Forensic Human Hair Examination Guidelines

Scientific Working Group on Materials Analysis (SWGMAT

April 2005

1. Introduction

Hair examinations and comparisons, as generally conducted by forensic scientists, often provide important investigative and associative information. Human and animal hairs have been used in forensic investigations for over a century. Reports abound in the literature concerning the use of human and animal hairs encountered in forensic casework. These guidelines represent a recommended procedure for the forensic examination, identification, and comparison of human hair.

Hairs are readily available for transfer, easily transferred, and resilient. Hair examination may be used for associative and investigative purposes and to provide information for crime scene reconstruction.

The ability to perform a forensic microscopical hair comparison is dependent on a number of factors. These factors include the following:

- Whether an appropriate known hair sample is representative.
- The range of features exhibited by the known hairs.
- The condition of the questioned hair.
- The training and experience of the hair examiner.
- The usage of the appropriate equipment and methodology.

DNA analysis can be performed on hair but should be performed only after an initial microscopical assessment. A full and detailed microscopical comparison with possible known sources of hair should be done prior to DNA analysis. Microscopical comparisons cannot always be done after DNA analysis, which is destructive to at least a portion of the hair. DNA analysis should always be considered in those cases when the source of a hair is crucial to an investigation.

2. Referenced Documents

2.1. Scientific Working Group on Materials Analysis. Trace evidence quality assurance guidelines, *Forensic Science Communications* [Online]. (January 2000). Available: www.fbi.gov/hq/lab/fsc/backissu/jan2000/swgmat.htm.

2.2. Scientific Working Group on Materials Analysis. Trace evidence recovery guidelines, *Forensic Science Communications* [Online]. (October 1999). Available: www.fbi.gov/hq/lab/fsc/backissu/oct1999/trace.htm.

3. Terminology

The terms in this section are defined by how they are used in forensic hair examinations.

Amorphous medulla is a medulla that has no distinct form, pattern, or shape when viewed with a transmitted light microscope.

Anagen is the active growth phase of a hair follicle in the hair growth cycle. The root from a pulled anagen hair is elongated, may be covered with a root sheath, and is usually fully pigmented.

Association is the determination that two or more hairs could share a common origin.

Bleaching is a chemical or a natural process used to make a hair colorless or lighter than its usual color.

Buckling is an abrupt change in the shape and orientation of a hair shaft with or without a slight twist, often seen in pubic hairs.

Catagen is the transitional phase of the hair follicle from the active growth phase (anagen) to the resting growth phase (telogen) in the hair growth cycle.

Caucasoid is an anthropological term designating one of the major groups of human beings originating from Europe and originating from the Indian subcontinent.

Characteristic is a microscopic or macroscopic feature or attribute of a hair.

Color is the aspect of objects that may be described in terms of hue, lightness, and saturation. It should be recognized that the macroscopical and microscopical colors of hairs might appear different.

Comparison is the examination of two or more hairs to evaluate whether or not they could have come from the same source.

Continuous medulla is a medullary appearance showing no disruptions along the shaft of the hair.

Convolution is a rotation or twisting of the hair shaft that can occur naturally, from disease, or as a result of mechanical force.

Cortex is the primary anatomical region of a hair between the cuticle region and the medullary region composed of elongated and fusiform cells.

Cortical fusi are small spaces that appear as tiny dark structures in the hair shaft; they can be filled with air or liquid.

Cortical texture is the relief or definition of the margins of the cortical cells when viewed using transmitted light microscopy.

Cracked cuticle is a cuticle with linear breaks that are perpendicular to the length of the shaft.

Cross-sectional shape is the shape of a hair shaft cut and viewed at a right angle to its longitudinal axis.

Cuticle is the outermost region of a hair composed of layers of overlapping scales.

Cuticle thickness is the relative size of the cuticle from its outer margin to the cortex when viewed microscopically. This is usually described as thin, medium, or thick.

Deoxyribonucleic acid (DNA) is a long macromolecule that carries a person's genetic information.

Discontinuous medulla is a medullary appearance in which the proportion of the visible areas of medulla is greater than the areas when the medulla is not visible.

Dissimilar is a term that refers to the existence of significant differences among questioned and known hairs.

Distal end is the end of the hair away from the root.

Dye is a chemical used to artificially color hair.

Eumelanin is the brown pigment occurring in human and animal hair.

Follicle is the cavity in the skin from which hair grows.

Follicular tag is tissue from a hair follicle that is still attached to the root end of a hair.

