Introduction

- Hair is encountered as physical evidence in a wide variety of crimes.
- Although it is not yet possible to individualize a human hair to any single head or body through its morphology, it still has value as physical evidence.
- When properly collected and submitted to the laboratory accompanied by an adequate number of standard/reference samples, hair can provide strong corroborative evidence for placing an individual at a crime scene.
- DNA analysis can provide individual identification.

Questions

- Can the body area from which a hair originated be determined?
- Can the racial origin of hair be determined?
- Can the age and sex of an individual be determined from a hair sample?
- Is it possible to determine if a hair was forcibly removed from the body?
- Are efforts being made to individualize human hair?
- Can DNA individualize a human hair?

Hair is Class Evidence

- Can often determine body area of origin
- Can often determine racial origin
  - African descent
    - kinky with dense uneven pigment
    - flat to oval in shape
  - European/Caucasian
    - straight or wavy fairly evenly distributed pigment
    - oval to round shape

Hair

- An appendage of skin which grows out of an organ called a hair follicle
- Resists chemical decomposition
- Retains structural features over long periods of time
- The length of a hair extends from its root or bulb embedded in the follicle, continues into a shaft, and terminates at a tip end.
- It is the shaft, which is composed of three layers—the cuticle, cortex, and medulla—that is subjected to the most intense examination by the forensic scientist.

Morphology of Hair
Cuticle and Cortex
- The cuticle is the scale structure covering the exterior of the hair.
  - The scales always point towards the tip of the hair.
  - The scale pattern is useful in species identification.
- The cortex is the main body of the hair shaft.
  - Its major forensic importance is the fact that it is embedded with the pigment granules that impart hair with color.
  - The color, shape, and distribution of these granules provide the criminalist with important points of comparison among the hairs of different individuals.

Cortex
- Composed of spindle-shaped cells aligned parallel to the length of the hair
- Embedded with pigment granules

Medulla
- The medulla is a cellular column running through the center of the hair.
  - The medullary index measures the diameter of the medulla relative to the diameter of the hair shaft.
  - The medulla may be continuous, interrupted, fragmented, or absent.
  - The presence of the medulla varies from individual to individual and even among hairs of a given individual.
  - Medullae also have different shapes, depending on the species.

Medulla
- A collection of cells appearing like a central canal
- Medullary Index
  - Comparison of medulla diameter to shaft diameter
Medulla Patterns

- Continuous
- Interrupted
- Fragmented

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.

Collection of Hair Evidence
- Questioned hairs must be accompanied with an adequate number of control sample hairs
  - from victim
  - from others suspected of depositing hair at crime scene
- Representative control samples
  - 50 full-length hairs from all areas of scalp
  - 24 full-length pubic hairs
- Hair samples are also collected from the victims of suspicious deaths during an autopsy.

Hair Comparison
- Uses comparison microscope
  - color
  - length
  - diameter
  - presence or absence of medulla
  - distribution, shape & color intensity of pigment granules
    - dyed hair has color in cuticle & cortex
    - bleaching removes pigment & gives yellow tint

Two matching hairs identified with the comparison microscope

Pubic Hair
Comparing Strands

- 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 dependent on the skills and integrity of the analyst.

Is It Human or Animal?

- Scale patterns
- Medullary Index
  - human hair generally <1/3
  - animal hair >=1/2
- Medullary Shape
  - human normally cylindrical
Shedding vs. Removal By Force

- Presence of follicular tissue on root indicative of forcible removal
  - by a person
  - by a comb

Hair

Naturally shed hairs, such as a head hair dislodged through combing, display undamaged, club-shaped roots.

A hair forcibly removed from the scalp will exhibit stretching and damage to the root area or may have tissue attached.
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.

Often, when hair is forcibly removed a follicular tag, a translucent piece of tissue surrounding the hair's shaft near the root may be present.

This has proven to be a rich source of nuclear DNA associated with hair.

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.

Definitive determination of sex can be accomplished through the staining of sex chromatin in the cells found in the follicular tissue.

Female

Male

Hair affected by burning
Fiber Evidence
- The quality of the fiber evidence depends on the ability of the criminalist to identify the origin of the fiber or at least be able to narrow the possibilities to a limited number of sources.
- Obviously, if the examiner is presented with fabrics that can be exactly fitted together at their torn edges, it is a virtual certainty that the fabrics were of common origin.

Fiber Evidence
- Microscopic comparisons between questioned and standard/reference fibers are initially undertaken for color and diameter characteristics, using a comparison microscope.
- Other morphological features that could be important in comparing fibers are:
  - Lengthwise striations on the surface of the fiber
  - The presence of delustering particles that reduce shine
  - The cross-sectional shape of the fiber
- Compositional differences may exist in the dyes that were applied to the fibers during the manufacturing process.

Collection of Fiber Evidence
- Investigator must identify & preserve potential fiber “carriers”
- Clothing items are packaged individually in paper bags
  - different items must not be placed on the same surface before being bagged
- Tape lifts of exposed skin areas of bodies & inanimate objects

Methods For Fiber Comparison
- The visible light microspectrophotometer is a convenient way for analysts to compare the colors of fibers through spectral patterns.
- A more detailed analysis of the fiber’s dye composition can be obtained through a chromatographic separation.
- Infrared spectroscopy is a rapid and reliable method for identifying the generic class of fibers, as does the polarizing microscope.
- Depending on the class of fiber, each polarized plane of light will have a characteristic index of refraction.

