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 ⅓, while animals have medullary ratios of more than ½.
- 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 suspects' 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

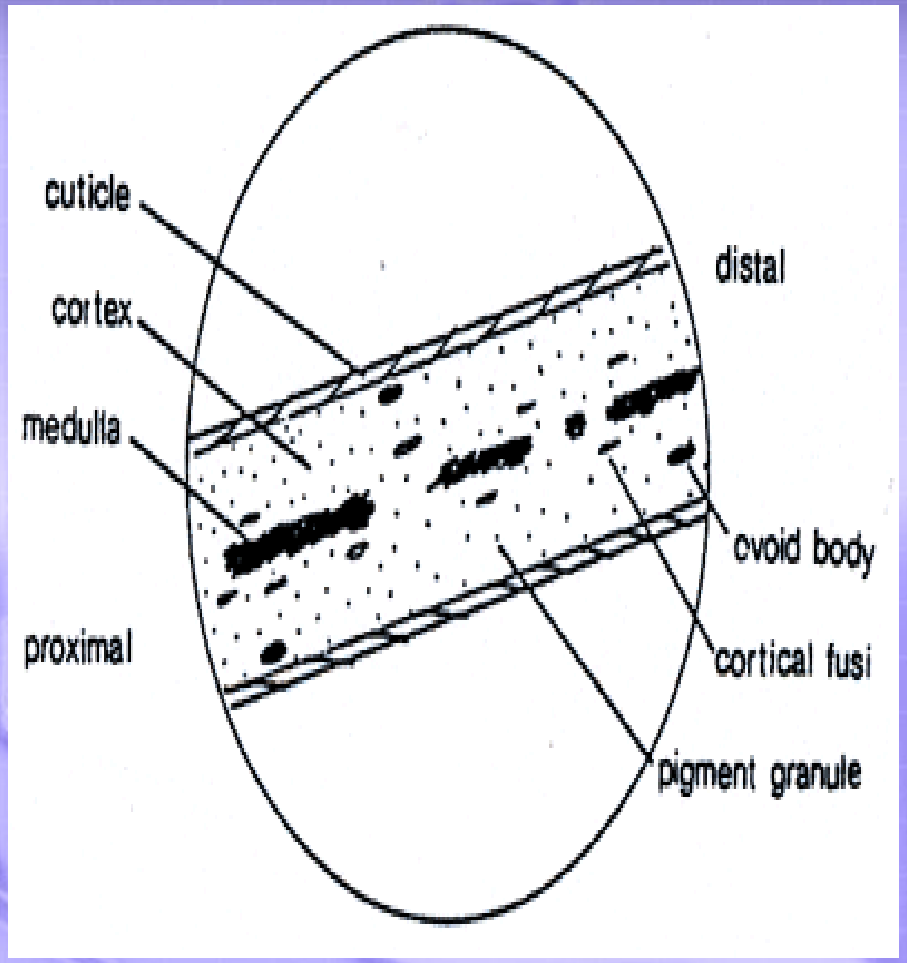
- 1891 - Han Gross published the first description of the uses of physical evidence to help solve crimes
- 1897 - Rudolph Virchow became the first person to do an in depth study of hair.
- 1906 - Hugo Marx wrote a paper on the use of hair in forensic investigations to determine identity.

Edmond Locard (1877-1966), noted for his exchange principle.

- 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.

