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***Part 1: Hair Evidence***

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**Hair Evidence**

Hairs, which are composed primarily of the protein keratin, can be defined as slender outgrowths of the skin of mammals. Each species of animal possesses hair with characteristic length, color, shape, root appearance, and internal microscopic features that distinguish one animal from another. Considerable variability also exists in the types of hairs that are found on the body of an animal. In humans, hairs found on the head, pubic region, arms, legs, and other body areas have characteristics that can determine their origin. On animals, hair types include coarse outer hairs or guard hairs, the finer fur hairs, tactile hairs such as whiskers, and other hairs that originate from the tail and mane of an animal.

Because hairs can be transferred during physical contact, their presence can associate a suspect to a victim or a suspect/victim to a crime scene. The types of hair recovered and the condition and number of hairs found all impact on their value as evidence in a criminal investigation. Comparison of the microscopic characteristics of questioned hairs to known hair samples helps determine whether a transfer may have occurred.

**Hair Microscopy**

The examination of human hairs in the forensic laboratory is typically conducted through the use of light microscopy. This examination routinely involves a two-step process—the identification of questioned hairs and the comparison of questioned and known hairs. The purpose for conducting this examination is to ascertain whether two or more individuals could have come into contact or whether one or more individuals could have come into contact with an object. This associative evidence is particularly useful in crimes of violence, such as homicide, sexual assault, and aggravated assault, where physical contact may have occurred. Crimes such as burglary and armed robbery typically involve the recovery of debris and articles of clothing which may contain hairs useful for the identification of suspects.

The value of hair evidence is related to the variability of hair characteristics between individuals in the population, which can be visualized through the use of comparison microscopy. There are many factors that impact on the reliability of a hair association, including experience, training, suitability of known hair standards, and adequacy of equipment. Although hair evidence is a valuable tool in human identification, it is difficult to establish a statistical probability for a particular association due in part to the lack of reliable quantitative assessments of the microscopic characteristics present in hairs.

The comparison microscope consists of two compound light microscopes connected by an optical bridge that allows for the simultaneous viewing of questioned hairs and known hairs. Typically, a glass microscope slide containing known or reference hairs is positioned on the stage of one microscope, and a glass microscope slide containing a questioned hair or hairs is positioned on the stage of the other microscope. This enables the hair examiner to compare the microscopic characteristics of the known and questioned hairs in one field. The range of magnification used is approximately 40X to 400X.

**The comparison microscope is integral to trace evidence examinations.**

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The hair examination process involves many different steps, the first of which is to determine whether the hair in question originated from an animal or a human being. If the hair originated from an animal, it is possible to further identify it to a particular type of animal. Although certain hairs can be attributed to species, it is not possible to identify hairs to a specific animal to the exclusion of other similar animals. An example of this occurs when dog hairs can be associated to a particular breed but cannot be identified to a specific dog within that breed.

**Two matching hairs identified with the comparison microscope**

**Hair Anatomy and Growth**

Hair is present on many different regions of the body. Each region, such as the head, pubic area, chest, axillae, and limbs, has hairs with microscopical characteristics attributable to that region. Although it is possible to identify a hair as originating from a particular body area, the regions of the body that are primarily used in forensic comparisons are the head and pubic areas. As hairs undergo a cyclical growth (anagen) and resting phase (telogen), the visible microscopic characteristics are sufficient to determine the phase of growth of the hair.

During the anagen phase, the hair is actively growing, and materials are deposited in the hair shaft by cells found in the follicle. Metabolically active and dividing cells above and around the dermal papilla of the follicle grow upward during this phase, to form the major components of the hair—the medulla, cortex, cuticle, and accompanying root sheath. In the telogen phase, the follicle is dormant or resting. The transition period between the anagen and telogen phases is referred to as the catagen phase.

Hairs are routinely lost during the telogen phase and often become a primary source of evidentiary material. An example of this natural shedding process can be seen when one combs through the hairs on the head. It is not uncommon for hairs of this type to be transferred to another individual or to an object during physical contact. Hairs can also become dislodged from the body while they are in an actively growing state, such as by pulling or by striking with an object. The microscopical appearance of the root area will allow for the determination of the growth phase.

