Standard Practice for Training in the Forensic Examination of Hair by Microscopy

Materials (Trace) Subcommittee
Chemistry/Instrumental Analysis Scientific Area Committee
Organization of Scientific Area Committees (OSAC) for Forensic Science

OSAC Proposed Standard

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Prepared by
Materials (Trace) Subcommittee
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1. Scope

1.1 This document is intended for use by laboratory personnel responsible for training forensic hair examiners to prepare them to perform forensic hair examinations, including microscopical human hair comparisons. It contains relevant suggested reading assignments and structured exercises for hands-on practical experience for the trainee.

1.1.1 When possible, additional training beyond that which is listed here should be made available to the trainee. Such training might include off-site courses, internships, and specialized training by experienced examiners. Additional training will provide a hair examiner the opportunity to remain current in the field.

1.1.2 This document focuses on the microscopical examination of hair. However, additional analyses can be performed on hairs that have been chemically altered (e.g., dyed hair) or have trace materials on the surface (e.g., hair care products) that is outside the scope of this document. The correlation between the results of microscopical examinations and the potential for DNA analysis is also addressed.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards[1]
E1459 Standard Guide for Physical Evidence Labeling and Related Documentation
E1492 Standard Practice for Receiving, Documenting, Storing, and Retrieving Evidence in a Forensic Science Laboratory
E1732 Standard Terminology Relating to Forensic Science
E2917 – 19 Standard Practice for Forensic Science Practitioner Training, Continuing Education, and Professional Development Programs
2.2 SWGMAT Document[2]
Forensic Human Hair Examination Guidelines

3. Terminology

3.1 *anagen-* the active growth phase of a hair follicle in the hair growth cycle.
3.1.1 *Discussion* - The root from a pulled anagen hair is elongated, and is usually fully pigmented.

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[1] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.
[2] For referenced SWGMAT documents, visit the archived SWGMAT material under the Resources tab on the American Society of Trace Evidence Examiners (ASTEE) website, www.asteetrace.org.

3.2 *ancestral group*–populations differentiated by the morphological and microscopic characteristics representative of individuals originating from geographically separated regions of the world such as Asia, Africa, and Europe.

3.2.1 *Discussion* – The racial terms Caucasoid, Mongoloid, and Negroid should not be used as these terms are no longer acceptable in the field of anthropology (the field from which these designations originated).

3.3 *association*- the result of a comparison between two hair samples in which the characteristics of the questioned hair are represented in the known hair sample, and therefore the donor of the known sample can be included as a possible source of the questioned hair.

3.3.1 *Discussion:* A microscopical association of hair cannot identify the definitive source of a questioned hair to the exclusion of all others, and the number of individuals who could be included as a possible donor of a specific hair is unknown.

3.4 *buckling*- an abrupt change in the shape and orientation of a hair shaft with or without a slight twist, often seen in pubic hairs.

3.5 *catagen*- the transitional phase of the hair follicle between the active growth phase (anagen) and the resting phase (telogen) in the hair growth cycle.

3.6 *classification*-the systematic arrangement of hairs into categories (e.g., human, animal, body area, ancestry) based on shared traits or characteristics.

3.7 *cortex*- the primary anatomical region of a hair between the cuticle region and the medullary region composed of elongated and fusiform cells.

3.8 *cortical fusi*- small spaces that form between the cortical cells in the hair shaft and, under transmitted light, appear as tiny, dark structures when filled with air.

3.9 *cortical texture* - the relief or definition of the margins of the cortical cells when viewed using transmitted light microscopy.

3.10 *cross-sectional shape*- the shape of a hair shaft when cut at a right angle to its longitudinal axis.

3.10.1 *Discussion*- When viewed longitudinally, the apparent cross-sectional shape can be determined by slowly focusing through the hair (optical cross-sectioning).

3.11 *cuticle*- the outermost region of a hair composed of layers of overlapping scales.

3.11.1 *Discussion*- the dimension of the cuticle as measured from its outer margin to the cortex is often described in relative terms (e.g., thin, medium, thick).

3.12 *cuticle, cracked*- a cuticle with linear breaks that are perpendicular to the length of the shaft.

3.13 *cuticle, looped* - a feature in which the distal edges of the cuticular scales are curved from or cupped toward the hair shaft.

3.14 *cuticle, serrated* - a cuticle in which the outer margin has a notched appearance like a saw blade.

3.15 *decompositional changes* – alteration in the root or the proximal end of a hair that can include discoloration, postmortem root banding, or a tapered or brush-like appearance, as well as fungal tunneling along the length of the shaft.

3.16 *distal end*- the end of the hair farthest away from the root.

3.17 *Exclusion, absolute* – a conclusion reached in a comparative examination when gross differences are noted in the macroscopic or microscopic characteristics between the questioned and known hairs. In these circumstances the source of the known hairs, as represented by the known sample, can be excluded as a possible donor of the questioned hair.

3.17.1 *Discussion* – There are few circumstances where an absolute exclusion can be rendered for hairs. One such circumstance is when hairs exhibit gross differences in color and characteristics indicative of ancestry. A non-association is a more commonly rendered type of exclusion conclusion in a comparative examination when meaningful differences are noted between samples; however, a definitive exclusion of a person as a possible source cannot be made due to the natural variation that occurs in hairs as a biological specimen, and the effect that time and environment can have upon a hair sample.

3.18 Exclusion, non-association - a non-association is a type of exclusionary conclusion in a comparative examination when meaningful differences are noted in the macroscopic or microscopic characteristics between the questioned and known hairs; however, due to the variation within the sample(s) an absolute exclusion of a person as a possible source cannot be made. In these circumstances the source of the known hairs, as represented by the known sample, cannot be included as a possible donor of the questioned hair.

