a sample.
- Electron microscopes provide magnification of 50,000 times or more.

Figure 3-14 *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. Deedrick

Hair Examination and Testing

- DNA is extracted and amplified using PCR.
- DNA is profiled using an automated process.
- **mtDNA (mitochondrial DNA) can be used to establish a genetic relationship through the mother**.
- Suspects can be excluded if their mtDNA is not consistent with the crime-scene mtDNA.

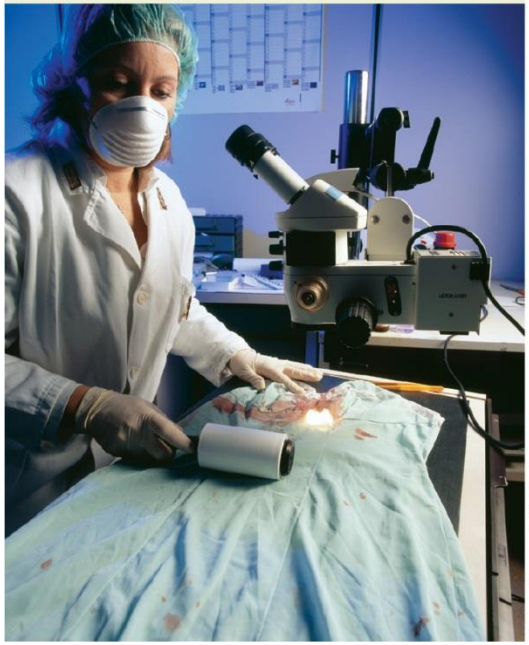
Section 2 Fibers - Introduction

- Fibers are used in forensic science to create a link between crime and suspect.
- Fibers are not specific to a single person.
- Fibers are a form of trace evidence.
  - Direct transfer – from victim to suspect or vice versa.
  - Secondary transfer – from a source (such as carpet) to a person, then to another person.
- Collecting fibers within 24 hours is critical.

Collecting, Sampling, and Testing Fiber Evidence

- Fiber evidence is collected using tape, forceps, a vacuum, or a sticky lint roller.

Figure 4-2 *Collecting fiber evidence.*



Mauro Fermariello/Science Source

Evaluating Fiber Evidence

- The value of fiber evidence in a crime investigation depends on its **potential uniqueness**.
  - Type of fiber
  - Fiber color
  - Number of fibers found
  - Where the fiber was found
  - Textile from which the fiber originated
  - Multiple fiber transfers
  - Type of crime committed
  - Time between crime and discovery of fiber

Fiber and Textile Evidence

- Fiber Classification – 2 types of fibers
  - **Natural Fibers**
  - **Synthetic (Manufactured) Fibers**

Natural Fibers

- **Natural fibers come from animals, plants, and minerals** that are mined from the ground.
- Fibers are composed of polymers, or long, repeating molecules.

Animal Fibers

- Three sources of animal fibers are hair, fur, and webbing.
- All animal fibers are made of **proteins**.

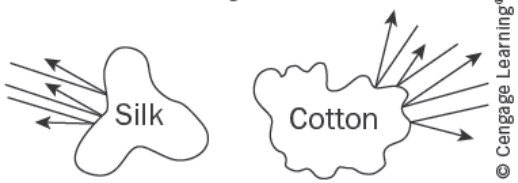
Figure 4-4 *Wool fibers can be spun on spinning wheels like this to make yarns.*

Figure 4-5 *Silk cocoons.*

Plant Fibers

- **All plant fibers share the column polymer cellulose.**
- Cellulose is made up of simple glucose units.
- **Proteins and cellulose have very different chemical and physical properties that allow a forensic scientist to tell animal and plant fibers apart.**

Figure 4-6 *Cross-section of cotton and silk fibers.*



Natural Fibers (continued)

- Seed fibers
  - **Cotton** is found in the seed pod of the cotton plant.
  - It is used extensively for clothing and household textiles.
- Leaf fibers
  - Manila – from Manila hemp, used for papers
  - Sisal - from leaves, used for rope and twine

Natural Fibers (continued)

- Fruit fibers
  - Coir fiber is obtained from coconuts
    - It is relatively waterproof.

Figure 4-7 *Coir fibers are often used in things like floor mats because they are so durable.*

Susan Van Etten

- Stem fibers
  - Flax, jute, and hemp are all produced from the thick region of plant stems.

Figure 4-8 *The rough fibers of jute are made into rope and twine.*

© eleana/Shutterstock.com

Natural Fibers (continued)

- Mineral fibers
  - Neither proteins nor cellulose
  - May not even be long, repeating polymers
  - Although it is very durable, because of its health risks, asbestos is no longer commonly used.