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

On a healthy head, 80 to 90 percent of the hair follicles are in the anagen phase, 2 percent are in the catagen phase, and 10 to 18 percent are in the telogen phase. Once the hair reaches the telogen phase, the follicles have achieved a mature, stable stage of quiescence. During the telogen phase, the hair is anchored in the follicle only by the root, which is club-shaped. The germ cells below the club-shaped root will give rise to the next generation of an anagen hair. The replacement of human scalp hair occurs in a scattered mosaic fashion with no apparent wave-like or seasonal pattern. The average period of growth for scalp hair is approximately 1,000 days; the resting phase lasts about 100 days. Approximately 10 percent of the hairs on a human head (100/1000), therefore, are in the quiescent telogen phase, and a minimal amount of force—such as that from combing—is required to dislodge the hairs from the dormant follicle.

**A hair forcibly removed from the scalp will exhibit stretching and damage to the root area.**

**Forcibly removed hairs**
**may have tissue attached.**

The basic morphology of human hairs is shared by each individual in the population, but the arrangement, distribution, and appearance of individual microscopic characteristics within different regions of hair routinely allow a skilled hair examiner to differentiate hairs between individuals. An analogy would be the ability of an individual to recognize the face of a friend or relative in a crowd even though each person in the crowd possesses ears, eyes, a nose, and a mouth.

**Animal Hairs**

Animal hairs discovered on items of physical evidence can link a suspect or location to a crime of violence. A victim placed in a vehicle or held at a location where animals are routinely found often results in the transfer of animal hairs to the victim's clothing. Cat or dog hairs can be found on the adhesive portions of ransom and extortion notes prepared by pet owners. The transfer of pet hairs to the victim or crime scene may also occur when the suspect is a pet owner and has animal hairs on his or her clothing when the contact occurs. This is referred to as a secondary transfer of trace material.

When an animal hair is found, it is identified to a particular type of animal and microscopically compared with a known hair sample from either an animal hair reference collection or a specific animal. If the questioned hair exhibits the same microscopic characteristics as the known hairs, it is concluded that the hair is consistent with originating from that animal. It is noted, however, that animal hairs do not possess enough individual microscopic characteristics to be associated with a particular animal to the exclusion of other similar animals.

The collection of a suitable known animal hair standard is necessary before a meaningful comparison can be conducted. Because hairs can vary widely in color and length on different areas of the body of an animal, hairs should be collected from each area. While a minimum number of hairs is difficult to determine, good judgment should be used in collecting enough hairs to represent the various types and colors of hairs found on the animal. The sample should contain full-length hairs and should include combings as well as pluckings. If the animal is not available for sample collection, a brush or comb used for the animal may be substituted. Sometimes hair samples collected from a dog or cat bed may be useful when actual samples from the animal cannot be obtained.

**A muskrat hair**

**A deer hair**

Animal hairs found at crime scenes or on the clothing of suspects and victims may also have originated from a fur coat or pelt. These hairs may have been artificially colored or trimmed and often do not have a root. It is preferred that the entire fur garment be obtained so that suitable known samples can be submitted for comparison.

**Human Hairs**

As stated previously, physical contact may result in the transfer of hairs. These can transfer directly from the region of the body where they are growing—a primary transfer—or they can transfer from the clothing of individuals—a secondary transfer. It has been reported that approximately 100 head hairs are shed by an individual each day. These hairs are shed on clothing and on items in the environment. Contact between a victim and a suspect's environment can easily cause a secondary transfer of hair. Hairs that are found on the clothing of suspects or victims and appear to have fallen out naturally may be the result of primary or secondary transfer. Hairs that have been forcibly removed may suggest a violent confrontation.

**Body Area Determination**

The body area from which a hair originated can be determined by general morphology. Length, shape, size, color, stiffness, curliness, and microscopic appearance all contribute to the determination of body area. Pigmentation and medullar appearance also influence body area identification. Hairs that exhibit microscopic characteristics shared by different anatomical areas are often referred to as body hairs. These include hairs found on the upper legs, lower abdomen, and back. Because there is a wide range of interpersonal variation in head and pubic hairs, the majority of work in forensics has been in comparing and differentiating hairs from the head and pubic regions.