3.18.1 *Discussion* - a non-association is a type of exclusion conclusion in a comparative examination when meaningful differences are noted; however, an absolute exclusion of a person as a possible source cannot be made. This could occur when hairs are of similar color and exhibit other general morphological similarities or if the reference sample did not contain the complete variation of the individual's hair.

3.19 *fungal tunneling* - air pockets in a hair shaft caused by fungal growth.

3.20 *hair*- a fibrous outgrowth from the skin of mammals.

3.21 *hair follicle* - an invagination of the epidermis which contains the root of the hair.

3.22 *inconclusive*– a conclusion for comparative examinations that reflects the inability to include or exclude hairs in a known sample as sharing a common source with a questioned hair.

3.23 *identification* – classification of a hair as belonging to a particular category (e.g., human, ancestral group, somatic origin).

3.24 *individualization* – a term indicating an individual can be discriminated to the exclusion of all other sources.

3.24.1 *Discussion* - hairs cannot be individualized via microscopical hair comparison.

3.25 *imbricate* - a term that describes a scale pattern in which the scales overlap, and the edges have an irregular wavy pattern. This pattern is typical of human hair.

3.26 *inner cuticle margin*- the border between the cortex and the visible cuticle.

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

3.28 *macroscopic*- a term that describes characteristics large enough to be perceived without magnification.

3.29 *meaningful difference*-a feature or property of a sample that does not fall within the variation exhibited by the comparison sample, considering the limitations of the sample or technique, and therefore indicates the two samples do not share a common origin. The use of this term does not imply the formal application of statistical tests.

3.29.1 *Discussion:* In hair comparisons, this would be a dissimilarity observed in a questioned hair that falls outside the range of morphological and microscopic characteristics observed in an individual's known hair sample.

3.30 *medulla*- the core of the hair shaft that is composed of vacuoles and cells that can be air- or fluid-filled.

3.30.1 *Discussion*- The medulla (if present) occurs in a continuous, discontinuous, or fragmented pattern along the length of a hair and appears translucent or opaque.

3.31 *microscopic*- a term that describes characteristics too small to be resolved by the unaided eye, but large enough to be resolved with a microscope.

3.32 *microscopical* – a term that describes the process of using a microscope to analyze material.

3.33 *ovoid bodies*- oval-shaped, heavily-pigmented inclusions usually found in the hair cortex.

3.34 *pigment granules* - small particles in hair composed of melanin that impart color.

3.34.1 *Discussion*- Melanin is a natural pigment of which two forms, eumelanin (brown to black) and phaeomelanin (reddish brown to yellow), determine the color of human and animal hair.

3.35 *postmortem root banding*- the appearance of an opaque band near the root/proximal end of a hair potentially observed in anagen or catagen hairs that have been removed from a decomposing body. The possibility of other conditions causing the same or similar characteristics cannot be eliminated.

3.36 *proximal end*- the portion of the hair closest to, and including, the root.

3.37 *questioned hair*- a hair for which the source is unknown.

3.38 *root*- the structure that anchors a hair to a follicle and from which cells divide and produce the hair shaft.

3.38.1 *Discussion* - the portion of follicular tissue surrounding a root structure is the sheath.

3.39 *sample, known* - a sample intended to be representative of the hairs on a particular body area of a specific person or animal.

3.40 *sample, limited* - a sample of known hairs that is insufficient in quality or quantity to reflect a representative range of characteristics or traits.

3.41 *sample, representative* - a collection of hairs from a specific body area that reflects the range of characteristics in a person's hair in that body area.

3.42 *scales*- overlapping, plate-like structures composed of keratin that form the cuticle.

3.43 *shaft*- the portion of the hair emerging from the hair follicle.

3.44 *shaft form*- the shape of the hair both longitudinally (e.g., curly, straight) and cross-sectionally (e.g., round, flattened).

3.45 *shaft thickness*- the diameter of the hair.

3.45.1 *Discussion* - this can be expressed numerically or in relative terms, such as fine, medium, or coarse.

3.46 *shouldering* - a variation of the hair form along the shaft, resulting in an irregular and often asymmetrical change of cross-sectional shape.

3.47 *somatic*- an area of the body, such as head, pubic, or leg.

3.48 *telogen*- the resting phase of the hair follicle in the hair growth cycle.

3.48.1 *Discussion* – during this phase, the hair has stopped growing and the root becomes keratinized and bulbous (club-like) in shape.

3.49 *tip*- the most distal end of a hair shaft.

4. Significance and Use

4.1 A training program provides a theoretical foundation and practical skills necessary to prepare a trainee to become a qualified forensic hair examiner. A trainee is under the direct supervision of a qualified examiner throughout their training. At the end of the training program, a successful trainee is capable of forming opinions presenting and explaining evidence, and the

limitations to conclusions, based upon sound scientific knowledge, proper examinations, and practical experience.

4.2 This document sets out lessons, practical exercises, and methods of progress monitoring and trainee evaluation that are designed to be incorporated into an individual laboratory's training program.

4.3 The procedures outlined here are grounded in the body of scientific literature that exists in the field of forensic hair examination.

4.4 During the training program, the trainee gains the theoretical knowledge and practical skills needed to conduct microscopical hair examinations and comparisons.

5. Syllabus

5.1 Training guidelines should give the trainee knowledge and practical skills in forensic hair examination and interpretation. This can be accomplished through a combination of the following training methods:

5.1.1 Reading of relevant literature

5.1.2 Instruction and observation of hair examiners

5.1.2.1 Lectures and discussions

5.1.2.2 Practical demonstration of basic skills

5.1.2.3 Casework

5.1.2.4 Court testimony

5.1.3 Practical skills

5.1.3.1 Practical exercises

5.1.3.2 Assisting in and performing supervised casework

5.1.4 Examinations and tests

5.1.4.1 Written or oral tests

5.1.4.2 Practical laboratory tests

5.1.4.3 Mock/moot court

5.1.5 Competency evaluation

5.2 This is an extensive training program and it is expected that it will take approximately six months to one year to complete.

