The Forensic Analysis of Hair
Objectives

- Know that the Locard exchange principle says that “every contact leaves a trace.”
- Know that keratin and melanin are the basic chemical components of hair.
- Know that the hair above the epidermis is the shaft; below the epidermis is the root.
- Know that humans have medullary ratios less than $\frac{1}{3}$, while animals have medullary ratios of more than $\frac{1}{2}$.
- Know that the SEM is typically used to view and compare hairs.
Objectives

- Know that 50 head hairs and 24 pubic hairs need to be collected from all parties involved for control/reference.
- Know that nuclear DNA (nDNA) comes from both parents.
- Know that mitochondrial DNA (mtDNA) comes only from the mother.
- Know that the odds of associating a suspect's nDNA with an evidential hair creates a 1 in a billion or trillion odd, which is as close to individualization that hair evidence comes.
- Know that both the RIA and the ELISA may be used to test for drugs and other chemicals in the body.
History

• 1891 - Han Gross published the first description of the uses of physical evidence to help solve crimes.

• 1897 - Rudolph Virchow became the first person to do an in-depth study of hair.

• 1906 - Hugo Marx wrote a paper on the use of hair in forensic investigations to determine identity.

• 1916 - Albert Schneider became the first to collect physical evidence with a vacuum.

• 1920 - Locard becomes known for the exchange principle – the fact that “every contact leaves a trace.”

• 1931 - Dr. Paul Kirk works on new ways to improve the use of hair in forensic investigations.
Hair Morphology

• The most basic components of hair are keratin, a very strong protein that is resistant to decomposition, and melanin, a pigment.

• The keratins form groups that interact and interconnect to form very stable fibrils. It is this property of hair that makes it such a prime example of physical evidence.
Hair Morphology

- Hairs are dead, cornified cells. The portion existing above the epidermis is called the shaft; below the epidermis, the root is embedded in the hair follicle.

- The hair shaft is composed of three layers:
  - Outer cuticle
  - Cortex
  - Central medulla
Cuticle

- The cuticle of a hair is the thin, translucent layer surrounding the shaft. It consists of scales of hardened, keratinized tissue that vary from species to species, and includes such patterns as:
  - Coronal, or “crown – like.” Rare in humans; typical of rodents. Found in hairs of very fine diameter.
  - Spinous, or “petal – like.” Never found in humans. Common in cats, seals, and minks.
  - Imbricate, or “flattened.” Common in humans.
Cuticle

Photomicrograph of a mink hair possessing a Spinous cuticle.

Photomicrograph of a bat hair possessing a Coronal cuticle.

Photomicrograph of a human hair possessing an Imbricate cuticle.
Cortex

- The cortex is the main body of the hair, composed of spindle-shaped cortical cells.
- Contains pigment bodies, which contains the melanin (hair color) and cortical fusi.
  - Cortical fusi are air spaces of varying sizes found near the root of a mature human hair.
  - Pigment granules are small, dark, granulated structures that vary in size, color, and distribution. Typically distributed toward the cuticle in humans.
    - Bleached hair is devoid of pigment granules, and dyed hair has dye in the cuticle and the cortex.
Medulla

- The medulla is a central core of cells that runs through the center of the cortex. The medulla may be:
  - Continuous
  - Fragmented
  - Interrupted

- In human hairs, the medulla is generally amorphous in appearance or completely absent.

- In animal hairs, it’s structure is frequently very regular and well defined.

- Medullar ratio, of the formula diameter of medulla/diameter of the cortex, is less than \( \frac{1}{3} \) in humans and more than \( \frac{1}{2} \) in animals.
Medulla

Photomicrograph of a human hair with no medulla.

Photomicrograph of a hair with trace medulla.

Photomicrograph of a hair with a clear, continuous medulla.
Hair Growth

• Growth of mammal hair goes through three distinct phases:
  – Anagenic phase can last for up to 6 years. Follicle is attached to the root by the papilla. The hair must be pulled to be lost. If pulled, a follicular tag is left, which can be used later to test the mitochondrial DNA.
  – Catagenic phase lasts only 2-3 weeks. Hair keeps growing, but the bulb shrinks.
  – Telogenic phase lasts for 2-6 months. Hair becomes naturally loose and sheds.
Collection of Hair Evidence

• The search for and collection of hair evidence should begin as soon as possible. Hair evidence is easily transferred to and from the crime scene.
• Collection should be done by hand if the location of the hair is important, which is usually the case. Sticky tape and lint rollers may be used to assist.
• A special filtered vacuum cleaner may be used to collect hairs and fibers en masse from carpet, bedding, etc.
• If the evidence is stuck to another object, the entire object should be packaged and labeled.
Collection of Hair Evidence

• Once collected, the hair evidence should be packaged into paper packets.

