Chapter 3
The Study of Hair

By the end of this Chapter you will be able to:
- Identify the various parts of a hair
- Describe variations in the structure of the medulla, cortex, and cuticle
- Distinguish between human and nonhuman hair
- Determine if two examples of hair are from the same person
- Explain how hair can be used in a forensic investigation
- Calculate the medullary index for a hair

Introduction
- Careful ______________ of hair can provide important clues in an investigation.
- Hair is considered __________________ unless the follicle cells are attached.
- If the __________ is attached it can be considered __________________ evidence because ________ evidence may be obtained.

Function of Hair
- Hair has __________________ ________ for the mammals, including humans, who have hair.
  - Regulates __________________
    - Hair stands upright when cold to trap warm air underneath
  - Decreases friction
  - ________________ against sunlight

Structure of Hair
- All hair has the same ____________ structure.
- The internal structure of a hair can be compared to that of a graphite ______________.

The Structure of Hair
- A follicle embedded in the skin produces the hair shaft, which is made of ____________.

- Three layers (illustrated above):
  - the inner ____________
  - the ____________
  - the outer ____________

Types of Cuticle and Cortex
- Cuticle:
  - the ________________ ______________
  - over-lapping ____________ that protect the inner layers
  - can have ________________ ______________ depending upon the species of the mammal
scales point from the scalp to the end, which helps determine ______________ and older hair.

- Cortex:
  - ______________ ______________
  - Contains most of the pigment
  - Distribution of ______________ varies
  - Usually denser nearer the cuticle

### Types of Medulla

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

### Types of Hair

- Hair can vary in:
  - ______________
  - Length
  - Diameter
  - Texture
  - ______________

- A ______________ ______________ can be circular, ______________, irregular, or flattened
- The shape influences the curl of the hair
- Texture: coarse or fine

### Hair from Different Parts of the Body

- Human hair varies on the body
  1. Head Hair
  2. Eyebrows and Eyelashes
  3. ______________ and ______________ Hair
  4. Underarm Hair
  5. ______________ ______________ (Auxiliary Hair)
  6. Pubic Hair
The Life Cycle of Hair

- Hair proceeds through 3 stages as it develops:
  - Anagen stage: (80-90% of hair)
    - ________ ________ ________ ________
      - cells around the follicle rapidly divide and deposit materials in the hair
  - Catagen stage: (2% of hair)
    - hair grows and changes (perhaps turning gray)
  - Telogen stage: (10 – 18% of hair)
    - ________ ________ ________ ________; hairs are easily lost

Treated Hair

- When a person chemically treats his or her hair, traces of the ________ used ________.
- Also creates subtle changes that can be detected only by using a ________.
- Bleaching
  - disturbs the scales on the cuticle and
  - removes pigment
  - leaves hair brittle and yellowish
- Dyeing colors the ________ and the ________

Racial Differences

- Broad ________ categorization can be made by identifying certain ________ of hair.
- These characteristics may NOT be applicable to ________ individuals in these groups.
- Therefore, ________ hairs CANNOT be assigned to any of these groups

Animal Hair and Human Hair

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

Medulla Index - Animals vs. Humans

- Cattle hair: Index = 0.50 or more
- Human hair: Index = 0.33 or less
Animal Hair and Human Hair

- Spinous
- Coronal
- Imbricate

- Animals: cuticle scales resemble _______ (spinous) or a stack of _________ (coronal)
- Humans: commonly flattened and narrow (__________)
- Using Hair in an Investigation
- Investigators often make observations about the macroscopic and microscopic features of a hair

Microscopy
- ________ (especially comparison microscopes) are important tools to the forensic investigation of hair.
- Different kinds of microscopes provide different kinds of ________.