5.2.1 Required topics include:

5.2.1.1 Occurrence, transfer, and persistence of hairs

5.2.1.2 Evidence recovery methods

5.2.1.3 Evidence handling to minimize contamination and loss

5.2.1.4 Evidence packaging and documentation

5.2.1.5 Use and maintenance of microscopes

5.2.1.6 Understanding of hair chemistry, biology, structure, and function

5.2.1.7 Recognition of roots in different growth stages

5.2.1.8 Recognition of diseases manifested in hairs

5.2.1.9 Recognition of characteristics indicative of mechanical damage (e.g., looped or serrated cuticle), environmental effects, decomposition (e.g., postmortem root band), and chemical treatments (e.g., cortical texture, cracked cuticle) used on hair

5.2.1.10 Identification and classification of hairs

5.2.1.11 Comparison of questioned and known hairs

5.2.1.12 Other analytical techniques (DNA)

5.2.1.13 Interpretation of comparison results

5.2.1.14 Preparation of laboratory reports

5.2.1.15 Presentation and interpretation of results in court

5.2.2 A trainee with experience in other areas of forensic science who has knowledge in microscopy, in other areas of trace evidence, or in court testimony, would not require such an extensive training regimen.

6. Records of Training

6.1 The trainer documents and reviews each stage of the training process for each trainee.

6.2 The laboratory is responsible for maintaining training documentation.

7. Responsibilities

7.1 Each trainee is trained by, and works under the supervision of, one or more experienced forensic hair examiners.

7.2 Only technically competent personnel shall be trainers; this would include expertise in the areas of microscopical hair examination, hair comparison, or evaluation of hairs for DNA suitability. These trainers are responsible for:

7.2.1 Introducing the trainee to the relevant scientific literature, proper procedures, training material, and reference collections.

7.2.2 Discussing readings and theory with the trainee.

7.2.3 Teaching basic microscopy methods and analysis of hair microstructure for comparison

7.2.4 Teaching case management.

7.2.5 Fostering ethical and proper professional conduct through discussion and by setting an example.

7.2.6 Teaching appropriate quality assurance and quality control procedures.

7.2.7 Reviewing tests, practical exercises, and casework samples with trainee.

7.2.8 Teaching expert testimony skills through moot court, observation of testimony, or both.

7.3 The trainer and supervisor regularly monitor the trainee's progress with frequent updates.

7.4 The trainee should meet the objectives set forth in the training program by:

7.4.1 Self-study of reading materials.

7.4.2 Practicing basic microscopy skills.

7.4.3 Successfully completing practical exercises.

7.4.4 Successfully completing written or oral tests, or both.

7.4.5 Observing casework being conducted by an experienced examiner.

7.4.6 Observing court testimony given by an experienced examiner or reviewing transcripts where hair evidence was presented, or both.

7.4.7 Conducting themselves in an ethical and professional manner.

7.4.8 Participating in the quality assurance and quality control program of their laboratory.

7.4.9 Successfully completing competency tests in identification, comparison, or evaluation for DNA suitability.

7.4.10 Demonstrating competency in supervised casework.

7.5 Each laboratory is responsible for maintaining:

7.5.1 An up-to-date training program.

7.5.2 Documentation of training, including competency tests.

8. Training Program Details

8.1 The following sections outline a suggested training program by topic area. Individual laboratories are expected to tailor the training program to reflect the examinations performed in their laboratory.

8.1.1 Each topic area is divided into sections that include general discussions of the subject of that particular topic area; the skill to be gained by learning that particular subject; the relevant readings; practical applications of the knowledge gained; and, when appropriate, testing of the trainee's knowledge and skills.

8.1.2 Reading assignments are selected to give the trainee a sound theoretical background and solid foundation in topics necessary for hair analysis. The listed publications can be supplemented by additional readings.

8.1.3 Essential skills are demonstrated by the trainer and practiced by the trainee.

8.1.4 Practical exercises are designed to allow the trainee to learn and practice the skills needed to perform casework. The trainer reviews the trainee's performance and documentation during the exercises to evaluate the trainee's ability to conduct microscopical examinations and make conclusions. Satisfactory completion of the exercises is documented.

8.1.5 Written or oral tests, along with practical laboratory tests, are recommended as a means of determining the trainee's comprehension of the material and as a way to document the training. Questions should be designed to test the trainee's theoretical and practical knowledge. Establish pass criteria prior to the beginning of the training program, as well as contingencies for not passing a test. The trainer should address deficiencies through additional readings and training.

8.1.6 The trainee should observe an experienced hair examiner in all aspects of casework. This helps the trainee understand the various aspects of casework including record keeping; processing of evidence; sample preparation; microscopical study of prepared specimens; and the characterization, identification, comparison, and interpretation (including the limitations) of hair evidence. During the observation of casework, the experienced examiner provides instruction to the trainee, performs all case examinations and comparisons, and is responsible for all conclusions.

8.1.7 A competency test is administered prior to the trainee analyzing and comparing hair evidence in supervised casework.

8.1.7.1 Discussion: The test should be designed to mimic actual casework, requiring the trainee to demonstrate his/her knowledge of the laboratory's procedures in handling evidence, taking notes, maintaining chain of custody, and writing a report, as well as the actual examination and comparisons of hair evidence. It is the responsibility of the laboratory to establish written objective criteria for successfully passing the competency test. Deficiencies or failures, if any, are noted, a remediation plan developed, and a subsequent competency exam given until the trainee meets the criteria for successfully passing the competency exam.