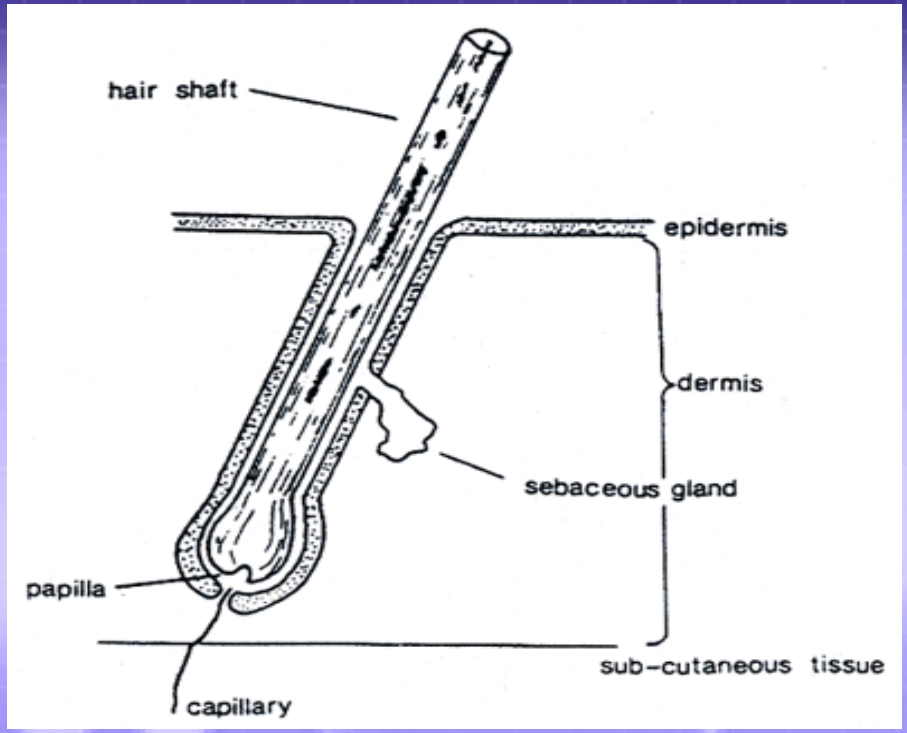
Hair Morphology

- 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

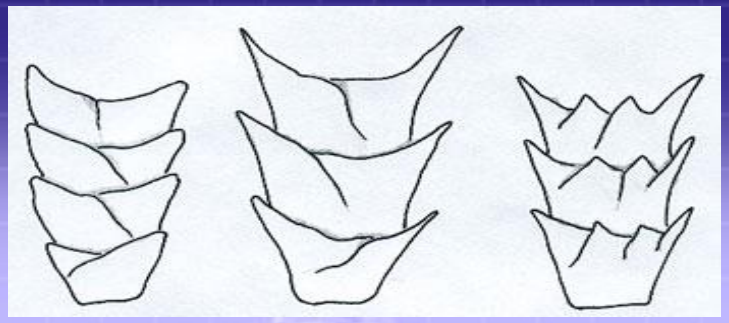
- Hairs are dead, cornified cells. The portion existing above the epidermis is called the shaft; below the epidermis, the root is embedded in the hair follicle.



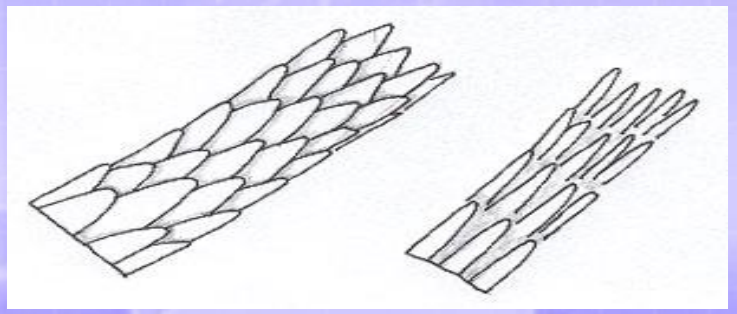
- The hair shaft is composed of three layers:
  - Outer cuticle
  - Cortex
  - Central medulla