Fragmented medulla is a medullary appearance in which the proportion of the visible areas of medulla is less than the areas when the medulla is not visible.

Fungal tunnels are air pockets in a hair shaft caused by fungal growth.

Fusiform is a term that refers to a spindle-shaped (tapered at each end) gap present in the hair shaft.

Hair is a fibrous outgrowth from the skin of mammals.

Hair peripilar cast is a freely movable, firm, yellowish-white material ensheathing scalp hairs resulting from scalp disorders, such as psoriasis or seborrhoeic dermatitis.

Identification is the process of classifying a given hair as a member of a defined class of hairs (e.g., human, animal, body area).

Imbricate is a term that describes a scale pattern with edges overlapping in a wavy pattern. This pattern is typical of human hair.

Inconclusive is a term that refers to a conclusion that is reached due to the inability to include or exclude a questioned hair as similar to the known hair sample.

Individualization is the process of attempting to determine whether a given hair came from one particular (person) source to the exclusion of all other sources. This is not possible with forensic microscopical hair comparison.

Inner cuticle margin is the apparent border between the cortex and the visible cuticle.

Keratin is a class of sulfur-containing fibrous proteins that forms the foundation of outgrowth tissue from the epidermis, such as hair, nails, feathers, and horns of animals.

Known sample is a collected hair sample intended to be representative of a particular body area of a specific person or animal.

Lanugo are fine hairs found on newborns, lost shortly after birth.

Lice are parasitic insects that may be found on humans. These include head lice, body or clothing lice, and crab lice that live in the pubic region, eyelashes, or eyebrows.

Limited sample is a sample of known hairs that is insufficient in quality or quantity to adequately represent all possible characteristics or traits.

Looped cuticle is a feature in which the distal edges of the cuticular scales are curved from or cup toward the hair shaft.

Macroscopic is a term that describes characteristics large enough to be perceived without magnification.

Medial region is the portion of the hair between the proximal and distal ends.

Medulla is the core of the hair shaft that is composed of air vacuoles and cells.

Medullary configuration is the form of medullary cells from the proximal end to the distal end of the hair shaft.

Melanin is a natural pigment of which two forms, eumelanin and phaeomelanin, determine the color of human and animal hair.

Microscopic is a term that describes characteristics too small to be resolved by the unaided eye but large enough to be resolved with the microscope.

Mitochondrial DNA (mtDNA) is DNA found in the mitochondria of cells.

Mongoloid is an anthropological term designating one of the major groups of human beings originating from Asia, excluding the Indian subcontinent and including Native American Indians.

Monilethrix is a hair disorder that results in periodic nodes or beading along the length of the hair with intervening, tapering constrictions that are not medullated.

Negroid is an anthropological term designating one of the major groups of human beings originating from Africa.

Nits are lice eggs attached to the hair shaft.

Nuclear DNA (nDNA) is DNA found in the nucleus of cells.

Opaque medulla is a medulla with large pockets of air causing it to appear black when viewed with transmitted light microscopy.

Ovoid bodies are oval-shaped, heavily pigmented bodies usually found in the hair cortex.

Peripheral region is the portion of the hair including the cuticle and the outer areas of the cortex most distant from the medullary or central region.

Phaeomelanin is a reddish-brown to yellow pigment occurring in human and animal hair.

Pigment aggregation is the cluster of individual pigment granules.

Pigment density is the relative abundance of pigment granules in the hair cortex when viewed microscopically.

Pigment distribution is the pattern of the pigment granules observed in the hair shaft, such as uniform, peripheral, one-sided, variable, or central.

Pigment granules are small particles in a hair that impart color.

Pili annulati is a hair disorder that results in ringed or banded hair, alternating bright and dark bands in the hair shaft. The dark bands are a manifestation of the abnormal air spaces in the cortex.

Pili torti is a genetic hair disorder characterized by the hair shaft being flattened and twisted 180 degrees numerous times along its axis. It is usually found at irregular intervals along the shaft.

Polymerase chain reaction (PCR) is a laboratory process in which specific short segments of DNA are replicated (amplified) to enable subsequent analysis and identification.

Postmortem banding is the appearance of an opaque microscopic band near the root area of hairs from a decomposing body.

Proximal end is the portion of the hair towards the root.

Putrid root is a tapered or brush-like appearance of the proximal end caused by decomposition.

Questioned sample is a sample of unknown origin.

Range is the variation of a specific characteristic exhibited by a hair or hairs from one person.

Representative sample is a collection of hairs from a specific body area that reflects the range of characteristics in a person's hair.

Root is the follicular structure at the proximal end of a hair.

