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# Forensic Science

FUNDAMENTALS & INVESTIGATIONS

2nd Edition

Bertino & Bertino

- Csi case 2 <http://forensics.rice.edu/>
- Kahoot review <https://play.kahoot.it/#/k/24e5ba4d-5553-44f6-9623-4ac1e4d6ec26>
- FF northern exposure  
<https://www.youtube.com/watch?v=mYtPJoxF0Wk>
- FF conviction overturned with a hair  
<https://www.youtube.com/watch?v=3JjevVi1ycU>
- FF hair of the dog <https://www.youtube.com/watch?v=uTdwo-RMF20>
- FF beaten by a hair  
<https://www.youtube.com/watch?v=0SKDCq4ojd8>





# Chapter 3 *Hair Analysis*

By the end of this chapter 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.



# Chapter 3 *Hair Analysis*

By the end of this chapter 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.



## Chapter 3

# Vocabulary

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

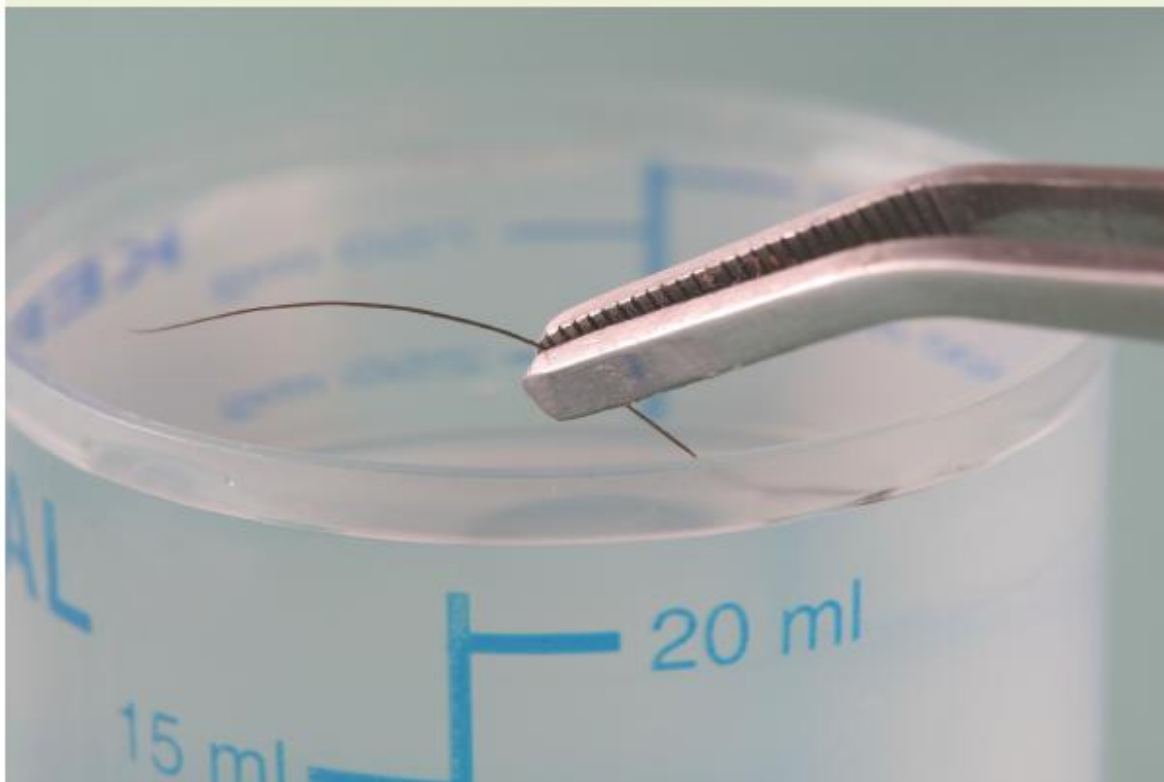


# Introduction

- 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.*



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# 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.



# Biology of Hair

Hair is composed of the protein **keratin**, which is also the primary component of finger and toe **nails**.

Hair is produced from a structure called the hair **follicle**. Humans develop hair follicles during **fetal** development, and no new follicles are produced after birth.

Hair color is mostly the result of **pigments**, which are chemical compounds that reflect certain wavelengths of visible light.



# The Functions of Hair

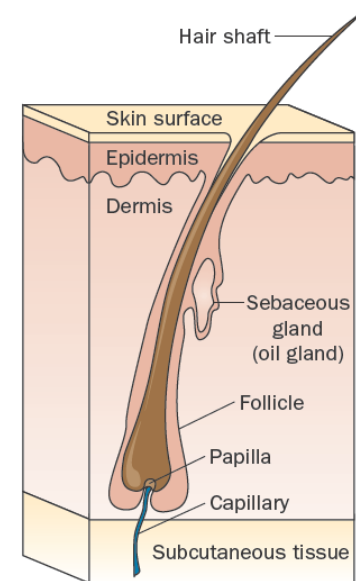
- Regulates body temperature
- Decreases friction
- Protects against sunlight
- Acts as a sense organ
- Humans are born with about 5 million hair follicles.