Cuticle

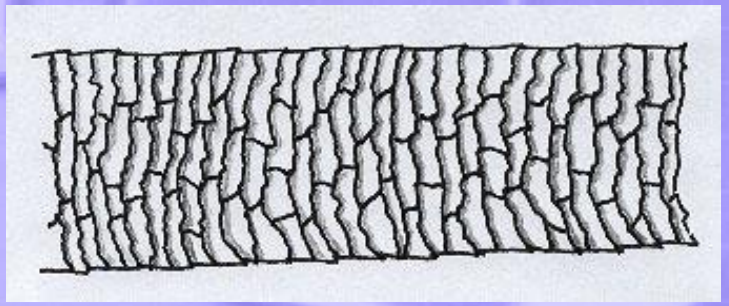
- The cuticle of a hair is the thin, translucent layer surrounding the shaft. It consists of scales of hardened, keratinized tissue that vary from species to species, and includes such patterns as:
  - Coronal, or “crown – like.” Rare in humans; typical of rodents. Found in hairs of very fine diameter.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



Coronal



Spinous

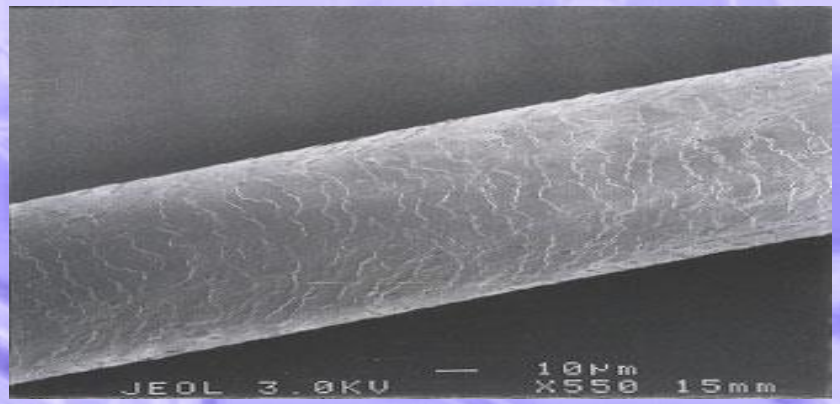


Imbricate

Cuticle

Photomicrograph of a mink hair possessing a Spinous cuticle.

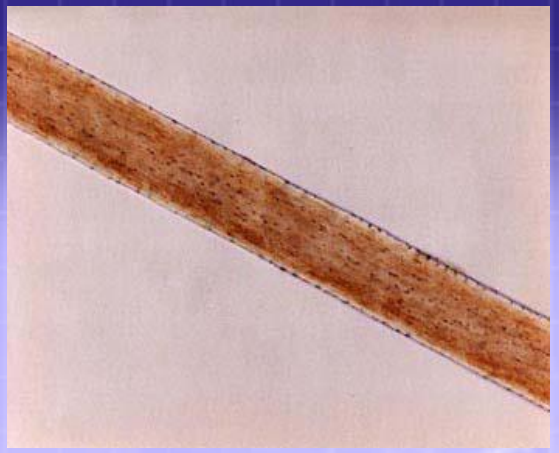
Photomicrograph of a bat hair possessing a Coronal cuticle.



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.