Root sheath is the follicular tissue occasionally found surrounding a root structure.

Sample is one or more hairs used for identification, comparison, and/or reference.

Scales are tiny plate-like structures composed of keratin that forms the cuticle.

Serrated cuticle is a cuticle in which the outer margin has the notched appearance of a saw blade.

Shaft is the portion of the hair external to the hair follicle.

Shaft form is the macroscopic shape of the hair.

Shaft thickness is the diameter of the hair. This may be expressed numerically or in relative terms, such a thin, medium, or thick.

Shouldering is a radial protrusion of the hair shaft causing an irregular cross-section.

Similar is a term used to describe an association among questioned and known hairs. This term implies that no significant unexplained differences exist among the known and questioned hairs or that they are indistinguishable. This term has been used interchangeably with consistent with, cannot be eliminated, could have come from, could have originated from, match, microscopically alike, and the same as.

Somatic is an area of the body, such as head, pubic, or leg.

Splitting is damage usually occurring at the distal end of a hair when the hair divides down the long axis.

Telogen is the last phase of the hair growth cycle when the hair root becomes keratinized and bulbous-shaped (club-like).

Texture is the appearance and feel of a hair due to its length, thickness, and shaft form.

Tip is the most distal end of a hair shaft.

Translucent is a condition when light is transmitted through a material and diffused so that objects beyond cannot be seen clearly. The appearance of a medulla that has cells filled with fluid rather than air is translucent rather than opaque.

Trichology is the study of hair.

Trichonodosis is a condition characterized by apparent or actual knotting of the hair.

Trichoptilosis is a disease condition characterized by longitudinal splitting or fraying of the hair shaft.

Trichorrhexis invaginati is a genetic disease characterized by a segment of bulbous, dilated hair enfolded into a concave hair terminal, recalling the appearance of a bamboo node. If the hair breaks at the bulbous end, the hair has a golf-tee cup end.

Trichorrhexis nodosa is a condition characterized by the formation of nodes. The hair is weaker at the node and subject to breakage.

Trichoschisis is a condition characterized by brittle hair with a transverse crack or a clean break.

Undulation is change in the true diameter along the length of the hair shaft that results in change in the cross-sectional shape. This can give the hair a wavy appearance.

Vellus are fine body hair.

4. Duties, Qualifications, and Training

The duties, qualifications, and training of a hair examiner are in the Scientific Working Group on Materials Analysis *Trace Evidence Quality Assurance Guidelines* available at www.fbi.gov/hq/lab/fsc/backissu/jan2000/swgmat.htm.

5. Summary of Guidelines

These guidelines include a summary of techniques for collecting hair samples, a description of the instrumentation used in the microscopical examination of hair, a description of the microscopical examination, a discussion on how to interface with subsequent DNA analysis of hair, and a discussion of the conclusions that result from the microscopical hair examination.

6. Significance and Use

A hair examination is usually used to determine if the item is

- A hair.
- From a human or another animal.
- From certain body areas.
- Characteristic of a certain racial group.
- Characteristic of a particular growth phase.
- Damaged.
- Diseased.
- Associated with other trace evidence.
- Chemically altered, such as dyed or bleached.
- Suitable for microscopical comparison.
- Suitable for DNA analysis.
- Similar to a known hair sample from a particular person.

Most often, hairs from the scalp and pubic regions of the body are used for microscopical comparisons. There is usually more interpersonal variability in the characteristics of scalp and pubic hairs than in the hairs from other body regions. Scalp hairs usually show more interpersonal variation than pubic hairs. Hairs from other body areas may also be compared, but these comparisons are usually less significant and less frequently conducted. Accordingly, these guidelines primarily reflect the considerations of human scalp and pubic hair comparisons.

It should be noted that microscopical hair comparisons are not a means of positive identification.

7. Sample Collection

Refer to the Scientific Working Group on Materials Analysis *Trace Evidence Recovery Guidelines*, Section 5, available at www.fbi.gov/hq/lab/fsc/backissu/oct1999/trace.htm for an overview of trace evidence recovery and packaging guidelines. The following is an expansion as applied to hair evidence.

7.1. Questioned Sample

Loose hairs should be collected from an object by picking them off individually. Hairs that are embedded in or adhering to a person or object must be carefully inspected before removal. If appropriate, the location of these hairs should be carefully documented. Care must be taken not to contaminate, crush, or break the hairs.