8.1.8 Prior to independent casework, the trainee performs supervised casework. The trainer or case supervisor verifies all laboratory results obtained by the trainee and documents that verification during supervised casework.

8.1.9 The trainee should observe experienced examiners testifying in court. The trainee should pay attention to general courtroom procedures, the witness's appearance and demeanor,

and the presentation of technical or expert knowledge. After each observation, the trainee and the examiner should discuss the courtroom experience and, if possible, review the transcript.

8.1.10 Court testimony training should include a moot court exercise. The trainee's moot court should be challenging and mimic as closely as possible a real courtroom experience. The trainee should be evaluated on appearance, demeanor, knowledge of the case, knowledge of the discipline, scientific accuracy, impartiality, and presentation skills.

8.1.11 The trainee's progress is continually monitored according to objective criteria established by the laboratory. Periodic progress assessments involving the trainee, trainer, and supervisor should be conducted. Deficiencies in the trainee's performance are addressed immediately. Remediation should be made available through additional training and a re-evaluation of the training program.

8.1.12 Continued deficiencies could suggest the unsuitability of the trainee for casework in this area.

8.2 Training Course Evaluation

8.2.1 The trainee should be given a chance to evaluate the hair training program and the trainer. Perceived deficiencies in the training program or the trainer should be addressed.

8.3 Authorization for Casework

8.3.1 Upon successful completion of the training program and a comprehensive competency test, the trainee will receive written approval from designated laboratory personnel (e.g., quality control officer, training manager) to perform supervised casework.

8.3.2 After successful completion of supervised casework, the trainee will receive written approval from designated laboratory personnel (e.g., quality control officer, training manager) to perform independent casework in microscopical hair examinations.

9. Casework Familiarization, Search, and Recovery of Hair Evidence

9.1 This section familiarizes the trainee with the proper documentation needed in casework and the proper methods of detection, collection, and preservation of trace evidence from crime scenes and from items submitted to the laboratory. This training exposes the trainee to evidence handling issues such as deposition, transfer, persistence, contamination, and loss of trace evidence.

9.2 A trainee should be exposed to a variety of cases involving hair examinations throughout the training period.

9.3 Required training topics include:

9.3.1 Proper procedures for case documentation

9.3.2 Recognition of hair and other evidential materials and the evaluation of their significance in a particular case

9.3.3 Detection, collection, and preservation techniques appropriate to the different types of forensic evidence, including hairs

9.3.4 Loss, transfer, and persistence of trace evidence

9.3.5 Prevention of contamination and loss in handling hair evidence

9.3.6 Proper procedures in the laboratory for maintaining the chain of custody of the original evidence and any secondary evidence collected

9.3.7 Safety procedures in the laboratory for the handling of potentially biohazardous materials

9.3.8 Documentation of analytical results, as required by the trainee's laboratory

9.4 Review relevant historical and current literature in the fields of anthropology, dermatology, cosmetology, developmental biology, and forensic science related to hair analysis.

    9.4.1. Recommended Reading Assignments:

1) ASTM Standards[3]
   a. E1459 Standard Guide for Physical Evidence Labeling and Related Documentation
   b. E1492 Standard Practice for Receiving, Documenting, Storing, and Retrieving Evidence in a Forensic Science Laboratory
2) Bisbing, R., "The Forensic Identification and Association of Human Hair." In: *The Forensic Science Handbook*, 2nd edition, volume 1:390-428 (chapter 7). Upper Saddle River, New Jersey: Pearson Education. 2002.
3) Inman, K. and Rudin, N., *Principles and Practice of Criminalistics, the Profession of Forensic Science*, chapters 4, 5, 9, and 10. Boca Raton: CRC Press. 2001.
4) Oien, C.T. "Forensic Hair Comparison: Background Information for Interpretation," Forensic Science Communications, 2009, Volume 11, Number 2.
5) Robertson, J., "Forensic and Microscopic Examination of Human Hair." In: *Forensic Examination of Hair*, 79-155 (chapter 2). London: Taylor and Francis. 1999.
6) Robertson, J. and Roux, C., "From the Crime Scene to the Laboratory– Transfer, Persistence and Recovery of Fibres." In: Robertson, J. and Grieve, M. (editors). *Forensic Examination of Fibres*, 2nd edition, 89-100 (chapter. 5.1). London: Taylor and Francis. 1999.
7) Springer F., "From the Crime Scene to the Laboratory – Collection of Fibre Evidence from Crime Scenes." In: Robertson, J. and Grieve, M. (editors). *Forensic Examination of Fibres*, 2nd edition, 101-115 (chapter. 5.2). London: Taylor and Francis. 1999.
8) Gaudette, B. D. "*Probabilities and human pubic hair comparisons." Journal of Forensic Sciences*, 1976, 21:514-517.
9) Gaudette, B. D. "Strong negative conclusions: A rare event." *Canadian Society of Forensic Science Journal*, 1985, 18:32-37.
10) Gaudette, B.D. and Keeping, E.D. "An attempt at determining probabilities in human scalp hair comparison." *Journal of Forensic Sciences*, 1974, 19:599-606.
11) Barnett, P. D., and R. R. Ogle. "Probabilities and human hair comparison." *Journal of Forensic Sciences* 1982, 27.2: 272-278.
12) Aitken C.G. and Robertson J. "A contribution to the discussion of probabilities and human hair comparisons." *Journal of Forensic Sciences*, 1987, 32.3: 684-689.