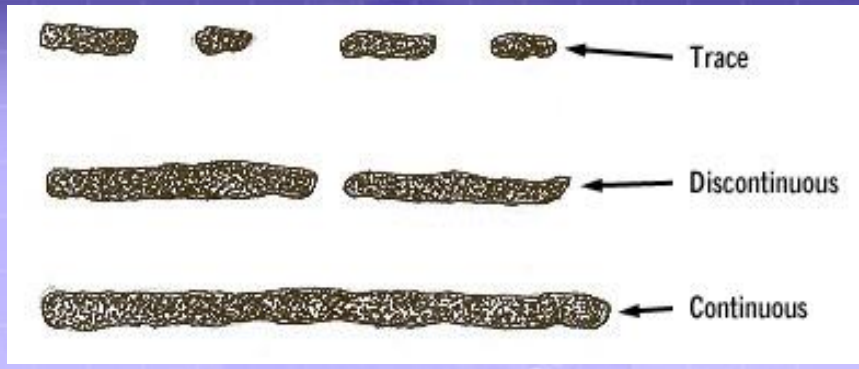


Photomicrograph of cortical fusi in human hair

Photomicrograph of pigment distribution in human hair

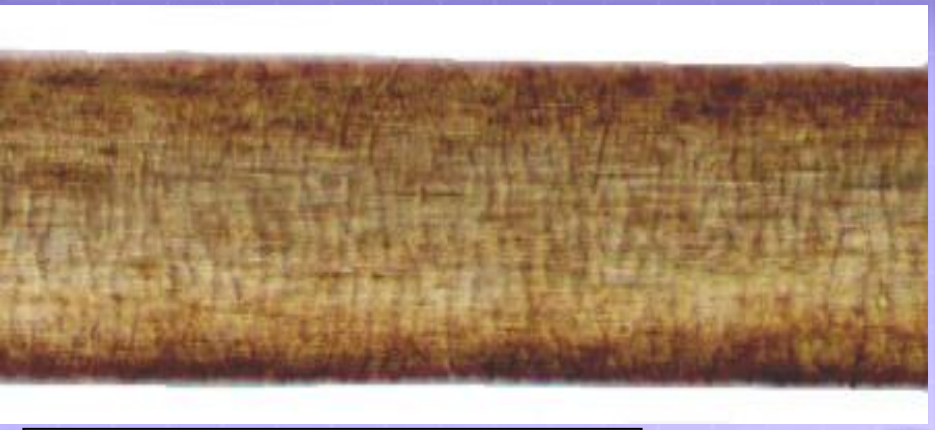
Medulla

- 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 ⅓ in humans and more than ½ in animals.



$$\textit{Medullary Index} = \frac{\text{diameter of medulla}}{\text{diameter of hair}}$$

Medulla



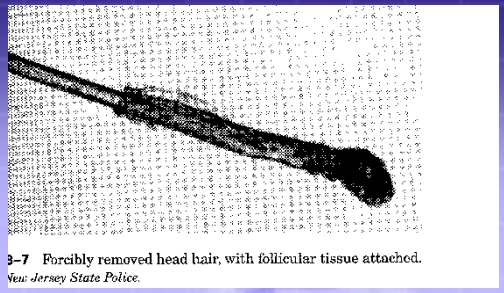
Photomicrograph of a human hair with no medulla.

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.



3–7 Forcibly removed head hair, with follicular tissue attached.
New Jersey State Police.

Hair in Anagenic Phase

Hair in Catagenic Phase

Hair in Telogenic Phase

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.

Evidence Collecting Vacuum

Evidence Collecting Kit

Collection of Hair Evidence

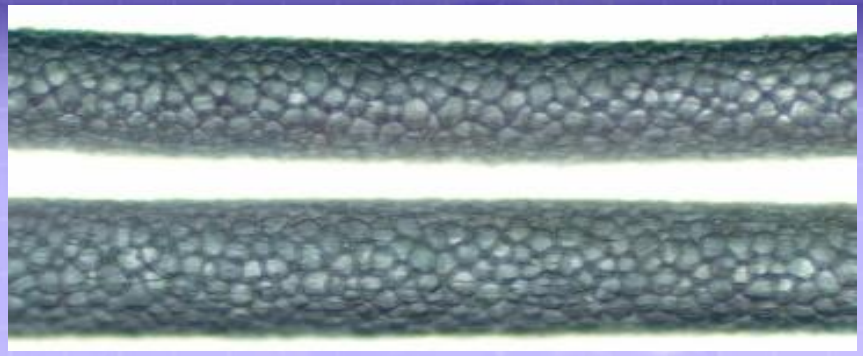
- Once collected, the hair evidence should be packaged into paper packets.
- If sticky tape or a lint roller are used, the entire surface used should be packed into a polyethylene storage bag – easy to see through, but with no direct contact.
- Control samples need to be collected from the victim, suspect, 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.