The remaining hairs can be collected from clothing, bedding, or other large surfaces by adhesive lifts. Be aware that the adhesive from the lifting material could interfere with the analysis of surface treatments that might be present on the hairs. Hairs can also be collected from an item by scraping or vacuuming. These techniques are described in the *Trace Evidence Recovery Guidelines*.

When retrieving evidence from a person's head or pubic region, the combing technique can be used. Always use a new comb or brush. Lacing the teeth of a comb with clean cotton or gauze may help to retain hairs and debris on the comb. Place a piece of clean paper under the area that is combed to catch loose hairs and debris. This paper should be included in the evidence package with the comb.

7.2. Known Sample

Collect known hairs from specific somatic regions of relevant people for comparisons to questioned hairs. Every effort should be made to see that these hairs are collected as soon as possible relative to the occurrence.

Full length hairs with roots should be obtained for the examiner to examine and compare hairs. Because the majority of pulled hairs will likely be in an active growing stage, a separate combing procedure can be used to obtain hairs in the telogen stage. A combing procedure for known hairs can be done after the combing for foreign hairs. The regions being sampled should be repeatedly combed or brushed over a large sheet of clean paper. It is desirable to package the pulled known hairs and combed known hairs separately.

Different hairs from the same body region of a person exhibit variation in microscopical characteristics and features. Therefore, it is important to obtain a sufficient number of hairs in order to adequately represent the range of values of all characteristics present. If the range is large, it becomes necessary to obtain a large number of hairs. Package hairs from the different body areas in separate containers.

A known head hair sample should consist of hairs from the five different areas of the scalp (top, front, back including nape, and both sides). Known hair samples should be obtained by a combination of pulling and combing from the sampled region. Ideally, a total of 50 hairs should be obtained from the scalp. A known pubic hair sample or a sample from any other somatic region should ideally consist of 25 hairs obtained by pulling and combing from different regions. A comparison can still be performed with less than the recommended number of hairs, but this may increase the likelihood of a false exclusion.

Known samples may be requested from all persons who might reasonably be considered a source of a questioned hair. If such samples are obtained and excluded as the source of the questioned hair, the significance of any ensuing association is increased.

8. Summary of Equipment

8.1. Stereomicroscope

A stereomicroscope with a magnification range up to 100X is useful for the initial examination of mounted and unmounted hairs.

8.2. Transmitted Light Microscope

A high-quality transmitted light microscope is necessary to examine and identify the microscopical characteristics of hairs. The objectives and eyepieces should permit observations in the range of approximately 40X to 400X. A polarized light microscope may enhance the hair examiner's ability to see certain features and determine the cross-sectional shapes of the hairs.

8.3. Comparison Microscope

The use of a high-quality transmitted light comparison microscope is mandatory when comparing the microscopical characteristics of hairs. High-quality objectives are important, but highly corrected planapochromats are not necessary. The objectives and eyepieces selected, however, should permit observations in the range of approximately 40X to 400X. A high-intensity tungsten light source, suitable for photomicrography and equipped with a daylight correction filter, provides adequate lighting. Both sides of a comparison microscope should be balanced for light intensity and color. A comparison microscope may be equipped with one of several types of stages.

8.4. Microscope Maintenance and Performance Check

8.4.1. Maintenance

The hair examiner should be familiar with the instruction manual and the manufacturer's maintenance recommendations for each microscope used in hair examination.

To ensure the precision, reliability, and performance of the polarized light and comparison microscopes, the following procedures for the maintenance of the microscopes should be performed on a routine basis.

- Clean dust, oil, and dirt from the optics according to the manufacturer's recommendations.
- Clean the external surfaces.
- Check the optical alignment and realign, if necessary, to establish proper illumination.
- When not in use, cover with dust cover.
- If the microscope cannot be cleaned or aligned properly, discontinue use until the microscope is repaired.
- Record all service and repairs in a log; however, routine cleaning and aligning of the microscope need not be recorded in the log.

8.4.2. Performance and calibration checks

8.4.2.1. Calibration of the ocular micrometer

In order to measure the thickness of a hair, the examiner must have a calibrated ocular micrometer in the microscope. The steps for calibrating the ocular micrometer are listed below.

- Place a stage micrometer with a linear scale of known dimensional divisions on the stage of the microscope.
- Focus on the dividing lines of the stage micrometer.
- Align the scale in the ocular with the scale on the micrometer.
- Determine the number of ocular divisions that equal a defined increment of the stage micrometer.
- If 10 ocular units equal 100 microns, then each ocular unit is 10 microns at this magnification.
- This procedure should be repeated for each objective.