# The Structure of Human Hair



- Hair consists of (a) a **hair shaft** produced by (b) a **follicle** embedded in the skin.

**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.



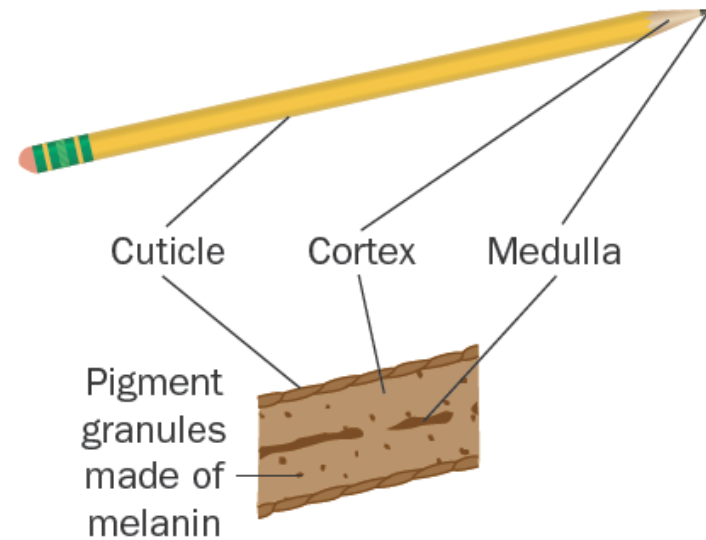
# The Structure of Human Hair

(continued)



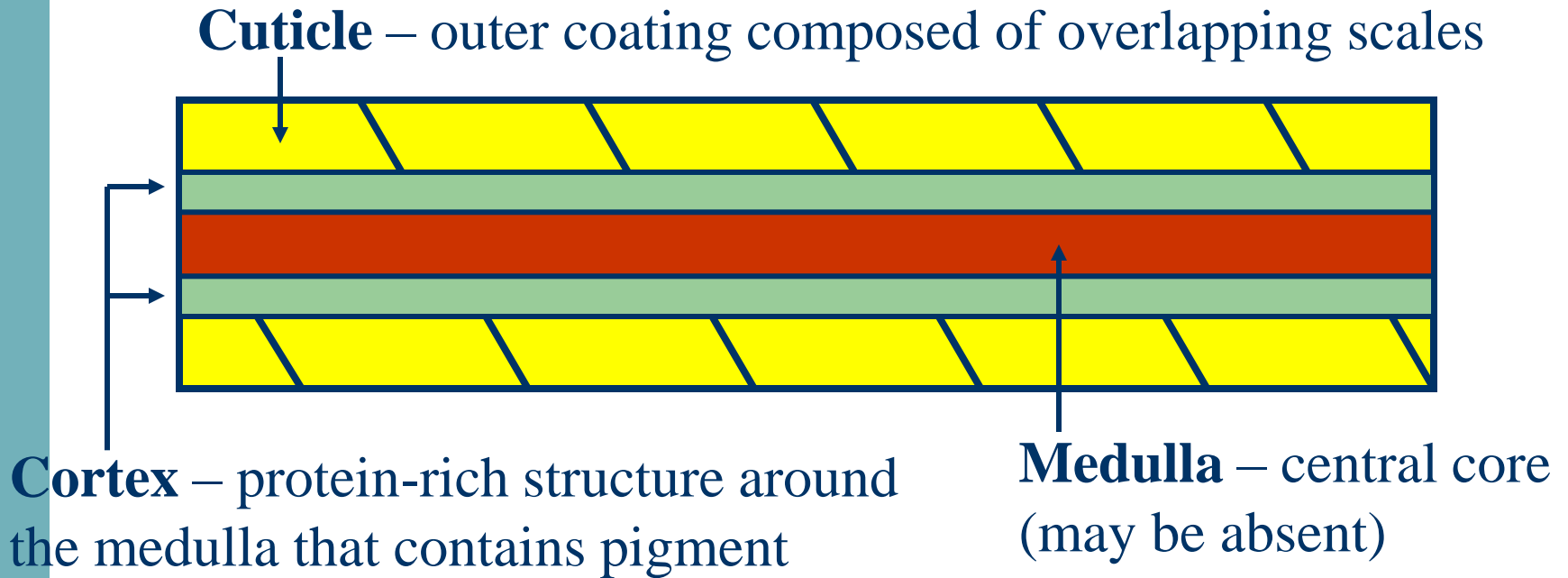
- The hair shaft is made up of three layers:
  - An inner medulla
  - A cortex
  - An outer cuticle

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



# Hair Structure

Hair is composed of three principal parts:



The structure of hair has been compared to that of a **pencil** with the medulla being the **lead**, the cortex being the **wood** and the cuticle being the **paint** on the outside.