Evidence Collection Bags

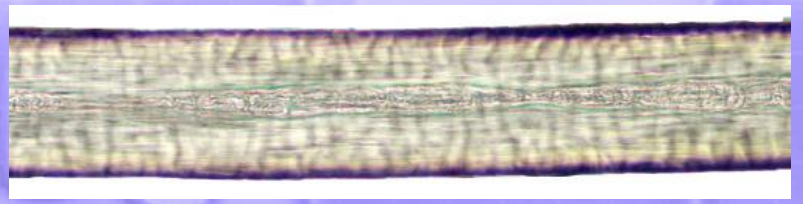
Evidence Collecting Lint Roller

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.



Deer Medullae

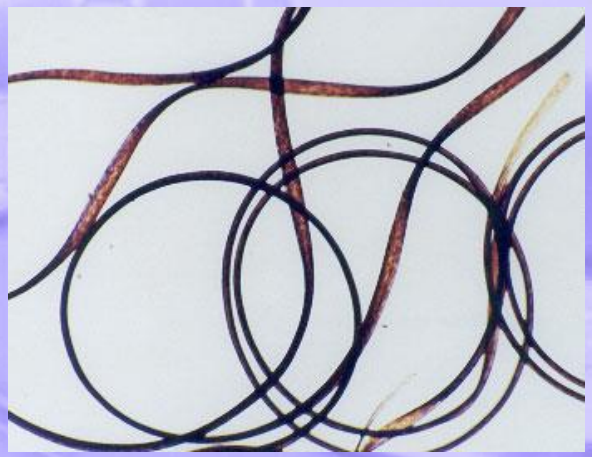


Human Medulla

African American Hairs

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

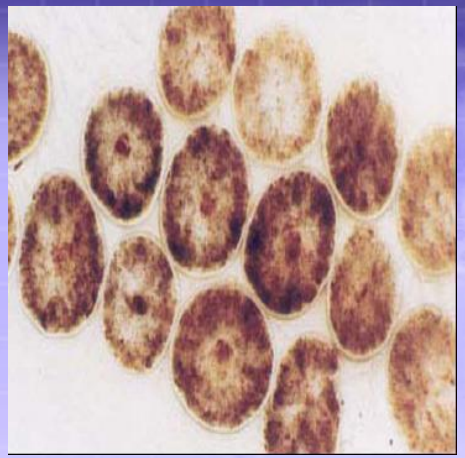
Cross Section of a Negroid Hair



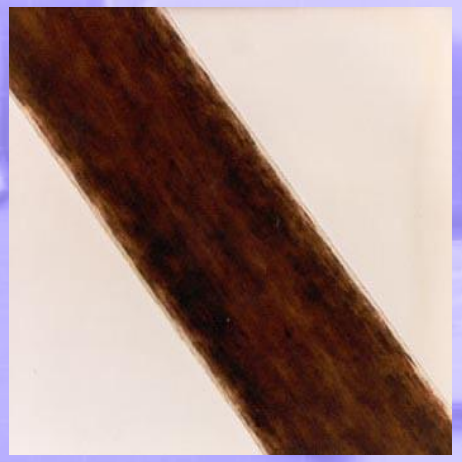
Photomicrograph of a Negroid Head Hair

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.