8.4.2.2. Magnification check

The magnification of the comparison microscope should be checked to ensure that the left and right images are magnified to the same degree. If the magnification is not the same, the examiner should request matching objectives from the manufacturer.

8.4.2.3. Color balance

The color balance of the comparison microscope should be checked to ensure uniform color between left and right fields of view. If the color balance is not acceptable, then the examiner should discontinue use and correct the problem. The color balance can be checked by the following procedure:

- Cut a uniformly colored sample in half and mount it on two separate slides.
- Place one slide on the left stage and the other slide on the right stage of the comparison microscope.
- Compare the color of the images.

If the color is balanced, the sample images and the background color on both sides should appear to be the same.

If the color is not balanced, then correct the problem or contact the microscope manufacturer for instructions on how to properly balance the microscope for color.

9. Microscopical Examination

The procedure used by the hair examiner should incorporate the general guidelines discussed in this document. Evidence handling and the correct use of equipment should be consistent with Scientific Working Group on Materials Analysis guidelines.

Blood or debris on a hair sample may be significant. If the adhering material is of evidential value, the examiner should consider removing and preserving it for possible future analysis. In a situation when the adhering material is not of evidential value, the hair may be washed or cleaned prior to mounting. The presence of a small amount of blood or debris on a hair may not interfere with the microscopical examination. A washed hair should be allowed to air dry prior to mounting.

Hair exhibiting thermal or mechanical damage may be more brittle and should be handled minimally and with more care.

9.1. Macroscopical and Stereomicroscopical Examination

Macroscopical and stereomicroscopical examinations are useful for observing hair characteristics, such as color, length, shape, and texture. This is an important step in identifying hairs, assessing which are suitable for comparison, determining the presence of other trace materials, and evaluating which hairs have roots suitable for nuclear DNA analysis.

9.2. Transmitted Light Microscopy

The internal microscopic characteristics of hair can be observed easily in transmitted light when the hairs are appropriately mounted.

9.2.1. Mounting

A colorless, nonyellowing mounting medium with a refractive index in the range of 1.50 to 1.60 should be used to view hairs in transmitted light. The analysis of surface particulates and biological material, compatibility with DNA analysis, and ease of artifact isolation can influence the selection of a mounting medium.

One hair or multiple hairs from the same source may be mounted on a glass microscope slide with an appropriate cover slip. Each mounted hair must be clearly visible. Each slide must be

labeled as to the source of the hairs. Questioned and known hairs should be mounted in the same type of mounting medium.

9.2.2. Questioned hairs

Questioned hairs are examined microscopically to determine if they originate from a human or another animal. If the hair is of human origin, determine, if possible, race, body area, and suitability for comparison (See Sections 6 and 10).

9.2.3. Known sample

An adequate number of hairs that represent the range of features present in the sample are selected for comparison. The selection should be primarily based on macroscopical and stereomicroscopical characteristics, such as length, shape, and color. These hairs are mounted and then examined in the same manner as the questioned sample.

9.3. Comparison Microscopy

Hair comparisons are usually conducted among questioned and known hairs. Comparisons must be conducted among hairs of the same somatic region. When possible, the hair examiner should use known hairs of similar length, each with a root present and in a similar growth phase as the questioned hair. A comparison using the unaided eye or a stereomicroscope may be sufficient for elimination purposes in some cases when the differences are obvious.

A hair characteristic at any one area along the length of a questioned hair should be compared with that characteristic at the corresponding area along the known or comparison hairs. The appearance of a particular hair characteristic is usually not constant along successive portions of a single hair from root to tip. These variations depend on genetic factors and external factors, such as growth phase, hair length, health, environment, and grooming habits. The hair examiner identifies the range of characteristics exhibited by the known sample and compares these characteristics on a side by side basis with the questioned hair(s) using a comparison microscope.

It is desirable to have a second hair examiner verify every microscopical hair association that may have probative value. The laboratory should have a procedure in place for resolving differences of opinion that occur during a verification of a hair association.

10. Hair Characteristics and Other Determinations

10.1. Human or Other Animal Origin

Human hair can be distinguished from other animal hair by examining features, such as scale pattern, medulla, root, color, hair length, and shaft configurations.

10.2. Somatic Origin

Somatic origin types may include scalp, pubic, facial, limb and body, and eyebrow and eyelash hairs. Somatic origin of human hair can usually be established by considering features, such as length, cross-sectional shape, shaft configuration, medullary configuration, texture, taper, and appearance of the root.