    9.5 Instruction and Observation:

    9.5.1 Observe hair casework, from the assignment of a case through an examination, to the preparation of a report.

    9.5.2 Discuss all aspects of casework, having the trainer explain each step as the case is processed.

    9.5.3 Instruction will be given in the following topics:

    9.5.3.1 Documentation required for a case file

    9.5.3.2 Description and labeling of evidence

    9.5.3.3 Procedures required to maintain chain of custody

    9.5.3.4 Procedures to prevent contamination and loss

    9.5.3.5 Procedures to clean and control the laboratory environment

9.5.3.6 Selection of the appropriate detection, collection and preservation techniques for hair and other trace evidence

9.5.3.7 Recognition of evidence as questioned specimens or known samples

9.5.3.8 Collection of representative known samples

9.5.3.9 General laboratory protocols

9.5.3.10 Health and safety hazards

9.5.3.11 Laboratory quality assurance procedures

9.6 Practical Exercises

9.6.1 Practice collecting hair from a variety of items (e.g., clothing, tape, items of various sizes and surface textures, weapons). Skills practiced should include:

9.6.1.1 Different techniques of recovery (e.g., scraping, tape lifting, vacuuming, picking)

9.6.1.2 Packaging and preserving evidence

9.6.1.3 Collection of known or reference materials on mock evidence.

9.7 Supervised casework

9.7.1 Under the direct supervision of the trainer, the trainee is assigned select cases to process for the purposes of recovering and safeguarding trace materials. The trainee will use the procedures and techniques learned to process and document the evidence.

9.8 Examinations and tests

9.8.1 Written, oral, or practical laboratory tests, or any combination thereof, are given to the trainee to evaluate the acquired knowledge and skills covered in each part of training.

9.9 Competency Evaluation

9.9.1 Evaluate the trainee's ability to choose and perform an appropriate evidence recovery technique.

9.9.2 Evaluate the trainee's knowledge of proper laboratory procedures for creating a case file, handling evidence safely, and labeling evidence.

10. Microscopy

10.1 This section familiarizes the trainee with the theory, basic procedures, and techniques for the proper operation of a stereomicroscope, compound microscope, and comparison microscope. The care and maintenance of these microscopes should also be discussed.

10.2 Required training topics include:

10.2.1 Why different types of microscopes are used in hair analysis

10.2.2 How microscopes work (theory)

10.2.3 The proper operation and maintenance of the different types of microscopes

10.2.4 Setting up Köhler (or modified Köhler) illumination

10.2.5 The proper selection of mounting media

10.3. Recommended Reading Assignments

1) Operation manuals for the microscopes used by the trainee.

2) De Forest, P.R., "Foundations of Forensic Microscopy." In: *The Forensic Science Handbook*, 2nd edition, pp 215-320. Upper Saddle River, New Jersey: Pearson Education. 2002.

3) Roe GM, Cook R and North C, "An Evaluation of Mountants For Use in Forensic Hair Examination," *JFSS,* Vol. 31, No. 1, 1991, pp. 59-65.

4) Collins, T. "Mounting Media and Antifade reagents." *Microscopy Today,* Vol 14, No.1, 2006, pp. 34-39.

5) Shamala R. and Surekha, R. "Mounting media: An overview." *Journal of Dr. NTR University of Health Sciences*, Vol. 3, No.5, 2014, pp.1-8.

6) Neuhaus, B. Schmid, T. Collection management and study of microscope slides: Storage, profiling, deterioration, restoration procedures and general recommendations." *Zootaxa,* Vol. 4322, No.1, 2017, pp.1-173.

10.4 Practical Exercises

10.4.1 Familiarization with the stereomicroscope, compound microscope, and the comparison microscope

10.4.1.1 Check the alignment of the condenser, the stage and the objectives on the compound microscope and the comparison microscope.

10.4.1.2 Check the color balance on the comparison microscope. The trainer demonstrates to the trainee how to properly balance the background color on both sides of the comparison microscope. The trainee should then practice this technique. Refer to SWGMAT Forensic Human Hair Examination Guidelines for color balancing techniques.

10.4.1.3 Experiment with, and understand the effect of, different colored contrast filters and neutral density filters.

10.4.1.4 Observe how to properly set up Köhler (or modified Köhler) illumination. The trainee should routinely employ this technique when using the microscope.

10.4.1.5 Calibrate the eyepiece micrometer for all objectives on the compound microscope and the comparison microscope

10.4.1.6 Evaluate how adjustments made to the microscope (e.g., apertures, condenser, focus) affect the appearance of the sample.

10.4.2 Selection of mounting media

10.4.2.1 Mount several hairs using different temporary or semi-permanent mounting media, or both. Discuss utility, precautions, and limitations in choosing a mounting medium with respect to possible changes to the original evidentiary hair.

10.4.2.2 Know the refractive index of the mounting media used and compare the relative refractive index of human hair to each of the media (greater or less than the medium).

10.4.2.3 Experiment with different refractive index media to see which produces the best visible detail in different parts of the hair.

10.4.3 Evaluation of effective cover slip thickness

10.4.3.1 Mount several hairs using different cover slip thicknesses and different mounting media thicknesses. The trainee should experiment with different thicknesses of each to see which gives the best image in different levels or depths within the preparation.

10.5 Competency Evaluation

10.5.1 Evaluate the trainee's knowledge and competency with a written quiz or a practical test.

10.5.2 Test the trainee's ability to properly set up a microscope that is misaligned and maladjusted, including achieving proper illumination, color and intensity balance of the light sources on the microscope(s).

11. Introduction to Hairs – Human & Animal Hairs

11.1 This section familiarizes the trainee with the fundamental biology, physiology and anatomy of hair, as well as the history of hair examinations, their limitations, and definitions of terms used in hair classification and comparison.

11.2 Required training topics include:

11.2.1 The purpose and function of human and animal hair

11.2.2 The structures of human and animal hair

11.2.3 The growth of human hair

11.2.4 The chemical composition of hair

11.2.5 The history of hair examination

11.2.6 Definitions of terms

11.2.7 Classification of hair

11.3. Recommended Reading Assignments

1) Robbins, C. R. "Chemical composition of different hair types." *Chemical and physical behavior of human hair*. Springer Berlin Heidelberg, 2012. 105-176.