**Head Hairs**

Head hairs are usually the longest hairs on the human body. They are characterized as having a uniform diameter and, often, a cut tip. Head hairs can appear uncut, with tapered tips but are more often cut with scissors, razors, or clippers. In general these hairs are subject to more alteration than hairs from other body areas. Alterations to the natural appearance of hair include use of hair dyes, rinses, permanents, frosts, and

**A razor-cut hair**

other chemical applications.
Environmental alterations can result from exposure to excessive sunlight, wind, dryness, and other conditions. Because these hairs can be affected by a number of environmental and chemical conditions, it is recommended that head hair samples be obtained as soon as possible from suspects and victims of crime. Head hair samples obtained years after a crime are generally not suitable for meaningful comparison purposes.

**A split hair**

As head hairs are routinely compared in a forensic laboratory, it is important to obtain suitable known samples from suspects and victims and possibly from other individuals (elimination samples). The known sample should contain a random sampling of hair from different areas of the scalp. The number of hairs required for a meaningful comparison may vary depending on the uniformity of characteristics present in the hairs from an individual. Because this is not known when the hair sample is taken, obtain at least 25 full-length hairs. This hair sample should include both plucked and combed hairs, packaged separately.

**A hair with a cut tip**

**Pubic Hairs**

Pubic hairs are also routinely compared in a forensic laboratory. As with head hairs, considerable variation exists between individuals in the population. Pubic hairs are not subject to as much change as head hairs over time, and because of this, a sample taken a year or more after a crime may still be suitable for meaningful comparison purposes. It is recommended that a known pubic hair sample be obtained as soon as possible after a crime and should contain at least 25 full-length hairs taken from different areas of the pubic region.

**A hair showing buckling**

Pubic hairs are generally coarse and wiry in appearance. They exhibit considerable diameter variation or buckling and often have a continuous to discontinuous medulla. While tapered tips are common, these hairs may also be abraded or cut.

**Facial Hairs**

Facial hairs are more commonly called beard hairs or mustache hairs. These hairs are coarse in appearance and can have a triangular cross section. Heavy shouldering or troughs in the hair are observed under magnification. Other characteristics include a wide medulla and a razor-cut tip.

The presence of facial hairs on the clothing of a suspect or victim may help establish contact between these individuals. While these hairs may be compared microscopically, the significance of the association may not be as great as head hair and pubic hair associations.

**Limb Hairs**

Hairs from the legs and arms constitute limb hairs. These hairs are shorter in length, arc-like in shape, and often abraded or tapered at the tips. The pigment in limb hair is generally granular in appearance, and the medulla is trace to discontinuous.

While limb hairs are not routinely compared in a forensic laboratory, they can differ in appearance between individuals. These differences, however, are not considered sufficient to allow limb hairs to be of value for meaningful comparison purposes. The presence of leg or arm hairs on certain items of evidence may help to corroborate other investigative information.

**Fringe Hairs**

Hairs originating from areas of the body outside those specifically designated as head or pubic are generally not suitable for significant comparison purposes. These hairs might originate from the neck, sideburns, abdomen, upper leg, and back.

**Other Body Area Hairs**

Axillary (underarm) hairs, chest hairs, eye hairs, and nose hairs are not routinely compared. As with limb hairs and fringe hairs, their presence may help to corroborate information obtained during an investigation.

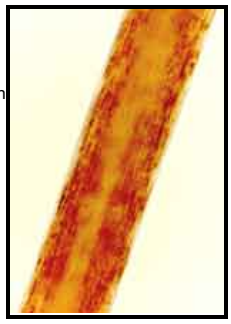
**Racial Determination**

A human hair can be associated with a particular racial group based on established models for each group. Forensic examiners differentiate between hairs of Caucasoid (European ancestry), Mongoloid (Asian

ancestry), and Negroid (African ancestry) origin, all of which exhibit microscopic characteristics that distinguish one racial group from another. Head hairs are generally considered best for determining race, although hairs from other body areas can be useful. Racial determination from the microscopic examination of head hairs from infants, however, can be difficult, and hairs from individuals of mixed racial ancestry may possess microscopic characteristics attributed to more than one racial group.

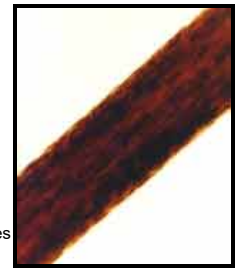
The identification of race is most useful as an investigative tool, but it can also be an associative tool when an individual's hairs exhibit unusual racial characteristics.