10.3. Racial Group

Features, such as color, shaft configuration, cross-sectional shape, pigment distribution, hair diameter, and cuticle can be used to classify a hair as having characteristics typical of particular racial groups, such as Caucasoid, Negroid, and Mongoloid. The examiner should be alert to the possibility of mixed racial characteristics and atypical features. Opinions about the racial origin of a hair should be formulated with caution.

10.4. Human Hair Characteristics

The following is a list of characteristics that may be used for classification and comparison of hairs. The characteristics listed below are not all-inclusive.

10.4.1. Macroscopic

10.4.1.1. Color (in reflected light)

- White
- Blonde
- Red
- Brown
- Black

10.4.1.2. Structure

Shaft form

- Straight
- Arced
- Wavy
- Curly
- Twisted
- Tightly coiled
- Crimped

Shaft length range in centimeters or inches

Overall shaft thickness

- Fine
- Medium
- Coarse

10.4.2. Microscopic

10.4.2.1. Color (in transmitted light)

Color

- Colorless (white)
- Blonde
- Red
- Brown

- Black

Natural pigmentation

- Pigment size
  - Coarse
  - Medium
  - Fine
- Pigment aggregation
  - Streaked
  - Clumped
  - Patchy
- Pigment aggregate size
  - Large
  - Medium
  - Small
- Pigment density
  - Absent
  - Light
  - Medium
  - Heavy
  - Opaque
- Pigment distribution
  - Uniform
  - Peripheral
  - One-sided
  - Random or variable
  - Central or medial
  - Pigment in cuticle
  - Banded

Color treatments

- Dyes (permanent, semipermanent)
- Temporary dyes (rinses, sprays, gels, mousses)
- Bleaches or lighteners

10.4.2.2. Structure

Shaft characteristics

- Diameter range in µm
- Cross-sectional shape
  - Round
  - Oval
  - Triangular
  - Flattened
- Shaft configurations
  - Buckling
  - Convoluting
  - Shouldering
  - Undulating
  - Splitting
  - Regular

Medulla

- Absent
- Continuous
- Discontinuous
- Fragmented
- Opaque
- Translucent
- Relative width
- Amorphous
- Other (i.e., doubled, tripled)

Cuticle

- Cuticle
  - Present
  - Absent
- Cuticle thickness
  - Thin
  - Medium
  - Thick
- Outer cuticle margin
  - Flattened
  - Smooth
  - Serrated
  - Cracked
  - Looped
  - Irregular or other
- Inner cuticle margin
  - Distinct
  - Indistinct
- Cuticle color and clarity
  - Natural
  - Pigment
  - Dye

Cortex

- Cellular texture
  - Coarse
  - Medium
  - Fine
- Ovoid bodies
  - Size
  - Distribution
  - Abundance
- Cortical fusi
  - Size
  - Shape
  - Distribution
  - Abundance

Ends

- Proximal ends
    - Root present
        - Telogen
        - Catagen
        - Anagen
        - Sheathed
        - Follicular tag
        - Postmortem banding
        - Putrid
    - Root absent
        - Severed
        - Decomposed
        - Crushed
- Distal ends
    - Tapered tips (uncut)
    - Rounded or abraded
    - Square cut
    - Angular cut
    - Frayed
    - Split
    - Crushed
    - Broken
    - Singed

10.4.2.3. Acquired characteristics

Artifacts

- Nits or lice
- Mold
- Fungal tunnels
- Insect bite marks
- Debris
- Blood

Abnormalities

- Pili annulati
- Trichoschisis
- Monilethrix
- Trichorrhexis nodosa
- Trichorrhexis invaginati
- Pili torti
- Trichonodosis
- Trichoptilosis

Artificial treatments (other than color)

- Hair spray
- Hair gel
- Permanents
- Hair cosmetics

Damage

- Environmental/chemical damage
- Mechanical damage
- Crushed
- Burned
- Glass cut
- Broken
- Frayed
- Twisted
- Tangled

10.5. References

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11. DNA Analysis and Hairs

11.1. DNA Profiling of Hairs

Almost every cell type in the human body is nucleated. Chromosomes are contained in the nucleus. Nuclear DNA (nDNA) is the major component of these chromosomes. In contrast, mitochondrial DNA (mtDNA) is located in mitochondria, which are found in the cytoplasmic portion of all cells. Numerous mitochondria are present in each of these cells; therefore, there are many more copies of mitochondrial DNA in each cell. Although nuclear DNA is inherited from both parents, mitochondrial DNA is inherited solely from the mother. When appropriate, the analysis of nuclear DNA is the recommended approach because of its potentially greater discrimination power.