2) Kaszynski, E., "Hair Growth: Mechanism and Regulation." From: *The Proceedings of the International Symposium on Forensic Hair Comparison*, pages 23-34. Washington, DC: Federal Bureau of Investigation, U.S. Government Printing Office. 1985. This reference can also be found at https://www.ncjrs.gov/pdffiles1/Digitization/116592NCJRS.pdf, accessed on January 28, 2016.

3) Deedrick, D., and Koch, S., "Microscopy of Hair Part 1: A Practical Guide and Manual for Human Hairs." *Forensic Science Communications* Vol 6, no. 1, 2004.

4) Deedrick, D. and Koch, S., "Microscopy of Hair Part 2: A Practical Guide and Manual for Animal Hairs." Forensic Science Communications, Vol 6, no. 3, 2004.

5) Robertson, J., "Forensic and Microscopic Examination of Human Hair." In: *Forensic Examination of Hair*, 79-155 (chapter 2). London: Taylor and Francis. 1999.

6) Tridico, S., "Examination, Analysis, and Application of Hair in Forensic Science-Animal Hair." *Forensic Science Review*, vol 17(1):17-28. 2005.

7) Long B., Walbridge-Jones S., Lundgren K. *et al* "Synthetic Wig Fibers: Analysis & Differentiation from Human Hairs." *Journal of the American Society of Trace Evidence Examiners*, 5.1: 2-21. 2014.

11.4 Practical Exercises

11.4.1 Become familiar with the basic appearance of hair by utilizing a stereomicroscope. This can be accomplished by examining several known human and animal hairs, and making notations regarding the general appearance and characteristics that are visible under the lower power magnification.

11.4.2 Examine the samples from 10.4.2.1 utilizing a compound microscope, noting the greater number of characteristics visible in the mounted hairs under higher magnification.

11.4.3 Classify the basic root types.

11.4.3.1 Remove several hairs from a used hair brush and classify the roots.

11.4.3.2 Pull several head hairs from your head and one other person's head and classify the roots and whether there is a follicular tag or tissue suitable for DNA analysis.

11.4.3.3 Observe the root shapes of a variety of animal hairs.

11.4.4 Using human and animal hairs, identify the cuticle, cortex, medulla, cortical fusi, ovoid bodies, and pigment granules, when present.

11.4.4.1 Observe hairs and learn features of cuticle looping, imbricate scale pattern, cortical texture, pigment patterns (e.g., Pigment aggregation, pigment density, and pigment distribution), fungal tunneling, shouldering,

11.4.5 Practice cross-sectioning.

11.4.5.1 Compare to optical cross section.

11.4.5.2 Discuss utility and precautions in using these techniques as to possible changes to the original evidentiary hair.

11.4.5.3 Discuss the importance and retention of surface debris.

11.4.6 Examine synthetic wig-type fibers and human wig hairs.

11.4.7 Practice documenting observations using the laboratory's approved documentation method, specifically concentrating on the characteristics that enable the trainee to differentiate between human and animal hair.

11.5 *Competency Evaluation*

11.5.1 Evaluate the trainee's knowledge and competency with a written, oral, or practical test, or any combination thereof. This could include drawing the microscopic features of a hair and defining the terms.

12. Animal Hairs - Introduction to the Recognition of Animal Hairs

12.1 This section familiarizes the trainee with the microscopic characteristics in animal hair, including differentiating animal hair from human hair; describing features that aid in the determination of animal species, genus, or family; and familiarizing the trainee with available identification schemes for the classification of animal hair.

12.1.1 This section is intended to be an introduction to the identification of animal hairs and is not meant to be an in-depth training program for the purpose of classifying and comparing animal hairs.

12.2 *The knowledge, training, and experience required for the trainee to complete this section include the ability to:*

12.2.1 Recognize animal hairs and hair types (e.g., guard and fur)

12.2.2 Make scale casts and observe scale patterns

12.2.3 Identify and characterize the differences in the microscopic characteristics between animal species, genera, and families.

12.3 *Recommended Reading Assignments*

1) D'Andrea, F., Fridez, F. and Coquoz R., "Preliminary Experiments on the Transfer of Animal Hair During Simulated Criminal Behaviour." *Journal of Forensic Sciences*, vol 43. 1998.

2) Deedrick, D. and Koch, S. "Microscopy of Hair Part 2: A Practical Guide and Manual for Animal Hairs." *Forensic Science Communications*, vol 6, no. 3, 2004.

3) Deedrick, D. "Hairs, Fibers, Crime and Evidence Part 1: Hair Evidence," *Forensic Science Communications*, volume 2, no. 3, 2000.

4) Moore, T.D., et al., *Identification of the dorsal guard hairs of some mammals of Wyoming*. No. 14. Wyoming Game and Fish Dept., 1974.

5) Tridico, S., "Examination, Analysis, and Application of Hair in Forensic Science-Animal Hair." *Forensic Science Review*, volume 17(1):17-28. 2005.

6) Tridico, S., "Hair of the dog: A case study." In: *Trace Evidence Analysis — More Cases in Mute Witnesses*, Houck M.M. (ed), pp 27–52. Elsevier Academic Press: Amsterdam. 2004.

7) Teerink, B. J. *Hair of West European Mammals: Atlas and Identification Key*. Cambridge University Press, 2004.

8) Petraco, N., Kubic T., *Color Atlas and Manual of Microscopy for Criminalists, Chemists, and Conservators*, 69-76 (chapter 6). Boca Raton, FL, 2003.

9) Robertson, J., "Forensic and Microscopic Examination of Human Hair." In: *Forensic Examination of Hair*, 79-155 (chapter 2). London: Taylor and Francis. 1999.

