

Hair Analysis Notes

Human hair is one of the most frequently found pieces of physical evidence located at the scene of a violent crime and can provide a substantive link between the criminal and their act. Hair is class evidence and thus it usually not possible to determine in a court of law that a particular hair sample specifically came from a certain person. But with careful observation and analysis, the hair sample often leads to other, more convicting evidence.

Although the shaft of the hair alone can't be matched to an individual, it has several properties that make it useful to criminalists. It's small; easily shed, clings to clothing and other materials, and goes unnoticed by perpetrators at crime scenes. Hair is hardy and survives for a long period of time even years after bodies decompose. Examiners can find many toxins, particularly heavy metals like arsenic, in hair. Also, if the follicle is attached to the hair, examiners can often extract DNA and use it to make an exact match.

The bulk of hair analysis deals with its structure and chemical characteristics. The value of hair as evidence depends upon how confidently an examiner can match two or more hairs. But hair varies not only from person to person but also from one area of an individual's body to another – the hair on your head is different from the hair on your arms or other parts of your body. Investigators most often examine head or pubic hair as evidence.

Hair's Anatomy

Hair grows out of the skin from a pocket of specialized cells called a **follicle**. In gross structure, hair is made of two distinct parts. The **shaft** of the hair projects from the skin, and the **root** lies below the epidermis. The root of a mature human hair is similar in appearance to a flower bulb. The root end is called the **proximal end** and the growing tip end is called the **distal end**. The shaft of the hair is made up of three parts (cortex, cuticle, medulla), each of which an examiner can use to match hairs. The structure of hair is similar to the yellow pencil you use in school. The lead would be the medulla, the wood the cortex, and the yellow paint the cuticle.

Cortex: In human hair, the cortex is the largest portion of the shaft and is the component that contains hair pigment, which gives hair its color. Pigment particles (*melanin*) show highly variable colors, shapes, and distribution patterns, all of which help examiners determine race, match known and unknown hair, and identify sources of hair. Under microscopic examination, investigators use the pattern of air pockets (*cortical fusi*) and structures within the cortex to seek a match.

Cuticle: The cuticle is a layer of cells that cover the surface of the shaft and look like scales on a fish or perhaps even roofing tiles. Examiners use scale patterns to determine whether the hair is human and to match one hair to another. Scales overlap and always point up the shaft, away from the bulb. These scales are of the following three basic types and vary by species:

- **Coronal** (crown like) scales give the hair a mosaic surface appearance. Human hair rarely has these scales, but they're common among rodents.
- **Spinous** (petal like) scales tend to be somewhat triangular in shape. These scales aren't found in humans but are typical of cats.
- **Imbricate** (flattened) scales are found in humans and many other animals.

Note that the scales always point toward the tip of the hair.

Medulla: The central core of the hair, the medulla contains a collection of cells but appears as if it's an empty or mud-filled central canal. If the medulla is filled with air, it appears as a black or opaque structure under transmitted light, or as a white structure under reflected light. If it is filled with mounting medium or some other clear substance, the structure appears clear or translucent in transmitted light, or nearly invisible in reflected light. In human hairs, the medulla is generally amorphous in appearance, whereas in animal hairs, its structure is frequently very regular and well defined. The medulla's appearance can be classified as *fragmented*, *intermittent*, or *continuous*. The basic structure of medulla also can vary. Some of the more common medulla types are *uniserial* (rabbit), *multiserial* (rabbit), *vacuolated* (dog, fox, common), *lattice* (deer), and *amorphous* (human, common).

Forensic science investigators determine the medullary index of hair which is the diameter of the medulla relative to the diameter of the hair, expressed as a fraction.

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

Humans have a medullary index of less than 1/3, and the medullary index of animals is 1/2 or greater. The width of the medulla relative to the overall width of the hair is called the *medullary index*. In most animals, this index is greater than 0.5, which means that the medulla is more than half the thickness of the hair. In humans, however, the medulla typically is narrow, with an index of approximately 0.3. Whether the material within the medulla appears solid and continuous, interrupted, or fragmented helps criminalists determine the hair's species of origin. Databases of hair types from various animals help them make the match.

Matching Criminal to Curly Lock

To compare hairs, an examiner must have an unknown (crime scene) hair and known hair samples from the victim and any suspects. Known hair samples are taken from various areas of the victim's and suspect's bodies. A typical sample includes 50 hairs removed from various parts of the head and several pubic hairs. The ME also combs the pubic region for foreign hairs and other trace materials.

To make sure that he's comparing apples with apples, the examiner tries to determine where on the body the unknown hair came from – whether it's a head hair, a pubic hair, or a hair from some other location. This determination is essential because the examiner wants to match crime-scene hair with hair taken from the same location on the suspect. In general, hairs taken from different areas of the body have different cross-sectional geometries (shapes). Head, eyebrow, and eyelash hairs are more likely to be round, axillary (armpit) hairs are oval, and beard hairs are triangular.

Examiners use a comparison microscope to view known and unknown hairs side by side and work through the following checklist of comparisons:

- Color and width
- Distribution pattern of the medulla
- Color and distribution pattern of pigment in the cortex
- Cuticle pattern

A study performed by the Royal Canadian Mounted Police shows that if a crime-scene head hair matches a suspect's head hair in all the respects mentioned in the previous list, the probability that the crime-scene hair came from someone other than the suspect is 4,500 to 1. With pubic hairs, the probability falls to about 800 to 1.

Dyed Hair

If you dye your hair, more than your roots may give you away. With infrared microspectrophotometry, a trace evidence examiner may be able to determine not only whether your hair has been dyed, bleached, or treated but also when you last visited the hairdresser – important details for determining your identity. A complete strand of hair reveals the history of your color treatments. Because hair grows approximately half an inch a month, a one-inch segment of undyed or unbleached hair near the root suggests that the last treatment was two months earlier.