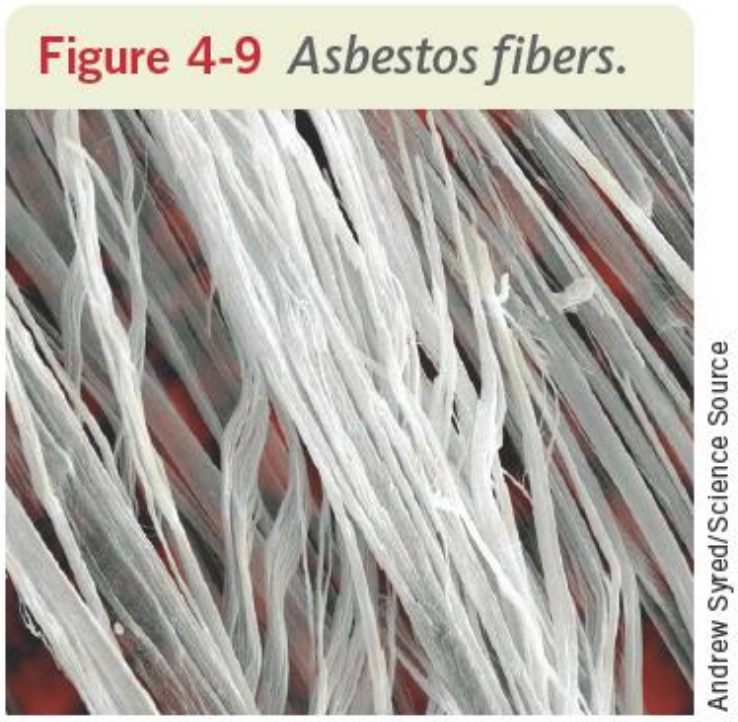


Figure 4-9 *Asbestos fibers.*

Andrew Syred/Science Source

Synthetic (Manufactured) Fibers

- Half of the fabrics produced today are synthetic fibers.
  - The fibers are produced by joining many monomers together to form polymers.
  - Rayon, acetate, nylon, acrylics, and polyesters

Comparison of Natural and Synthetic Fibers

- **Synthetic fibers are stronger** than the strongest natural fibers.
- Manufactured fibers are not damaged by microorganisms.
- Manufactured fibers **can deteriorate in bright sunlight** and **melt at a lower temperature** than natural fibers.

Yarns

- Fibers too short in their raw state to be used to make textiles may be spun together to make yarns.
- Very thin yarns are often called **threads**.
- For identification purposes, forensic scientists **analyze twist direction** of yarn.

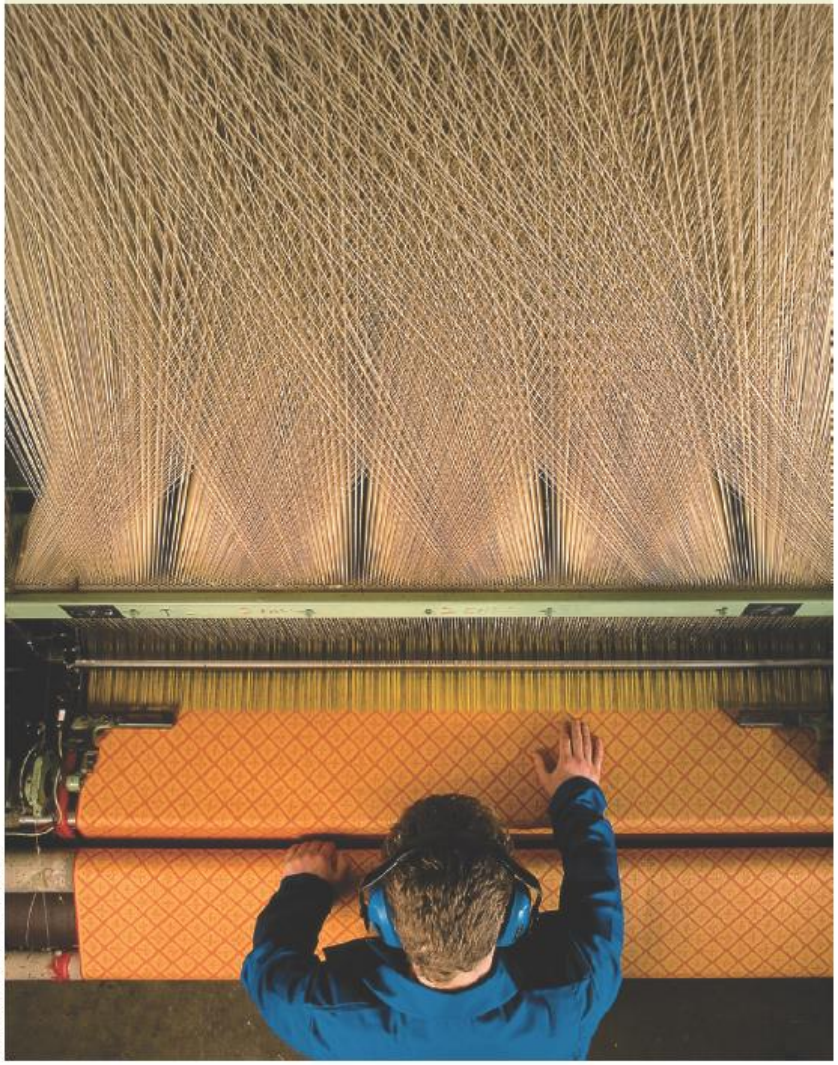
Figure 4-11 *Descriptions of some common fibers.*