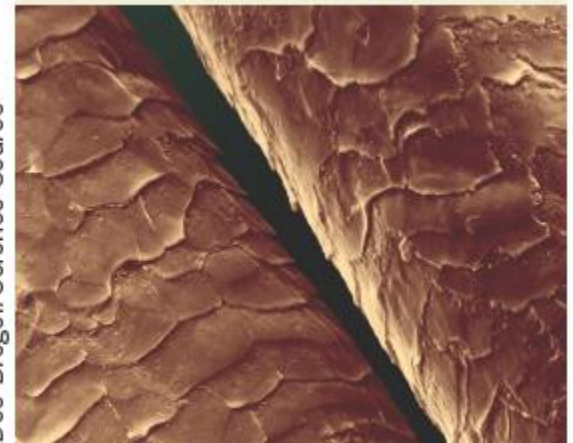
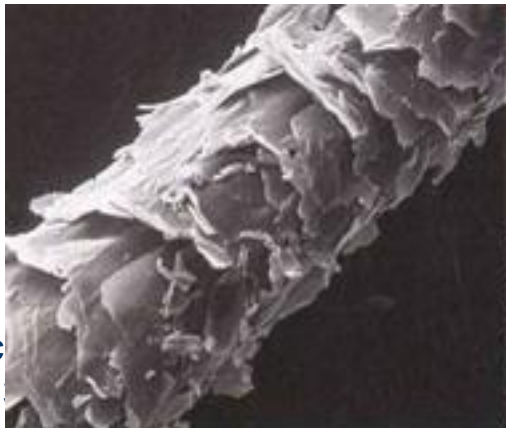
# The Structure of Human Hair

(continued)

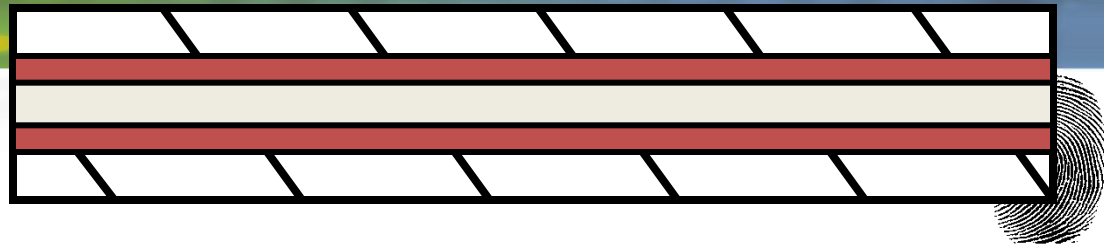


- o The cuticle is a transparent outer layer of the hair shaft
- . The cuticle varies in:
  - Its **scales**
  - Its **thickness**, and
  - Whether or not it contains **pigment**.

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



# Hair Structure



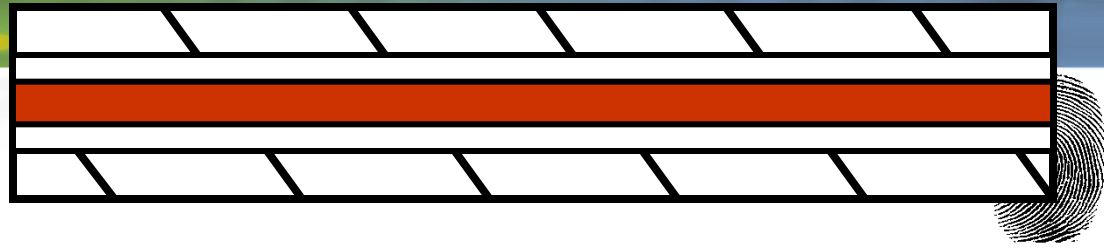
## Cortex

The cortex varies in:

- **Thickness**
- **Color (pigment)**
  - The distribution of pigment in the cortex varies from person to person.
  - Pigment, commonly, is denser nearer the cuticle
- Distribution of the cortex pigment is perhaps the **most important** component in determining from which individual a **human** hair may have come.



# Hair Structure



## Medulla

The medulla may vary in:

- **Thickness**
  - **Continuity** - one continuous structure or broken into pieces
  - **Opacity** - how much light is able to pass through it
- 
- It may also be **absent** in some species.



Figure 3. Light micrographs of three human hairs. The left example illustrates dark hair with a typical fragmentary medulla. The middle hair is blond and has no medulla. The right coarser hair is white with a continuous medulla.



Like the cuticle, the medulla can be important for distinguishing between hairs of different **species**, but often does not lend much important information to the differentiation between hairs from different **people**.





# Types of Medulla

**Figure 3-5** Five different patterns of medulla pigmentation pattern are identified in forensic hair analysis.

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

# Medulla Index— Animals vs. Humans



Index = 0.50 or more



Cattle hair

Index = 0.33 or less



Human hair



# 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.



# Types of Hair



**Buckled**



**Blunt**



**Double Medulla**

- The cross section of a hair can be circular, triangular, irregular, or flattened influencing the curl of the hair.
- The texture of a hair can be coarse or fine.
- Different regions of the body on which hair can vary are (1) head, (2) eyebrows and lashes, (3) mustache and beard, (4) underarms, (5) overall body (auxiliary hair), and (6) pubic.