Finding Further Clues

Microscopic examination of the hair may reveal tissue adhering to its root. Because yanking hair from the scalp often rips out follicular tissues, finding tissue suggests that the hair was forcibly removed instead of falling out naturally. A cut edge indicates that a sharp instrument was employed to cut the hair. In such situations, the examiner can often determine what instrument was used.

Determining Race

Neither age nor sex can be determined by analyzing hair; however, the general nature of the hair (color, thickness, curliness) sometimes separates the source along broad racial lines. Caucasians, for example, tend to have straight or wavy hair with a round or oval cross-sectional shape and a finer and more evenly distributed cortical pigment pattern. People of African ancestry have curly hair that's flat or oval when viewed in cross-section. In addition, the cortical pigment is denser and unevenly distributed. These characteristics aren't completely reliable.

Race	Characteristic
Caucasian	Straight to wavy, evenly distributed pigment granules, fragmented medullae or absent of medullae, cross section oval/round, fine to coarse pigment
Asian	Dense pigment distributed evenly, cross section round, hair shaft coarse and straight, presence of continuous medullae
African American	Curly, heavy pigment distributed unevenly, variations in diameter, fragmented medullae or absent of medullae

Making it Individual

You can also find many of the chemicals within your body also in your hair. Techniques such as neutron activation analysis (NAA) can detect more than a dozen different chemicals. Because two people rarely have the exact same chemicals in their hair, comparing the types and amounts of these substances may enable a forensic examiner to determine whether two hairs likely came from the same person.

In certain circumstances, hair can supply DNA, which is highly individualizing. Hair is composed of dead cellular debris that has no nuclei, so you can't find any nuclear DNA within the hair's shaft. The bulb, or so-called root, where hair manufacture and growth take place, is composed of live cells, so examiners can often find DNA there. If hair is pulled from the victim or the assailant, root or follicular tissue, which contains DNA, may be attached. With the newer techniques of PCR amplification and STR analysis, a single hair follicle can yield enough DNA for comparison.

Occasionally, the examiner can extract **mitochondrial DNA** (mtDNA) from the hair shaft. Because the hair is built from cellular remnants, and because the cell cytoplasm houses mtDNA, you may be able to obtain a usable sample of who shed the hair through mtDNA analysis and comparison of its pattern with the pattern of samples from the suspect's siblings or maternal-line relatives.

Scale Casts

It may be necessary to make a scale cast of the hair specimen in order to see the scale pattern more clearly, particularly in the identification of some animal hairs. Ogle and Mitosinka (1973) devised a quick and easy method of making a scale cast with the use of a Polaroid film-print coater. A thin layer is applied to a glass microscope slide with two or three passes of the Polaroid print coater. The hair specimen is lightly pressed onto the film and allowed to stand until the film is dry. The hair is then pulled from the film, and the cast remains.

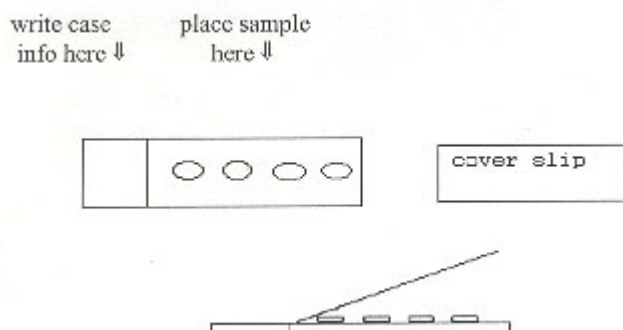
A method developed by Crocker (1998) at the Centre of Forensic Sciences in Toronto, Canada, uses clear tape as a mounting medium and coverslip together, which allows for quick observation of such surface features as the scale pattern.

Scale casts may also be prepared using clear nail polish. A thin coat is painted on a glass microscope slide or, if the lacquer is thinned with acetone, a drop may be allowed to run down the surface of the slide. The hair is placed on the slide and allowed to dry. When the surface has dried, the hair is removed to reveal the scale pattern.

Glass Microscope Slide Preparation

Hair specimens are prepared for microscopic examination by mounting them in a semipermanent medium, such as Permount®. Whatever mounting medium is selected, the refractive index of the medium should approximate that of hair (1.52) in order to visualize the internal microscopic characteristics.

Positioning a hair on the glass slide is made easier by first applying a thin film of solvent on the slide surface. Longer hairs are configured in a figure eight in order to fit it under the cover slip. This enables the examiner to view the entire hair from root to tip. One or more hairs can be mounted on a slide, depending on their thickness and curl. Too many hairs on one slide can cause excessive overlapping that may obscure the viewing of characteristics of underlying hairs. Excess solvent can be removed with a small square of blotter paper. Several drops of mounting medium are applied on top of the hair(s), and a cover slip is carefully lowered to prevent the presence of air bubbles. Figure 1a diagrams this process. It may be necessary to apply some weight to the cover slip in order to ensure a thin mount. The thinner the mount, the easier it is to examine the hairs.

Figure 1a. Illustration of Slide Preparation

In most cases, hairs can be mounted directly onto the slide; however, occasionally, in order to observe structural detail, it may be necessary to clean debris from the hairs. If covered with blood, hairs can be cleaned with a saline solution, but because water is not miscible in Permount®, the sample must be dried completely before applying the mounting medium. Oily or other debris-contaminated hairs can be cleansed with xylene or an ether-alcohol solution. Before cleaning the hairs, consider if any blood and other materials on the surface may have evidentiary value.