Human hairs are amenable to nuclear DNA and mitochondrial DNA analyses. DNA analysis should always be considered in those cases when the source of a hair is crucial to an investigation. The condition and microscopical assessment of the hair will determine which type of DNA analysis should be employed.

Hair roots that are in the active growing phase (anagen) contain an abundance of nucleated cells in the root and in the surrounding sheath material. Shed hairs from telogen follicles are the most commonly encountered in casework. Telogen hairs without follicular tissue may not be amenable to nuclear DNA analysis because of the lack of nucleated cells. These hairs may contain sufficient mitochondrial DNA in their roots and hair shafts for analysis.

DNA analyses are destructive techniques and consume portions of the hair. A full and detailed microscopical comparison with possible known sources of hair should be done prior to DNA analysis because it cannot always be done afterwards. Microscopy and DNA analysis are often complementary. In some instances, the microscopical hair comparison may be inconclusive because the hair is fragmentary or the known hair sample was collected years after the questioned hair. These hairs can still be analyzed for DNA. Hairs that are excluded as having come from a person by a microscopical examination may not require DNA analysis.

In cases when useable DNA was not extracted from a hair, comparison microscopy may have provided an association of the questioned hair to the known hairs. Therefore, microscopical hair comparisons should be performed prior to DNA analysis. In addition, there will be instances when mitochondrial DNA may not provide adequate discrimination among people. People of the same maternal line of descent may not have different mitochondrial DNA types. In these cases, a microscopical examination might provide sufficient discrimination of their hair to associate a questioned hair to a particular person in that family group. A combination of mitochondrial DNA and comparison microscopy will often help to exclude or provide a stronger association than the use of either technique alone.

11.2. Preparing Hair Evidence for DNA Analysis

The hair examiner may need to isolate and prepare the hair for DNA analysis. The hair should be prepared and transferred in such a way as to minimize contamination and degradation. If the hair is

- Unmounted, place the appropriate portion of the hair in a clean container.
- Mounted in a temporary mounting medium, remove the hair from the medium. Clean with an appropriate solvent, dry, and place the appropriate portion of the hair in a clean container.
- Mounted in a semipermanent mounting medium, soak the slide in a solvent that dissolves the mountant until the coverslip can be removed. The coverslip can also be removed by rapid chilling (e.g., liquid nitrogen, dry ice). Remove the hair and rinse off remaining mountant with solvent. Place the appropriate portion of the hair in a clean container.

Reinspect the hair slide and container to ensure that the transfer of the appropriate portion of the hair was complete.

11.3. References

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12. Other Analytical Techniques

Other analyses may be performed on hairs that have been chemically altered or have trace materials on the surface, such as dyed hairs or hair care products. These techniques are beyond the scope of these guidelines because they are not used widely.

13. Documentation

The examiner's notes should accurately reflect macroscopical and microscopical observations and results that lead to the examiner's conclusions. They should identify the questioned hairs, including the associated and eliminated questioned hair specimens. Notes should be taken contemporaneously with the examination.

Photographs can be used to assist in documenting the following:

- Presence of significant hair characteristics.
- Presence and condition of a root that will be used for nuclear DNA analysis.
- Presence of other significant trace evidence on a hair before it is removed.

Photography is strongly recommended for hairs that will be submitted for DNA analysis because the hairs will be altered or consumed in analysis.

14. Conclusions

The following conclusions may be reached as a result of a microscopical hair examination. Many factors may strengthen or weaken a conclusion. The magnitude and significance of any factor can determine what conclusion is formed. The examiner should consider what meaning could be attached to an exclusion or nonexclusion based on the known case circumstances.

Probabilities and population statistics should not be used to interpret microscopical hair comparisons. Databases from which population statistics can be generated, as in DNA analysis, are not practical or realistic.

14.1. Identification of a Hair, Racial Group, Somatic Origin, and Other Features

An item can be identified as a human hair. It may also be classified by its racial and somatic characteristics. Other features may be identified that could assist in an investigation. (See Section 10.)

14.2. Dissimilarity

If significant differences exist in the macroscopic and/or microscopic characteristics exhibited by the questioned and known hairs, the questioned hairs cannot be associated with the source of the known hairs.

The following circumstances may add weight to a conclusion of dissimilarity:

- Known and questioned hairs exhibit gross differences (e.g., racial, color, diameter, chemical treatment).
- Adequate known samples are available.
- Known hair has little intrasample variation.