# 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
  - Hair actively grows
  - 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



Forensic investigators sometimes can link hair from a location with an individual.

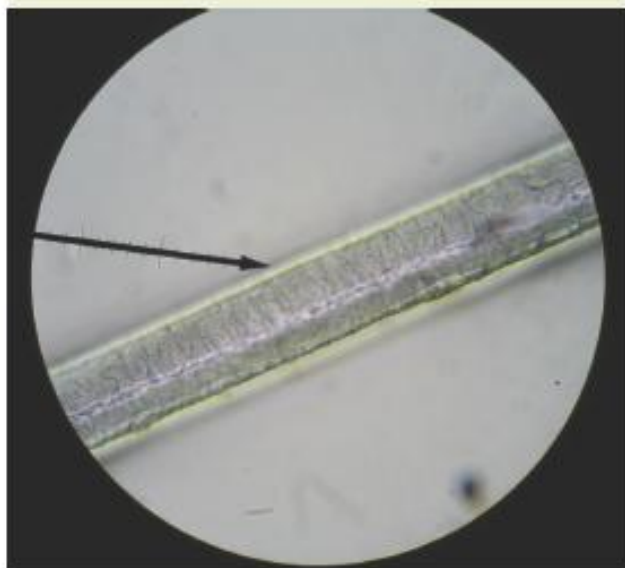
- Bleaching
  - disturbs the scales on the cuticle and
  - removes pigment
  - leaves hair brittle and yellowish
- Dyeing colors the cuticle and the cortex

Because of this and because hair grows daily, a person's treated hairs will have specific characteristics in common with her or his lost hairs.



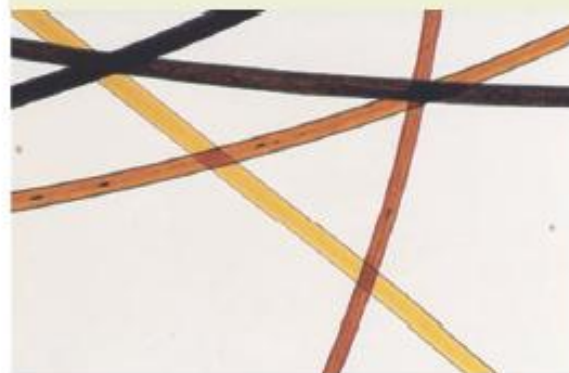
# Treated Hair

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



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**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


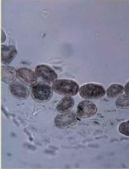

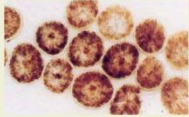


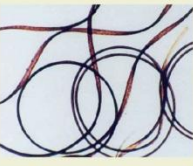


# Ethnic or Ancestral Differences



- 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
<b>European</b>	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
<b>Asian</b>	Straight 	Densely distributed	Round with large diameter 	Shaft tends to be coarse and straight; thick cuticle; continuous medulla; color black
<b>African</b>	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 	

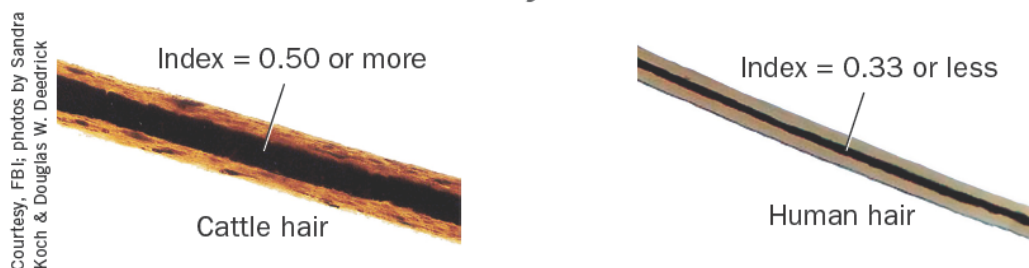
Courtesy, FBI; photos by Sandra Koch & Douglas W. Deedrick



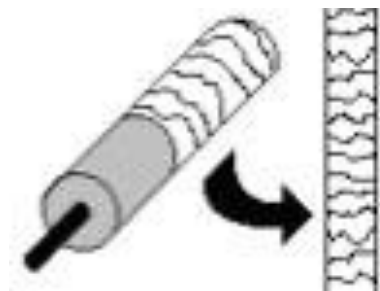
# Animal hair and Human Hair

- o Animal hair and human hair have several differences including:
  - The pattern of pigmentation
  - The medullary index
  - The cuticle type

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



# Animal Hair and Human Hair



- Pigmentation:
  - animal hair is denser toward the medulla
  - human hair tends to be denser toward the cuticle
- Banded Color Patterns:
  - possible in animals
  - not in humans
- Medulla: much thicker in animals