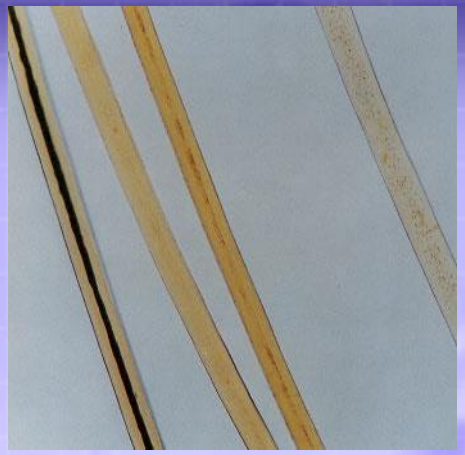
Cross Section of a Mongoloid Hair



Photomicrograph of a Mongoloid Head Hair

Caucasian Hairs

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

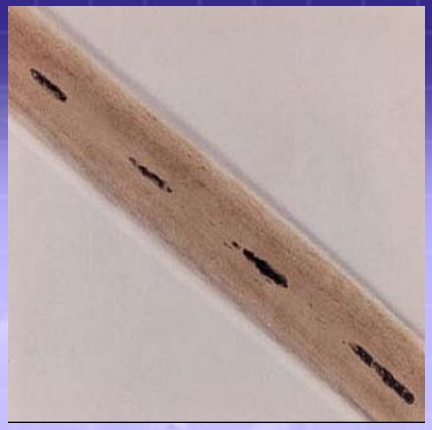


Photomicrograph of a Caucasian Hair

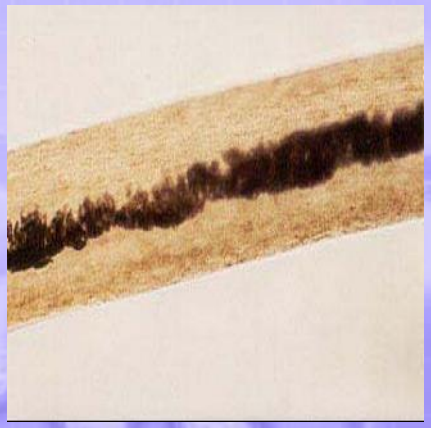
Cross Section of Caucasian Hair

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.