12.4 Observation and Discussion

12.4.1 Examine several types of human and animal hairs using macroscopical and microscopical techniques to study/evaluate the various characteristics that distinguish animal hair from human hair (e.g., different medullary patterns, scales, roots, tips, color, banding, shape, and diameter).

12.4.2 Observe and discuss the various procedures for making scale casts.

12.5 Practical Exercises

12.5.1 Mount guard hairs and fur hairs (under hairs) from several different animal types. Include, at a minimum, dog, cat, rabbit, horse, cow, bear, rat, and deer hairs.

12.5.2 Microscopically examine these known animal hairs for medullary structure, scale features and other microscopic characteristics, noting how they differ from human hairs, how they differ between animal families, and how they differ within the same animal and the same hair as well. Practice note taking on the characteristics observed under the microscope.

12.5.3 Make scale casts of the entire length of both guard hairs and fur hairs using various techniques. Examine casts and describe scale patterns, noting the different characteristics.

12.5.4 Repeat these exercises using hairs that are commonly used for apparel, such as chinchilla, wool, llama, mink, etc.

12.5.5 Compare all of the above prepared animal hairs to human hairs derived from different body areas.

12.6 Competency Evaluation

12.6.1 Evaluate the trainee's ability to differentiate human hairs from other animal hairs using a set of unknown hair samples.

13. Characterization and Assessment of Human Hairs

13.1 This section familiarizes the trainee with the microscopic characteristics of human hair.

13.1.1 The observed characteristics are used to determine if a hair is human or animal, indicate somatic origin, and indicate possible ancestry.

13.2 The knowledge, training, and experience required for the trainee to complete this section includes the ability to:

13.2.1 Identify macroscopic and microscopic characteristics of human hair

13.2.2 Determine somatic origin

13.2.3 Determine characteristics common to different ancestral groups

Note: Assessments of ancestry during a microscopical analysis of hair are based on a set of shared hair traits generally found among peoples whose ancestors descended from broadly-defined continental populations (e.g., European, African, Asian). Based on the microscopical and morphological characteristics observed, the hair traits can be suggestive of a person with a particular ethnogeographic ancestry or mixed ancestry; however, the amount of a particular ancestry is not known, and such an assessment does not necessarily conform with how an individual self-identifies.

13.2.4 Identify cross-sectional shape

13.2.5 Characterize features of the distal end

13.2.6 Characterize root features in order to assess growth phase, possible mode of separation from the follicle, and suitability for DNA analysis

13.2.7 Identify acquired characteristics such as those from crushing, burning, etc.

13.2.8 Identify diseases, abnormalities, decomposition, cosmetic treatments and adhering trace materials

 13.3 *Recommended Reading assignments*

1) Robbins, Clarence R. *Chemical Composition of Different Hair Types*. Springer: Berlin, Heidelberg, 2012.

2) Deedrick, D. and Koch, S. "Microscopy of Hair Part 1: A Practical Guide and Manual for Human Hairs." In: *Forensic Science Communications*, vol 6, no. 1, 2004.

3) Robertson, J., *Forensic Examination of Hair*. London: Taylor and Francis. 1999.

4) Bisbing, R., "The Forensic Identification and Association of Human Hair." In: *The Forensic Science Handbook*, 2nd edition, vol 1:390-428 (chapter 7). Upper Saddle River, New Jersey: Pearson Education. 2002.

5) Petraco, N., Fraas, C., Callery, F., and De Forest, P., "The Morphology and Evidential Significance of Human Hair Roots." *Journal of Forensic Sciences*, vol 33:68-76. 1988.

6) Ogle, R. and Fox, M., *Atlas of Human Hair – Microscopic Characteristics.* Boca Raton, FL: CRC Press. 1999.

7) Petraco, N. and Kubic, T., *Color Atlas and Manual of Microscopy for Criminalists, Chemists, and Conservators,* pp 57-67 (chapter 5). Boca Raton, FL: CRC Press. 2004.

8) Koch, S. L., Michaud, A. L., and Mikell, C. E. "Taphonomy of Hair – A Study of Postmortem Root Banding." *Journal of Forensic Sciences*, 58(s1), S52-S59, 2013.

9) Tridico, S. R., Koch, S., Michaud, A., Thomson, G., Kirkbride, K. P., and Bunce, M. "Interpreting biological degradative processes acting on mammalian hair in the living and the dead: which ones are taphonomic?" *Proceedings of the Royal Society B: Biological Sciences,* 281(1796), 2014.

10) Henson, C.R. and Rowe, W.F. "The Effect of Elevated Temperature on the Microscopic Morphology of Human Head Hair." *Microscope*, 50, 21-24, 2002.

11) Tolgyesi, E., Coble, D.W., Fang, F.S., and Kairinen, E.O. "A comparative study of beard and scalp hair." *Journal of the Society of Cosmetic Chemists*, 34, 367-382, 1983.

12) Franbourg, A.,Hallegot, P.,Baltenneck, F., Toutain, C., and Leroy, F. "Current research on ethnic hair." *Journal of American Academy of Dermatology*, 48, 115-119, 2003.

13) Khumalo, N.P., *et. al*. "What is normal black African hair? A light and scanning electron-microscopic study." *Journal of American Academy of Dermatology*, 43, 814-820, 2000.

14) Koch, S. L., Shriver, M. D., and Jablonski, N. G. "Variation in human hair ultrastructure among three biogeographic populations." *Journal of structural biology*, *205*(1), 60-66, 2019.

13.4 Observation and Discussion

13.4.1 Examine and discuss the distinguishing features of hairs from the different somatic regions of each ancestral group. The trainer should point out and discuss the macroscopic and microscopic characteristics typically observed in hairs from different body regions (e.g., buckling) to the trainee, the limitations associated with such characterizations, and how features should be documented or measured in examination notes.