# Animal Hair and Human Hair



**Spinous**



**Coronal**



**Imbricate**

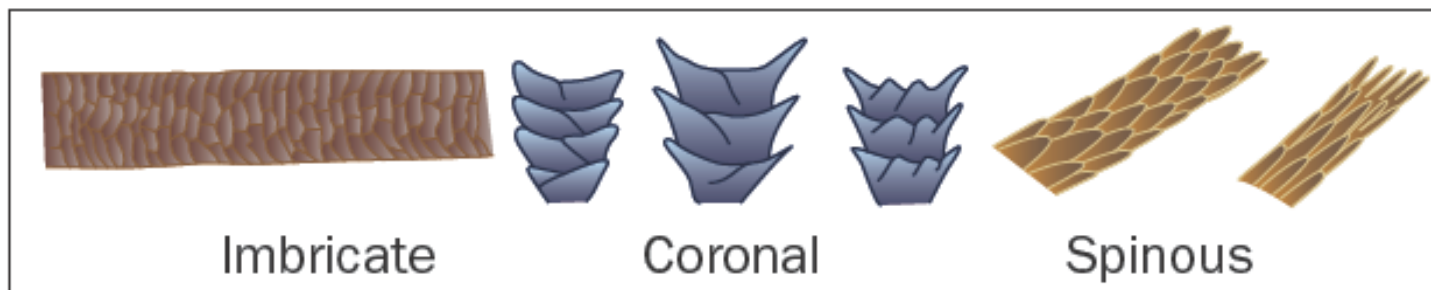
- Animals: cuticle scales resemble petals (spinous) or a stack of crowns (coronal)
- Humans: commonly flattened and narrow (imbricate)



# Hair Cuticles

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

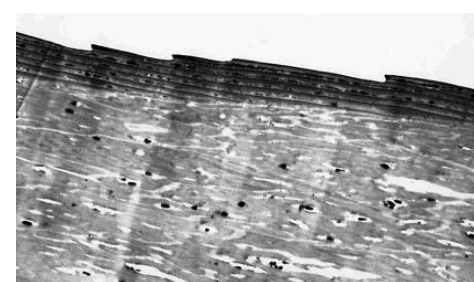
**Figure 3-12** *Imbricate (human), coronal (mouse), and spinous (cat) cuticles.*



# Using Hair in an Investigation



- Macroscopic investigations indicate
  - Length, color, curliness
- Phase contrast microscopy shows
  - presence of dye or other treatments
- Electron microscopes yield yet more detail
- Chemical tests
  - presence of various substances
- Examining a hair shaft
  - timeline for exposure to toxins
- Neutron Activation Analysis (NAA)
  - concentrations of substances





# Testing the Hair Follicle

- Microscopic assessment
  - Cost effective and quick
- Blood test
  - Determine blood type
- DNA analysis
  - Identification with a high degree of confidence

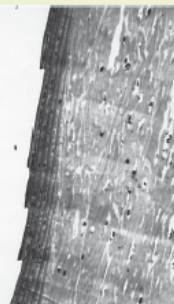


# Electron Microscopes

- o Electron microscopes direct a beam of electrons at a sample.
- o 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 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.

# Fiber Evidence

A **fiber** is the smallest unit of a textile material that has a **length** many times greater than its **diameter**. A fiber can be spun with other fibers to form a **yarn** that can be woven or knitted to form a fabric.

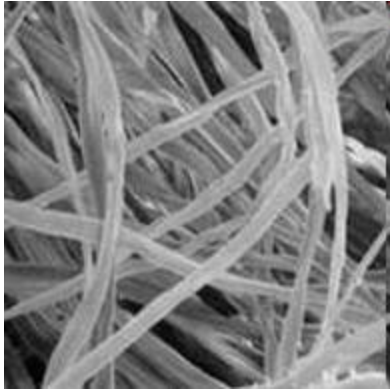
The **type** and length of fiber used, the type of **spinning** method, and the type of **fabric** construction all affect the transfer of fibers and the significance of fiber associations. This becomes very important when there is a possibility of fiber **transfer** between a suspect and a victim during the commission of a crime.

Matching **unique** fibers on the clothing of a victim to fibers on a suspect's clothing can be very helpful to an investigation, whereas the matching of **common** fibers such as white cotton or blue denim fibers would be less helpful.

The discovery of **cross transfers** and multiple fiber transfers between the suspect's clothing and the victim's clothing dramatically **increases** the likelihood that these two individuals had physical contact.

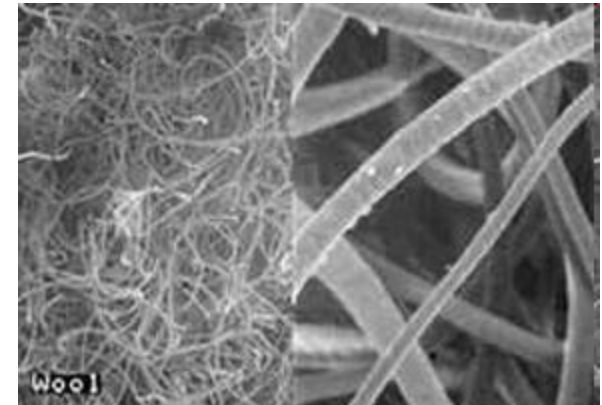
# Natural Fibers

Many different **natural** fibers that come from plants and animals are used in the production of fabric.