Head Hair

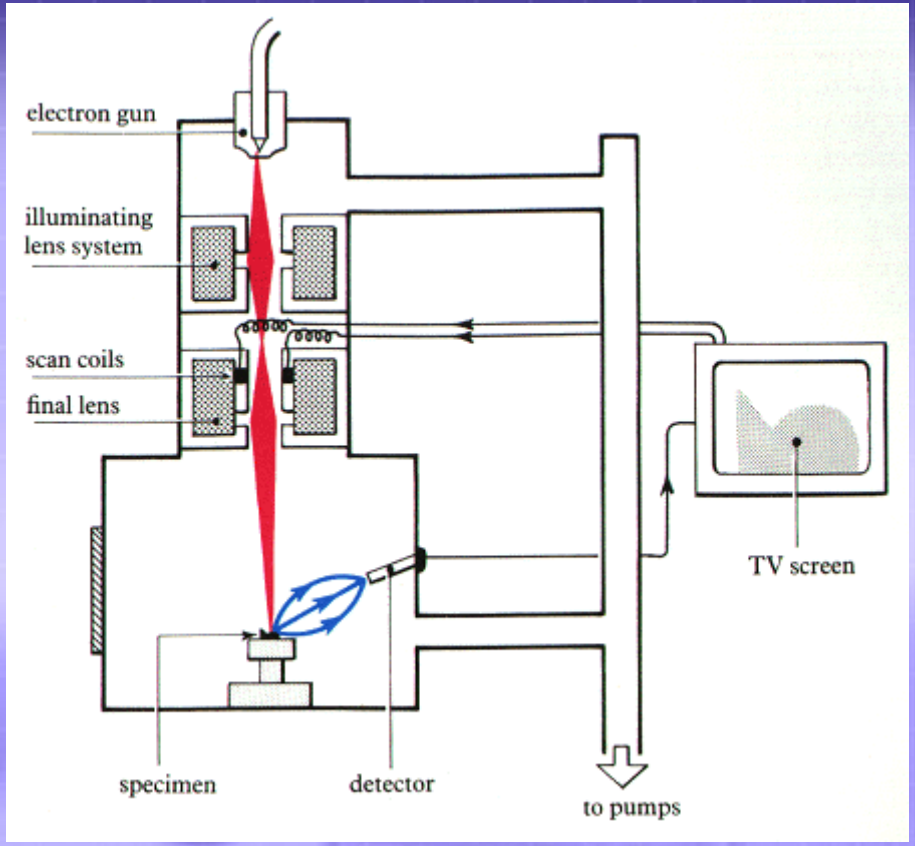


Pubic Hair

Beard Hair

Forensic Analysis of the Hairs

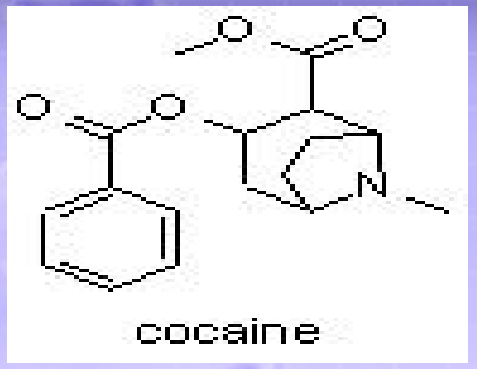
- Using a microscope (SEM), forensic scientists can typically determine the species, race, and somatic origin of a hair. They may use comparative microscopy to do one of the following:
  - Link the suspect to a crime scene, meaning that a control hair matches the evidential hair.
  - Exclude the suspect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



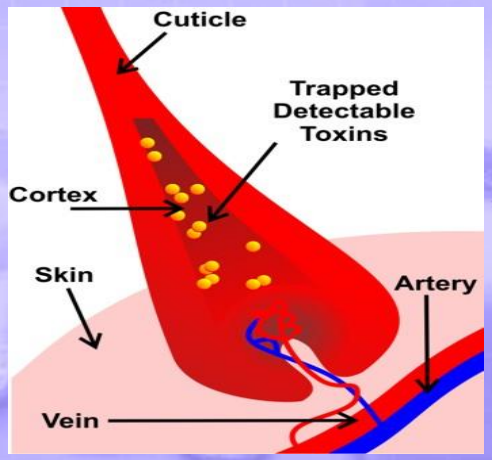
Scanning Electron Microscope, a typical device used to study the structures of hair.

Forensic Analysis of the Hairs

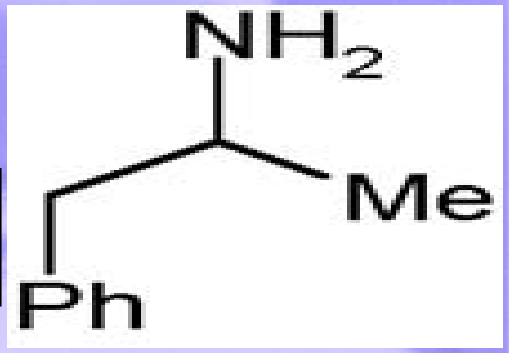
- Hair analysis is used in forensic toxicology to test and determine whether a drug was used.
- When a drug is ingested, it enters the blood stream and is broken down to a specific metabolite.
- Hair strands normally grow at an average rate of 1.3 centimeters every month; they absorb metabolized drugs that are fed to the hair follicle through the blood stream.
- 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.



Cocaine's Structure



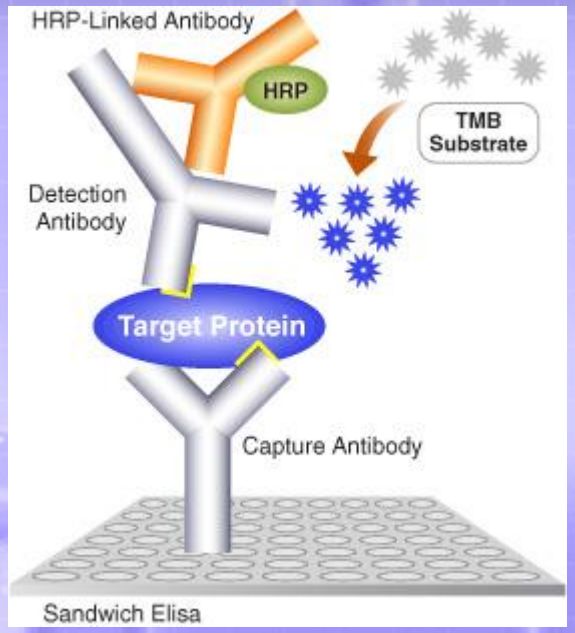
Depicting how drugs enter the hair.



General structure for amphetamines.