Testing for Substances in the Hair Shaft
- Some _________ and _________ which an individual has _______ leave traces in the hair.
- Chemical _________ determine presence of various substances
- Examining a hair shaft
  - Investigators can calculate the __________________________ during which a person was taking drugs or ingesting other toxins.
  - Neutron Activation Analysis (NAA)
    - Determines the concentrations of 9 different _________
    - Probability of two individuals having the same concentration is about one in a million

Testing the Hair Follicle
- Microscopic assessment
  - __________________________
- Blood test
  - Determine blood type
- DNA analysis
  - Identification with a high degree of _________

Root
- The _________ and other surrounding cells in the hair follicle provide the tools necessary to produce hair and continue its _________.
- When pulled from the head, some _________ _________ surrounding the hair’s shaft near the root may be found. This is called a _________ _________.
- By using DNA analysis on the follicular tag, the hair may be individualized.
Comparing Strands

- The comparison microscope is an indispensable tool for comparing the ____________ of hair.
- The criminalist is particularly interested in ____________ the color, length, and diameter.
- Microscopic examination will reveal features that can distinguish ____________ hair from the hair of ____________.
- Scale structure, medullary index, and medullary shape are particularly important in animal hair identification.
- Other important features for comparing human hair are:
  - the presence or ____________ of a medulla.
  - the distribution, shape, and color intensity of the pigment granules present in the cortex.
- The most common request is to determine whether or not hair ____________ at the crime scene ____________ to hair removed from the ____________.
- However, microscopic hair examinations tend to be ____________ and highly dependant on the skills and integrity of the analyst.

Hair and DNA

- Recent major breakthroughs in DNA profiling have extended this technology to the ____________ of human hair.
- The probability of detecting ____________ in hair roots is more likely for hair being examined in its ____________ or early growth phase as opposed to its catagen (middle) or telogen (final) phases.
- The follicular tag has proven to be a rich source of ____________ associated with hair.

Hair and Mitochondrial DNA

- ____________ DNA can be extracted from the hair ____________.
- Mitochondrial DNA is found in cellular material located outside of the nucleus and it is transmitted only from the ____________ to child.
- As a rule, all positive microscopic hair comparisons must be ____________ analysis.

Collection and Preservation

- As a general rule, forensic hair comparisons involve either head hair or pubic hair.
- The collection of _____ full-length hairs from all areas of the ____________ will normally ensure a representative sampling of head hair.
- A minimum collection of _____ full-length ____________ hairs should cover the range of characteristics present in pubic hair.
- Hair samples are also collected from the victim of ____________ deaths during an ____________.
Chapter 3
The Study of hair

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

- Identify the various parts of a hair
- Describe variations in the structure of the medulla, cortex, and cuticle
- Distinguish between human and nonhuman hair
- Determine if two examples of hair are from the same person
- Explain how hair can be used in a forensic investigation
- Calculate the medullary index for a hair

Introduction

- Careful analysis of hair can provide important clues in an investigation.
- Hair is considered class evidence unless the follicle cells are attached.
- If the follicle is attached it can be considered individual evidence because DNA evidence may be obtained.

Function of Hair

- Hair has important functions for the mammals, including humans, who have hair.
  - Regulates body temperature
    - Hair stands upright when cold to trap warm air underneath
  - Decreases friction
  - Protects against sunlight

Structure of Hair

- All hair has the same basic structure.
- The internal structure of a hair can be compared to that of a graphite pencil.

The Structure of Hair

- A follicle embedded in the skin produces the hair shaft, which is made of keratin.
- Three layers (illustrated above):
  - the inner medulla
  - the cortex
  - the outer cuticle

Types of Cuticle and Cortex

- Cuticle:
  - the outermost layer
  - over-lapping scales that protect the inner layers
  - can have different shapes depending upon the species of the mammal
  - scales point from the scalp to the end, which helps determine younger and older hair.
- Cortex:
  - Thickest layer
  - Contains most of the pigment
  - Distribution of pigment varies
  - Usually denser nearer the cuticle
### Types of Medulla

<table>
<thead>
<tr>
<th>Medulla Pattern</th>
<th>Description</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>One unbroken line of color</td>
<td>![Diagram]</td>
</tr>
<tr>
<td>Interrupted (Interrupted)</td>
<td>Pigmented line broken at regular intervals</td>
<td>![Diagram]</td>
</tr>
<tr>
<td>Fragmented or Segmented</td>
<td>Pigmented line unevenly spaced</td>
<td>![Diagram]</td>
</tr>
<tr>
<td>Solid</td>
<td>Pigmented area filling both the medulla and the cortex</td>
<td>![Diagram]</td>
</tr>
<tr>
<td>None</td>
<td>No separate pigmentation in the medulla</td>
<td>![Diagram]</td>
</tr>
</tbody>
</table>