The following circumstances may weaken a conclusion of dissimilarity:

- Known and questioned hairs exhibit some similarities and no gross differences.
- Inadequate known samples.
- Inadequate questioned hairs.
- Known hair has large intrasample variation.

14.3. Similarity

In order to conclude that two hair samples could share a common origin, it must be determined that there are no significant macroscopic or microscopic differences. It is important to determine what differences are significant because no two hairs are exactly the same in every detail (identical). It must be determined that the characteristics exhibited by the questioned sample fit in the range of characteristics present in the other sample (typically the known sample). The ideal situation is to find one or more hairs in the known sample that correspond in all respects (no significant differences) with the questioned hair.

Microscopical examination of hair does not lead to unique identification of the donor. Therefore, when a hair examiner gives an opinion that a questioned hair is similar to a known hair sample, an attempt must be made to interpret the significance and weight that should be attached to this opinion.

The presence of some types of hair characteristics may add weight to a conclusion of similarity. Examples include the following:

- Presence of similar dyes or hair cosmetics.
- Presence of unusual hair characteristics, such as natural red hair color or hair abnormalities.
- Presence of similar hair damage.

Other hair characteristics may weaken a conclusion of similarity. Some examples include the following:

- Hairs are featureless and lack pigmentation characteristics.
- Hairs are too dark to see many of the microscopical hair characteristics.
- Hairs are very short in length, limiting the number of characteristics that can be used for comparison.
- Known hair sample has a large intrasample variation.

14.4. Inconclusive

The results of a microscopical hair comparison can be inconclusive. Situations when an inconclusive result may be reached include but are not limited to the following:

- An inadequate known hair sample.
- Questioned and known hair samples that exhibit similarities and unexplained dissimilarities.
- Hairs that do not exhibit sufficient distinguishing microscopical characteristics (e.g., broken, fragmented, too short, colorless, opaque).
- A significant lapse of time exists between the collection of the known sample and when the questioned hair was shed.

14.5 Reference

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15. Report Writing, Review, and Testimony

15.1. Report Writing

Refer to the Scientific Working Group on Materials Analysis *Trace Evidence Quality Assurance Guidelines*, Analytical Procedures Section, available at www.fbi.gov/hq/lab/fsc/backissu/jan2000/swgmat.htm. In addition, the hair examiner's report may include the following:

- An attempt to express the significance of the finding in relation to case circumstances.
- Qualifying statements that further describe the strengths and limitations of the evidence.
- Requests for additional known samples.
- A recommendation that DNA analysis be performed.

15.2. Technical and Administrative Review

Refer to the Scientific Working Group on Materials Analysis *Trace Evidence Quality Assurance Guidelines*, Analytical Procedures Section, available at www.fbi.gov/hq/lab/fsc/backissu/jan2000/swgmat.htm.

15.3. Court Testimony

15.3.1. General acceptance

Microscopical comparisons of human hairs have been used and generally accepted for over a century. The techniques are not novel, and the literature dealing with human hair characteristics and the reliability of the forensic hair comparison is extensive. Hair comparisons depend on the judgment and experience of the hair examiner. This comes from scientific education, training, professional associations, practice, and experience. Professional standards for the practice of forensic hair comparisons have been proffered through international cooperation and symposia.

The forensic science community has generally accepted DNA analysis of hair and other biological materials.

15.3.2. Content

Good court testimony usually requires educating the prosecutor and defense during pretrial conference(s) so that the record is clear regarding the use, reliability, and evidential value of forensic hair examinations. Topics to be discussed and prepared for trial testimony should include the following:

- Qualifying the expert witness.
- Chain of custody.
- Whether demonstrative evidence or visual aids are needed.
- What can be determined from a hair examination.
- Why hair examinations and comparisons are done.
- How hair examinations and comparisons are done.

- Results and conclusions from identifications and comparisons.
- Evidential value of hair (e.g., multiple hairs, two-way transfers, location).
- Need for DNA analysis and its relationship to the microscopical examination.
- Basis for opinions to be offered.

15.4. References

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16. Quality Assurance and Proficiency Testing

Annually each hair examiner should complete at least one proficiency test involving hair identifications and comparisons. Valid external human hair proficiency tests may not be available for purchase from an outside agency; therefore, external proficiency tests from other laboratories with hair examiners or an internal proficiency test can be used.

Proficiency tests should be designed to test specific skills required of the forensic hair examiner, such as the following:

- Determining if the hair is human versus other animals.
- Identifying racial characteristics.
- Identifying somatic origin.
- Comparing known and questioned hairs.

These tests should mimic as closely as possible actual-case scenarios.

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