Forensic Analysis of the Hair

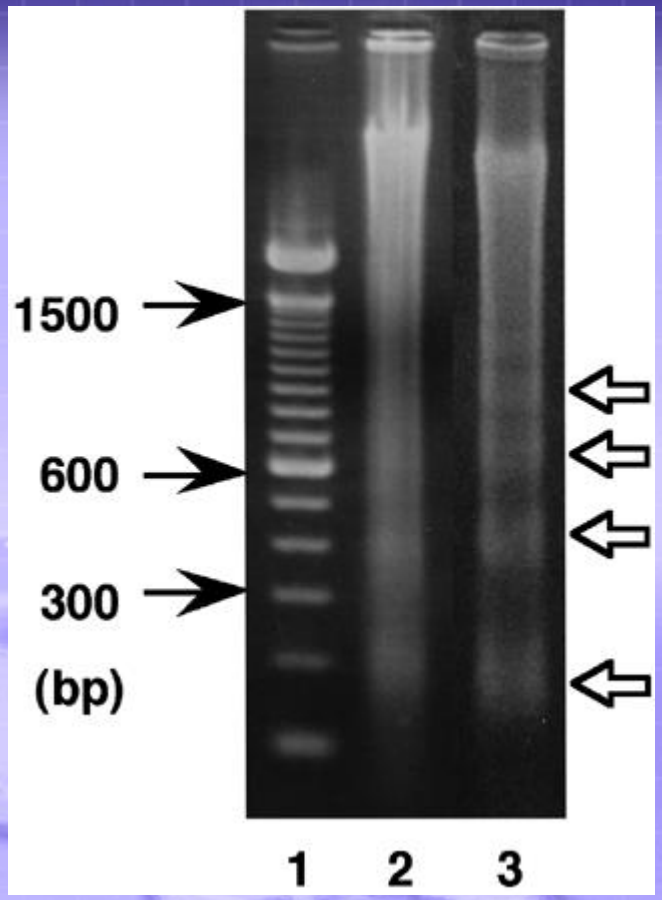
- The radioimmunoassay and enzyme-linked immunosorbent assay are two common assays that are used by forensic toxicologists to detect substances such as drugs in the hair.
- Recall that the immunoassays function on the basis of an antigen-antibody interaction. The analyte, or drug, is added and binds 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.



How an ELISA functions

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.



DNA Smear of anagenic hair

References

- James, Stuart. Forensic Science. 2. Boca Raton, FL: CRC Press, 2005.
- Bell, Suzanne. Forensic Chemistry. 1. Upper Saddle River, NJ: Pearson Prentice Hall, 2006.
- Girard, James E.. Criminalistics: Forensic Science and Crime. 1. Sudbury, MA: Jones and Barlett Publishers Inc., 2008.
- Saferstein, Richard. Criminalistics: An Introduction to Forensic Science. 9. Upper Saddle River, NJ: Pearson Prentice Hall, 2007.
- Deedrick, Douglas. "Hairs, Fibers, Crime and Evidence." Forensic Science Communications 2.3July 2000 16 003 2008 <http://www.fbi.gov/hq/lab/fsc/backissu/july2000/deedric1.htm>.
- Kathy, Steck-Flynn. "Trace Evidence: Hair." Crime and Clues: The Art and Science of Criminal Investigation. 03 009 2006. 16 Mar 2008 <http://www.crimeandclues.com/hair_evidence.htm>.
- Bisbing, Richard E., (2001) *Finding Trace Evidence*. in *Mute Witnesses: Trace Evidence Analysis*. Houck, Max., (ed.) Academic Press, San Diego, California
- www.coolphysics.org/**Hair**,%20Fiber,%20and%20Paints%2005.ppt
- Hamrick, Barbara. "Uranium in Hair Analysis: Responding to Public Concerns." 25 004 2004. Environmental Nuclear Council. 16 Mar 2008 <http://www.crcpd.org/AnnualMeeting-04/05-25-04_0810-Hamrick.pdf>.