### Types of Hair
- Hair can vary in:
  - Shape
  - Length
  - Diameter
  - Texture
  - Color
- A cross section can be circular, triangular, irregular, or flattened
- The shape influences the curl of the hair
- Texture: coarse or fine

### Hair from Different Parts of the Body
- Human hair varies on the body
  1. Head Hair
  2. Eyebrows and Eyelashes
  3. Beard and Mustache Hair
  4. Underarm Hair
  5. Body hair (Auxiliary Hair)
  6. Pubic Hair

### The Life Cycle of Hair
- Hair proceeds through 3 stages as it develops:
  - Anagen stage: (80-90% of hair)
    - hair actively grows
      - cells around the follicle rapidly divide and deposit materials in the hair
  - Catagen stage: (2% of hair)
    - hair grows and changes (perhaps turning gray)
  - Telogen stage: (10 – 18% of hair)
    - follicle becomes dormant; hairs are easily lost

### Treated Hair
- When a person chemically treats his or her hair, traces of the chemicals used remain.
- Also creates subtle changes that can be detected only by using a microscope.
Bleaching
- disturbs the scales on the cuticle and
- removes pigment
- leaves hair brittle and yellowish

Dyeing colors the cuticle and the cortex

Racial Differences
- Broad racial categorization can be made by identifying certain characteristics of hair.
- These characteristics may NOT be applicable to all individuals in these groups.
- Therefore, individual hairs CANNOT be assigned to any of these groups

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

Medulla Index - Animals vs. Humans

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)

Using Hair in an Investigation
- Investigators often make observations about the macroscopic and microscopic features of a hair

Microscopy
- Microscopes (especially comparison microscopes) are important tools to the forensic investigation of hair.
- Different kinds of microscopes provide different kinds of evidence.

Testing for Substances in the Hair Shaft
- Some toxins and drugs which an individual has ingested leave traces in the hair.
- Chemical tests determine presence of various substances
- Examining a hair shaft
  - Investigators can calculate the length of time during which a person was taking drugs or ingesting other toxins.
Neutron Activation Analysis (NAA)
- Determines the concentrations of 9 different elements
- Probability of two individuals having the same concentration is about one in a million

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

Root
- The root and other surrounding cells in the hair follicle provide the tools necessary to produce hair and continue its growth.
- When pulled from the head, some translucent tissue surrounding the hair’s shaft near the root may be found. This is called a follicular tag.
- By using DNA analysis on the follicular tag, the hair may be individualized.

Comparing Strands
- The comparison microscope is an indispensable tool for comparing the morphological (appearance/shape) characteristics of hair.
- The criminalist is particularly interested in matching the color, length, and diameter.
- Microscopic examination will reveal features that can distinguish human hair from the hair of animals.
- Scale structure, medullary index, and medullary shape are particularly important in animal hair identification.
- Other important features for comparing human hair are:
  - the presence or absence of a medulla.
  - the distribution, shape, and color intensity of the pigment granules present in the cortex.
- The most common request is to determine whether or not hair recovered at the crime scene compares to hair removed from the suspect.
- However, microscopic hair examinations tend to be subjective and highly dependant on the skills and integrity of the analyst.

Hair and DNA
- Recent major breakthroughs in DNA profiling have extended this technology to the individualization of human hair.
- The probability of detecting DNA in hair roots is more likely for hair being examined in its anagen or early growth phase as opposed to its catagen (middle) or telogen (final) phases.
- The follicular tag has proven to be a rich source of nuclear DNA associated with hair.

Hair and Mitochondrial DNA
- Mitochondrial DNA can be extracted from the hair shaft.
- Mitochondrial DNA is found in cellular material located outside of the nucleus and it is transmitted only from the mother to child.
- As a rule, all positive microscopic hair comparisons must be confirmed by DNA analysis.

Collection and Preservation
- As a general rule, forensic hair comparisons involve either head hair or pubic hair.
The collection of 50 full-length hairs from all areas of the scalp will normally ensure a representative sampling of head hair.

A minimum collection of 24 full-length pubic hairs should cover the range of characteristics present in pubic hair.

Hair samples are also collected from the victim of suspicious deaths during an autopsy.