**Cotton** fibers are the plant fibers most commonly used in textile materials

The animal fiber most frequently used in the production of textile materials is **wool**, and the most common wool fibers originate from sheep.

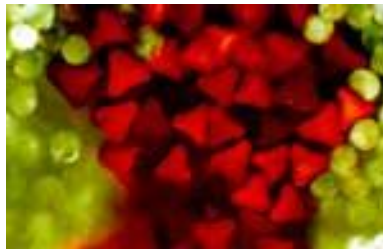


# Synthetic Fibers



More than half of all fibers used in the production of textile materials are synthetic or **man-made**.

Nylon, rayon, and polyester are all examples of **synthetic** fibers.



Cross-section  
of a man-made  
fiber



Fibers under a microscope

# Hair & Fiber Identification Lab

## Directions:

Your team will need to use a microscope to document all the hairs and fibers in your set.

Write the name of the hair or fiber on the line and then draw what you see under medium or high power. Be sure to indicate the power of magnification!

Add a description that highlights the unique characteristics of each hair and fiber sample.

Pay attention to details to help you identify samples during the Hair & Fiber Challenge activity.

Hair and Fiber Samples Name \_\_\_\_\_

Part 1: Use a microscope to examine the HAIR samples provided by your teacher. Sketch the view under MEDIUM POWER and write a DESCRIPTION that would help you identify the sample, such as unique marks or other details.

Power = ___ X Description:	Power = ___ X Description:	Power = ___ X Description:
Power = ___ X Description:	Power = ___ X Description:	Power = ___ X Description:
Power = ___ X Description:	Power = ___ X Description:	Power = ___ X Description:

Part 2: Use a microscope to examine the FIBER samples provided by your teacher. Sketch the view under MEDIUM POWER and write a DESCRIPTION that would help you identify the sample, such as unique marks or other details.

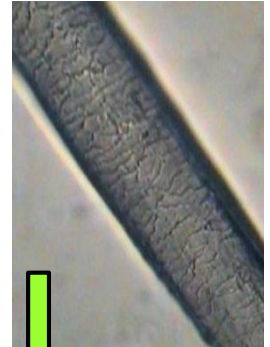
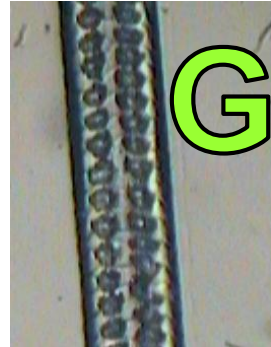
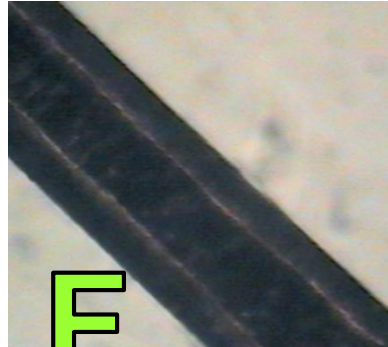
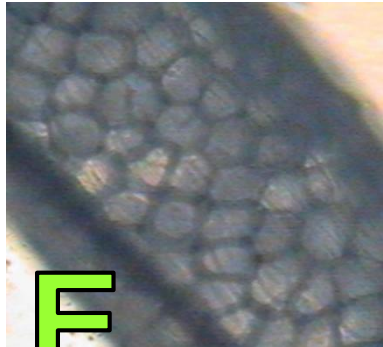
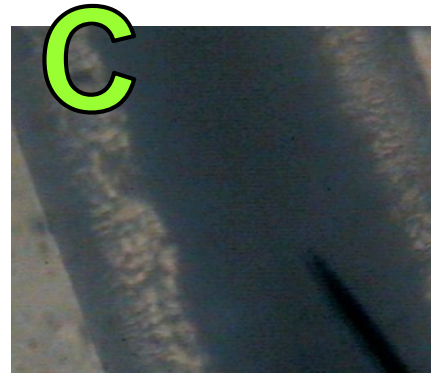
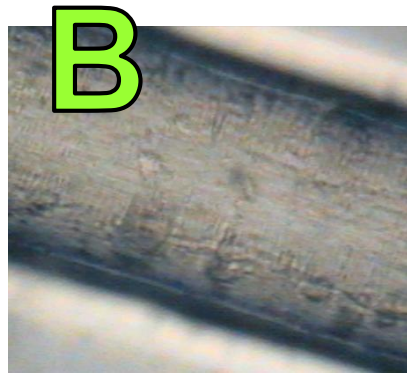
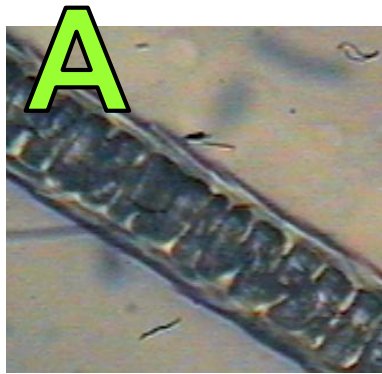
Power = ___ X Description:	Power = ___ X Description:	Power = ___ X Description:
Power = ___ X Description:	Power = ___ X Description:	Power = ___ X Description:

Part 3: Try to identify the HAIRS & FIBERS on the practice slides. Write your guesses in the space below.

#1 _____	#7 _____
#2 _____	#8 _____
#3 _____	#9 _____
#4 _____	#10 _____
#5 _____	#11 _____ & _____
#6 _____	#12 _____ & _____

T. Tringe 2006 <http://sciencspot.net/>

# Can you identify the animal hairs shown?

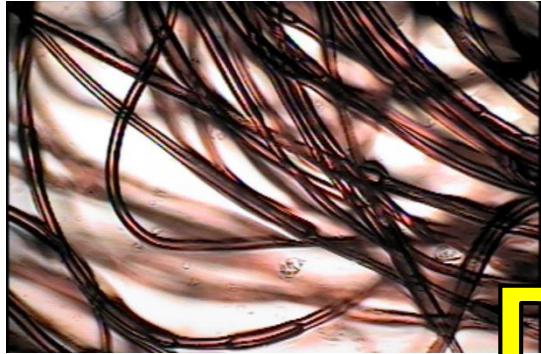
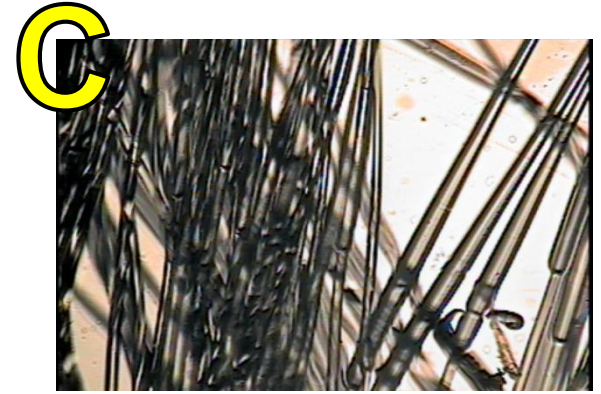
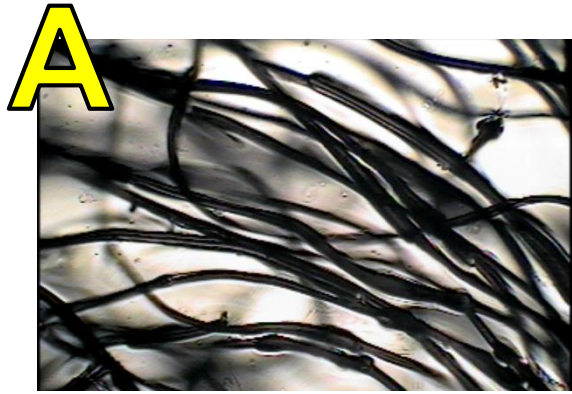


## Think About It ...

- (1) In which samples are we viewing the cuticle? How do they compare?
- (2) In which samples are we viewing the medulla? How do they compare?
- (3) What characteristics can be used to identify hair samples?



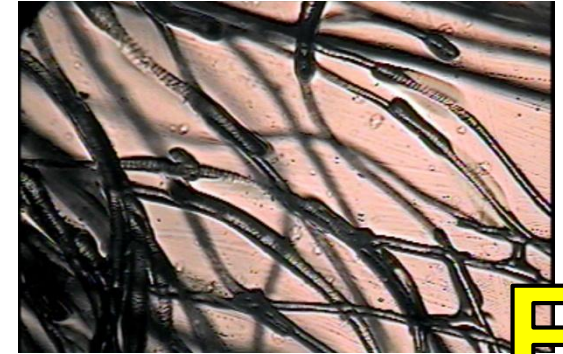
# Can you identify the types of fibers shown?



**D**



**E**




**F**

**Think About It ...**

- (1) Which samples are natural fibers?
- (2) Which samples are synthetic fibers?
- (3) What characteristics can be used to identify fiber samples?



A black and white micrograph showing several human hair fibers. The fibers are oriented in various directions, creating a complex pattern of light and dark bands. The text 'Answer Keys' is overlaid in a bright yellow, bold, sans-serif font in the center of the image.