**Caucasoid (European)**
Hairs of Caucasoid or Caucasian origin can be of fine to medium coarseness, are generally straight or wavy in appearance, and exhibit colors ranging from blonde to brown to black. The hair shafts of Caucasian hairs vary from round to oval in cross section and have fine to medium-sized, evenly distributed pigment granules.



**Caucasian or European hair**

**Mongoloid (Asian)**
Hairs of Mongoloid or Asian origin are regularly coarse, straight, and circular in cross section, with a wider diameter than the hairs of the other racial groups. The outer layer of the hair, the cuticle, is usually significantly thicker than the cuticle of Negroid and Caucasian hairs, and the medulla, or central canal, is continuous and wide. The hair shaft, or cortex, of Mongoloid hair contains pigment granules that are generally larger in size than the pigment granules of Caucasian hairs and which often appear to be grouped in patchy areas within the shaft. Mongoloid hair can have a characteristic reddish appearance as a product of its pigment.



**Mongoloid or Asian hair**

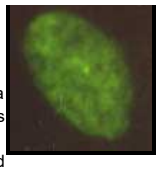
**Negroid (African)**
Hairs of Negroid or African origin are regularly curly or kinky, have a flattened cross section, and can appear curly, wavy, or coiled. Negroid pigment granules are larger than those found in Mongoloid and Caucasian hair and are grouped in clumps of different sizes and shapes. The density of the pigment in the hair shaft may be so great as to make the hair opaque. A Negroid hair shaft exhibits variation or apparent variation in diameter because of its flattened nature and the manner in which it lies on the microscope slide. Twisting of the hair shaft, known as buckling, can be present, and the hair shaft frequently splits along the length.

**Negroid or African hair**

**Age and Sex**

The age of an individual cannot be determined definitively by a microscopic examination; however, the microscopic appearance of certain human hairs, such as those of infants and elderly individuals, may provide a general indication of age. The hairs of infants, for example, are generally finer and less distinctive in microscopic appearance. As individuals age, hair can undergo pigment loss and changes in the configuration of the hair shaft to become much finer and more variable in diameter.

Although the sex of an individual is difficult to determine from microscopic examination, longer, treated hairs are more frequently encountered in female individuals. Sex can be determined from a forcibly removed hair (with tissue), but this is not routinely done. Definitive determination of sex can be accomplished through the staining of sex chromatin in the cells found in the follicular tissue, but nuclear DNA and mitochondrial DNA (mtDNA) tests will provide more specific information regarding the possible origin of the hair.



**Stained sex chromatin in the nuclei of human cells showing the female-indicative Barr body (bright spot, top) and the male-indicative Y body (bright spot, bottom)**

**Treatment and Removal**

The presence of artificial treatment such as dyes or rinses can be identified through microscopical examination. Inasmuch as head hairs grow at the rate of one centimeter per month, the approximate time of this treatment can be determined by measuring the length of untreated area of the hair. A direct, side-by-side comparison of the color of the questioned and known artificially treated hairs is typically conducted by a hair examiner.

As stated previously, the condition of the root area of a hair allows the hair examiner to microscopically determine whether the hair was forcibly removed from the body or shed naturally. Hairs that fall out naturally have a club-shaped root, whereas a forcibly removed hair will be stretched and may have tissue attached to it. The manner in which a hair was removed can have considerable value, especially when there is a possibility of violent contact between a suspect and a victim. The identification of burned, cut, or crushed hairs can also be established through microscopic examination.

**Biological or Environmental Alteration**

The microscopic appearance of hairs is affected by natural biological fluctuations and environmental influences. For this reason, it is important that known hair standards are collected contemporaneously to the deposition of questioned hairs. Head hairs are most affected by these factors, whereas pubic hairs are less influenced. A time period of several months to years can detract from a meaningful head hair comparison, whereas several years may not severely impact on meaningful pubic hair comparisons.

When hairs originate from a body in a state of decomposition, a dark band may appear near the root of the hair. This characteristic has been labeled a postmortem root band.