Descriptions of Fibers				
Fiber	**Source**	**Characteristics**	**Composition**	**Uses**
Cotton	Plant (seed)	Flattened hose appearance; up to 2 inches long, tapers to point; may have frayed root; twist to fiber; hollow core not always visible; smells of burning leaves; helix-shaped fibers	Cellulose polymer; 19 different amino acids, including cysteine; contains double sulfur bonds; absorbs water but not soluble in water	Many types of textiles
Linen	Plant (flax stem)	Short brittle fibers but longer than cotton; smooth, shiny, resists wear	Cellulose polymer; highly crystalline; resists rot and light damage	Clothing; bed linens; tablecloths
Jute and hemp	Plants (stem)	Dense, strong fiber	Cellulose polymer; highly crystalline, resists rot and light damage	Jute: twine, rope, mats; Hemp: clothing
Manila	Plant leaves (abaca plant)	Long fibers; quickly deteriorates	Cellulose polymer	Garden twine
Wool	Animal (sheep)	Helix-shaped; smells of burning hair when burned	Polymer of keratin with 19 different amino acids; includes amino acid cysteine; contains double sulfur bonds; noted for warmth	Clothing, blankets
Silk	Silkworm cocoon	Triangular fibers; reflects light; glossy appearance	Long fiber	Clothing, bedding
Asbestos	Mineral	Short, weak, brittle	Fiber form of glass	Insulation
Manufactured	Regenerated polymers	Melt at lower temperature than natural fibers	Varied; some made with cellulose; some made with petroleum products	Clothing, bedding, towels, carpets

Textiles

- Weaving consists of arranging **lengthwise threads (the warp)** side-by-side and close together.
- **Cross wise threads (the weft)** are then woven back and forth in one of several different patterns.

Figure 4-12 *An industrial loom used to weave textiles.*

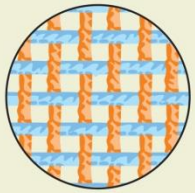
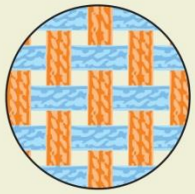
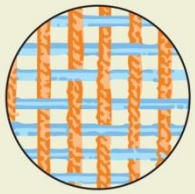
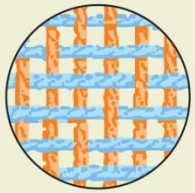
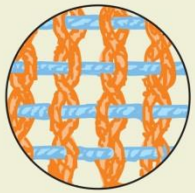


ImageState/Jupiter Images

Textiles (continued)

- The ways that fabrics differ include:
  - Weave pattern
  - Thread count
  - Two ply
- Fiber identification using various microscopes, gas chromatography, and mass spectrometers is possible.
- Fiber identification **provides class evidence only** and **should not be used to convict someone**.

Figure 4-13 *Weave patterns.*

Type of Weave	Diagram	Description	Characteristics
Plain		Alternating warp and weft threads	• Firm and wears well • Snag resistant • Low tear strength • Tends to wrinkle
Basket		Alternating pattern of two weft threads crossing two warp threads	• An open or porous weave • Does not wrinkle • Not very durable • Tends to distort as yarns shift • Shrinks when washed
Satin		One weft crosses over three or more warp threads.	• Not durable • Tends to snag and break during wear • Shiny surface • High light reflectance • Little friction with other garments
Twill		Weft is woven over three or more warps and then under one. In the next row, the pattern is shifted over one to the left or right by one warp thread	• Very strong • Dense and compact • Different faces • Diagonal design on surface • Soft and pliable
Leno		This uses two warp threads and a single weft thread. The two adjacent warp threads cross over each other. The weft travels left to right and is woven between the two warp threads.	• Open weave • Easily distorted with wear and washing • Stretches in one direction only

Summary

- Hair is a form of evidence that has been used in forensic analysis since the late 19th century.
- Hair is a characteristic 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.

Summary (continued)

- The shaft is composed of the protein keratin and consists of the outer cuticle, a cortex, and an inner medulla, most of which can vary within and among individuals and among species. The shaft also has pigments and mitochondrial DNA.
- Hair varies in length, medulla type, and cross-sectional shape, depending on where on the body it originates.
- Hair development is divided into three stages: anagen (growth), catagen (resting), and telogen (dormancy).

Summary

- Fibers are a form of class evidence used by crime-scene investigators; they are a form of trace evidence.
- Fiber evidence may be gathered using tape, forceps, a vacuum, or a sticky lint roller.
- Forensic scientists will try to determine the type of a fiber, its color, how many fibers of each kind were found, where they were found, what textile the fiber came from, and whether there were transfers of multiple types of fibers.
- Fibers may be analyzed using polarized light microscopy, infrared spectroscopy, burn tests, or tests for solubility in different liquids.

Summary (continued)

- Fibers may be classified as natural or synthetic.
- Natural fibers include animal hair; plant fibers from seeds, fruit, stems, or leaves; and mineral fibers.
- Synthetic fibers include regenerated or modified natural fibers as well as synthetic polymer fibers.
- Fibers are spun into yarns that have specific characteristics.
- Yarns are woven, with different weave patterns, into textiles.