• If sticky tape or a lint roller are used, the entire surface used should be packed into a polyethylene storage bag – easy to see through, but with no direct contact.

• Control samples need to be collected from the victim, suspect, and other individuals who could have left evidence at the scene. Take from all pertinent regions of the body; 50 head hairs, 24 pubic hairs. Root still in tact is preferable.
Forensic Analysis of the Hairs

• Humans hairs can be separated from animal hairs in any number of ways, including the medullary ratio, characteristics of the medulla, and the scale patterns of the cuticle.

• Different species of animals can be identified quite easily using the same basic principles.

• The next step tries to classify the racial origin of the hair as: negroid, mongoloid, and caucasian, typically using head hair. Mixed individuals sometimes exhibit properties of all of their ancestral lineage, and make classification difficult.
African American Hairs

- Curly.
- Dense pigment distributed unevenly.
- Variations in the diameter of the shaft.
- Fragmented or absent medullae.
- The cross-section is flattened.

Cross Section of a Negroid Hair

Photomicrograph of a Negroid Head Hair
Asian and Hispanic Hairs

• Coarse and straight shaft, with little diameter variation.
• Dense pigment distributed unevenly.
• Presence of a continuous medulla.
• The cross-section is round.
Caucasian Hairs

- Straight to wavy.
- Fairly evenly distributed, fine pigment.
- Moderate shaft diameter, with little variation.
- The cross-section is oval.
Forensic Analysis of the Hairs

Somatic regions can be determined based on the hair’s morphology, such as:

- Head hairs have a soft texture, cut or split tips, and moderate shaft diameter.
- Pubic hairs have a course, wiry texture, tapered, rounded, or abraded tips, and a buckling shaft.
- Facial hairs have a triangular cross-section and a course in texture.
- Eyelash/Eyebrow hairs are saber-like in appearance, short, and stubby.
- Limb hairs are soft, and arc-like in appearance. Tips are rounded and abraded; scales rounded due to wear.
Forensic Analysis of the Hairs

• Using a microscope (SEM), forensic scientists can typically determine the species, race, and somatic origin of a hair. They may use comparative microscopy to do one of the following:
  – Link the suspect to a crime scene, meaning that a control hair matches the evidential hair.
  – Exclude the suspect from a crime scene, meaning that a control hair does not match the evidential hair.

• In addition to comparing hairs with a microscope, the scientists may test for DNA on the follicular tag, and run a number of tests for drugs and environmental toxins, which will be described at length.

Scanning Electron Microscope, a typical device used to study the structures of hair.
Forensic Analysis of the Hairs

- Hair analysis is used in forensic toxicology to test and determine whether a drug was used.
- When a drug is ingested, it enters the bloodstream and is broken down to a specific metabolite.
- Hair strands normally grow at an average rate of 1.3 centimeters every month; they absorb metabolized drugs that are fed to the hair follicle through the bloodstream.
- The drug will only disappear if exposure to the drug is ceased, and the hair containing the drug is cut.
- Hair analysis can be used for the detection of many therapeutic drugs and recreational drugs, including cocaine, heroin, benzodiazepines (Valium-type drugs) and amphetamines.
Forensic Analysis of the Hair

- The radioimmunoassay and enzyme-linked immunosorbent assay are two common assays that are used by forensic toxicologists to detect substances such as drugs in the hair.
- Recall that the immunoassays function on the basis of an antigen-antibody interaction. The analyte, or drug, is added and binds to the solid phase, typically producing a color change, fluorescence, etc. that can be measured to determine the amount of drug present.
- Forensic toxicologists also look for toxic metals in the hair to explain poor mental and physical health.
Forensic Analysis of the Hair

- Individualization has been impossible to obtain with hairs in the past, but recent techniques are making it more realistic.
- Nuclear DNA (nDNA) and mitochondrial DNA (mtDNA) can be extracted from the root or follicular tag of an anagenic hair. Nuclear DNA comes from both parents; mitochondrial DNA is passed only from mother to offspring.
- Nuclear DNA can lead to individualization. Odds created by association of a suspect with evidential hairs are typically one to billions or trillions.
References

• www.coolphysics.org/Hair,%20Fiber,%20and%20Paints%2005.ppt