**A postmortem root band**

**Conclusions**

There are several possible conclusions that can be reached from the microscopic examination and comparison of human hairs. When the questioned hair(s) is compared to the known hairs using a comparison microscope, the full length of the hair(s) as well as the full range of microscopic characteristics must be considered. Following their analyses, hair examiners may conclude the following:

- The questioned hair exhibits the same microscopic characteristics as the hairs in the known hair sample and, accordingly, is consistent with originating from the source of the known hairs.
- The questioned hair is microscopically dissimilar to the hairs found in the known hair sample and, accordingly, cannot be associated to the source of the known hairs.
- Similarities and slight differences were observed between the questioned hair and hairs in the known hair sample. Accordingly, no conclusion could be reached as to whether the questioned hair originated from the same source as the known hairs.

When a hair exhibits the same microscopic characteristics as hairs in the known hair sample, a qualifying statement may be added to the report. This statement may read as follows:

> Hair comparisons are not a basis for absolute personal identification. It should be noted, however, that because it is unusual to find hairs from two different individuals that exhibit the same microscopic characteristics, a microscopic association or match is the basis for a strong association.

**Significance of Hair Evidence**

The significance of hair examination results is dependent on the method of evidence collection used at the crime scene, the evidence processing techniques employed, the methodology of the hair examination

process, and the experience of the hair examiner. Head hairs and pubic hairs are routinely held as more significant than hairs from other body areas.

Certain case situations affect the significance of identifying hairs. When a family member may be involved in a crime, the location, number, and condition (forcibly pulled or burnt, for example) of recovered hairs may be important. The involvement of the victim's associates, including dates, coworkers, and other people who may have logical contact with or access to the victim and/or crime scene is an additional consideration in hair examinations. Situations involving strangers have greatest significance when hair associations have been made.

**Hair affected by burning**

Questions concerning hair examinations and their significance include:

- Is the significance of a hair association dependent on a set number of compared characteristics?
- Does the length of the compared hairs affect the significance of an association?
- Does treatment influence the significance?
- Are hairs of specific racial groups more significant than others?
- Do hair sprays, gels, or other hair applications influence the significance of a hair match?
- Is a hair match significant when the comparison was made with a limited number of known hairs?

The hair identification process involves the examination and comparison of hair characteristics along the entire length of the hair(s). Longer hairs have more characteristics to compare, and the greater the variation along the length, the greater the degree of significance.

The value of the evidence in establishing a particular association can be influenced by

- the probability that the association (or elimination) was due to coincidence,
- the probability that the association (or elimination) was due to examiner error, and
- the probability that there is an alternative explanation for the evidence, such as secondary transfer, contamination, or deliberate planting.

The significance of a hair match is influenced by how often the examiner has seen certain characteristics as well as by how often the examiner has seen hairs of a particular race or body area.

The range of opinions concerning hair examinations includes:

- Nothing about hair is comparable to the specificity of fingerprints, and at best, the probability of establishing identification from hair is no greater than the probability of determining identification using the ABO blood group system;
- Research studies have shown that hairs from two individuals are distinguishable; that no accidental or coincidental matches occurred; and that such accidental or coincidental matches would, in actual casework, be a relatively rare event; and
- The significance of a hair match is a median point between the above statements.

It has also been stated that hair evidence is only of value when used in conjunction with other evidence.

Positive hair comparison conclusions may be weakened by the presence of incomplete hairs; by common, featureless hairs; and by known samples with large intrasample variation. Conversely, positive hair comparison conclusions are strengthened by the presence of two or more mutually dissimilar hairs that are similar to a known sample; by hairs with unusual characteristics; by two-way transfers; and by additional examinations of confirmation, such as DNA and sex-typing.

Normal negative hair comparison conclusions are weakened by deficiencies in the known hair sample, including too few hairs, unrepresentative hairs, incomplete hairs, and a significant temporal difference between the offense and the collection of the known sample. Negative hair comparison conclusions are also weakened by the presence of incomplete questioned hairs and by similarities and differences within the hair sample.

Factors which strengthen normal negative hair comparison conclusions include a large quantity of known sample hairs; little intrasample variation within the known sample; and hairs that are very dissimilar, such as those exhibiting distinct racial and/or microscopic characteristics. Two or more questioned hairs that are found together in a clump and are dissimilar to the known sample will also support a negative hair comparison conclusion.

**To Fiber Evidence**

**To Crime and Evidence**