Types of Fibers
- Natural fibers are derived in whole from animal or plant sources.
  - Examples: wool, mohair, cashmere, furs, and cotton.
- Man-made fibers are manufactured.
  - Regenerated fibers are manufactured from natural raw materials and include rayon, acetate, and triacetate.
  - Synthetic fibers are produced solely from synthetic chemicals and include nylons, polyesters, and acrylics.
- Polymers, or macromolecules, are synthetic fibers composed of a large number of atoms arranged in repeating units known as monomers.

Polymers
- Long strings of repeating chemical units
  - poly (many)
  - mer (unit)
Fibers are Polymers

Natural Fibers
- Classified according to their origin
  - vegetable or cellulose based
  - animal or protein based
  - mineral class
    - asbestos

Cellulose Based Fibers
- Cotton
- Jute
  - sacks & bags
    - burlap
  - backing for tufted carpets & hooked rugs
    - Oriental rugs
  - twines & ruff cordage

Protein Based Fibers
- More vulnerable to environmental degradation than cellulose based fibers
- Wool (sheep)
- Mohair (goat)
  - fiber structure similar to wool
    - half the scales of wool
    - scales lie flat (smooth surface)
    - <1% of fibers have a medulla
- Silk

Helical Proteins
- Based on alpha-keratin
Sheet Proteins
- Based on beta-keratin

A Hair Fiber

WOOL
- Microscopic images of wool fibers

Natural Fibers Are ...
- Nonthermoplastic
  - do not soften when heat is applied
- Particularly susceptible to microbial decomposition (mildew & rot)
  - cellulose based
    - decomposed by aerobic bacteria & fungi
  - protein based
    - decomposed by bacteria and molds
    - moths, carpet beetles, termites, silverfish

Mineral Polymers
- Asbestos
  - any of several minerals that readily separate into long, flexible fibers
    - Chrysotile (hydrous magnesium silicate)
      - $\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$
  - formerly used in
    - shingles
    - insulation
    - cement pipes

Man-Made Fibers
- Regenerated Fibers
  - derived from naturally occurring polymers
    - rayon
    - acetate
- Synthetic Fibers
  - made of polymers that do not occur naturally
    - polyesters
    - polyamides
Manufacture of Synthetic Fibers

- Melted or dissolved polymer is forced through fine holes of a spinnerette
  - Similar to a bathroom showerhead
- A fine filament is produced

Polyesters

- Polyethylene terephthalate (PET)
  - X=O
  - Can be melt-spun into very practical and cheap fibers
  - Dacron
- Clothing, furnishings, carpets, tire cord

Aromatic Polyesters (Aramid)

- Flexible CH₂ groups replaced by rigid aromatic rings
- High melting
- Flame retardant clothing, bullet-proof vests, tire cord

PET

Polyamides

- Polyhexamethylene adipamide (Nylon 6,6)
  - X=NH
- Synthesized from adipic acid and hexamethylenediamine
  - Each contain six carbon atoms
  - Nylon 6 or Nylon 6,6
- Apparel, carpets, and tire cord
**Nylon 6,6**

![Nylon 6,6 molecule diagram]

**Making Nylon 6,6**

![Making Nylon 6,6 reaction diagram]

**Nylon**

![Polarizing microscope image of a nylon fiber.]

**Microscopic Comparison**

- Color
- Diameter
- Lengthwise striations on surface
- Pitting with delustering particles
  - TiO
  - reduces shine

**Dye Composition**

- Visible Light Microspectrophotometry
  - non-destructive
  - fiber mounted on a microscope slide
- Chromatographic separation of dye components
  - dye extracted from fiber with solvent
  - TLC of questions extract vs. control extract

**Fiber Composition**

- Attempts to place fiber into both a broad generic class & a subclass
- Many man-made fibers exhibit birefringence
  - light passing through fiber emerges as two rays
    - one parallel to fiber length
    - one perpendicular to fiber length
Paint spread onto a surface will dry into a hard film that can best be described as consisting of pigments and additives suspended in the binder.

One of the most common types of paint examined in the crime laboratory involves finishes emanating from automobiles.

Automobile manufacturers normally apply a variety of coatings to the body of an automobile.

These coatings may include electrocoat primer, primer surfacer, basecoat, and clearcoat.

Methods For Paint Comparison

- The wide diversity of automotive paint contributes to the forensic significance of an automobile paint comparison.
- Questioned and known specimens are best compared side by side under a stereoscopic microscope for color, surface texture, and color layer sequence.
- Pyrolysis gas chromatography and infrared spectrophotometry are invaluable techniques for distinguishing most paint binder formulations, adding further significance to a forensic paint comparison.
- Crime laboratories are often asked to identify the make and model of a car from a small amount of paint and will make use of color charts for automobile finishes.

Collection and Preservation

- Paint chips are most likely found on or near persons or objects involved in hit-and-run incidents.
- Paper druggist folds and glass or plastic vials make excellent containers for paint.
- Paint smeared or embedded in garments or objects require the whole item to be packaged and sent to the laboratory.
- Uncontaminated standard/reference paint must always be collected.
- Tools used to gain entry into buildings or safes often contain traces of paint, requiring the tool be collected, along with reference paint samples.

Paint Library

Forensic garage