# Answer Keys



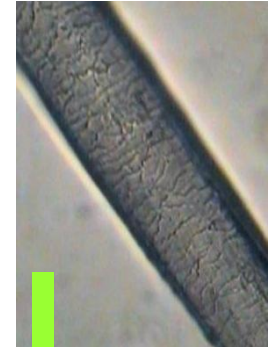
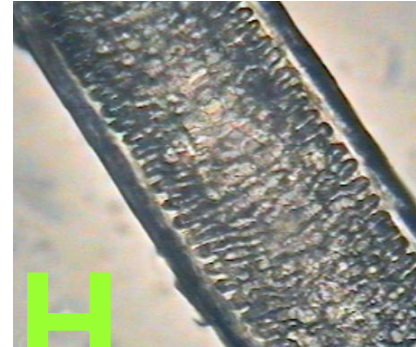
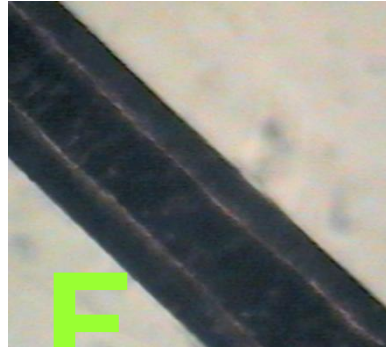
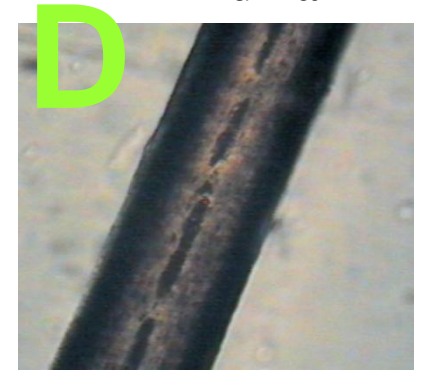
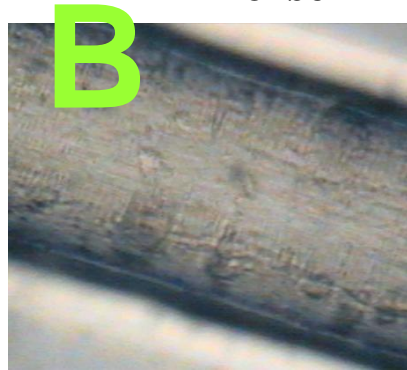
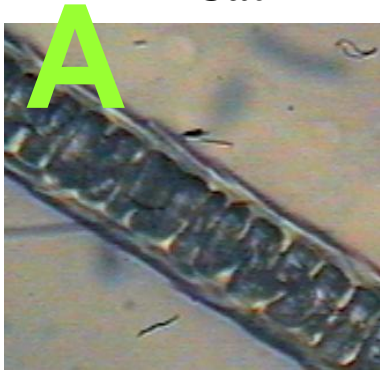
# Types of Animal Hairs - Key

Cat

Horse

Pig

Human



Deer

Dog

Rabbit

Rat

Human

# Types of Fibers - Key

**A**

Acrylic Yarn



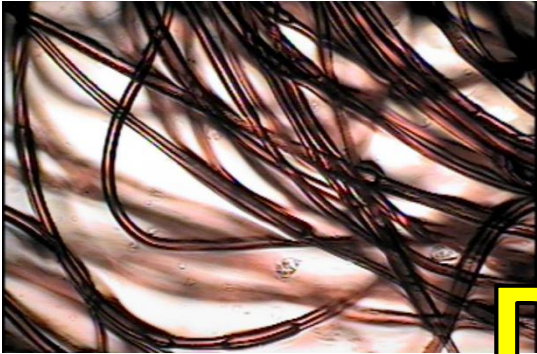
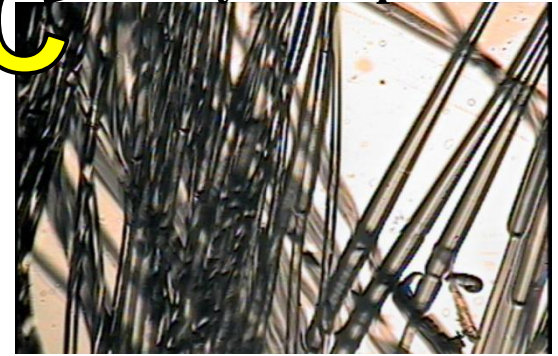
**B**

Cotton Yarn



**C**

Nylon Rope



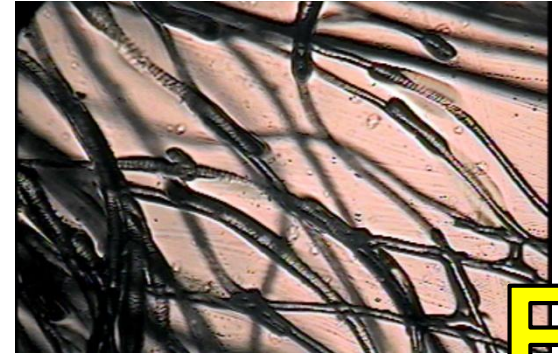
**D**

Polyester Yarn



**E**

Rayon Rope



**F**

Wool Yarn



## 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).