13.4.2 Examine and discuss hair subjected to various environmental conditions, cosmetic treatment, damage, abnormalities, decomposition, various growth phases, and adhering debris.

13.4.3 Discuss laboratory procedures and techniques that are used to remove and analyze cosmetics or debris adhering to a hair.

13.4.4 Discuss the suitability of the hair for microscopical comparison.

13.5   Practical Exercises

13.5.1 Collect and examine (macroscopically and microscopically) the following known hairs from a number of individuals in the three main ancestral groups, as well as hairs from individuals of multiple or mixed ancestral groups. These hairs should be examined with respect to length, thickness, medulla, pigmentation, spatial configuration, distal end, root, structure, etc.

1) Head
2) Pubic
3) Arm
4) Leg
5) Face
6) Chest
7) Axillary
8) Eyebrow
9) Eyelash
10) Transitional or fringe hairs of the above

13.5.2 Verbalize those macroscopic and microscopic characteristics that serve to distinguish different ancestral groups and somatic regions.

13.5.3 Since physical cross sections are not often made during routine casework, it is important for the trainee to be able to determine a hair's cross section by examining a longitudinal mount. Therefore, both longitudinally mount and cross-section representative hairs from each ancestral group and somatic origin. Associate the appearance of the longitudinal mount with the cross-sectional shape so that, during casework, physical cross sections do not need to be made.

13.5.4 Examine hairs that have acquired characteristics and abnormalities (such as diseases affecting the hair or damage).

13.5.5 Document (e.g., notes, photomicrographs, sketches) the various characteristics present in the observed hairs, as well as the visible similarities and differences between the different ancestral groups and somatic origins. The trainee is encouraged to consider preparing a personal reference collection of hairs exhibiting the variety of characteristics that can be encountered.

13.6 Competency Evaluation

13.6.1 Evaluate the trainee's ability to characterize human hairs as to possible ancestral group and somatic region with a practical test.

14. Hair Examinations – Comparison Microscopy

14.1 This section familiarizes the trainee with the microscopical comparison of human hair, including whether hairs are suitable for comparison, whether a hair standard is representative, as well as the conclusions that can be drawn from a comparison and their limitations.

14.1.1 A comparison is typically made between questioned head or pubic hairs and representative known samples of head or pubic hairs.

14.2 The knowledge, training and experience required for the trainee to complete this section include the ability to:

14.2.1 Evaluate the suitability of a questioned hair for comparison.

14.2.2 Evaluate the adequacy of a known hair sample set for comparison purposes.

14.2.3 Make proper microscopical comparisons between questioned hairs and known hair samples.

14.2.3.1 Observe and record characteristics of questioned sample(s).

14.2.3.2 Observe and record characteristics of known sample(s).

14.2.3.3 View the known sample and the questioned sample in a split view under the comparison microscope if the known sample and questioned sample are of the same somatic origin.

14.2.3.4 Determine whether the characteristics of the questioned hair fall within the range of the characteristics of the known sample.

14.2.4 Reach a valid conclusion as to the possible source of a questioned hair.

14.3 Recommended Reading Assignments

1) Bisbing, R. "The Forensic Identification and Association of Human Hair." In: *The Forensic Science Handbook*, 2nd edition, volume 1:390-428 (chapter 7). Upper Saddle River, New Jersey: Pearson Education. 2002.

2) SWGMAT. "Forensic Human Hair Examination Guidelines." *Forensic Science Communications*, vol 7, no. 2, 2005.

3) Bisbing, R., "Human Hair in Forensic Perspective." *The Proceedings of the International Symposium on Forensic Hair Comparison*, pages 35-50, 1985. Washington, DC: Federal Bureau of Investigation, U.S. Government Printing Office. 1987. This reference can also be found at https://www.ncjrs.gov/pdffiles1/Digitization/116592NCJRS.pdf, accessed on January 28, 2016.

4) Ogle, R. and Fox, M., *Atlas of Human Hair – Microscopic Characteristics.* Boca Raton, FL: CRC Press. 1999.

5) Petraco, N. and Kubic, T., *Color Atlas and Manual of Microscopy for Criminalists, Chemists, and Conservators*. Boca Raton, FL: CRC Press. 2003.

6) Robertson, J., *Forensic Examination of Hair*. London: Taylor and Francis. 1999.

7) Deedrick, D. and Koch, S. "Microscopy of Hair Part 1: A Practical Guide and Manual for Human Hairs." In: *Forensic Science Communications*, volume 6, no.1, 2004.

14.4 Observation & Discussion

14.4.1 Observe the trainer performing a hair comparison.

14.4.2 Learn what constitutes an adequate representative sample and how all of the characteristics present within the known hair sample should be observed in order to define the range of characteristics used for a comparison.

14.4.3 Learn the process of comparison and the significance of the characteristics observed while comparing two sets of samples.

14.4.3.1 Discuss with the trainer what constitutes a meaningful difference between a questioned hair and a known hair sample. A meaningful difference is a feature or property of a sample that does not fall within the variation exhibited by the comparison sample, considering the limitations of the sample or technique, and therefore indicates the two samples do not share a common origin. For hairs, this would also include samples that could not be associated. The use of the term meaningful difference does not imply the formal application of statistical tests.

14.4.3.2 The trainer will provide the trainee practical examples of hair comparisons for each conclusion that can be reached regarding the comparison of questioned hairs to known hair samples.

14.4.3.3 Discuss the criteria for arriving at possible conclusions resulting from a comparison and the limitations of each possible conclusion.

14.5 Practical Exercises

14.5.1 Variations within a known hair sample set

14.5.1.1 Collect both combed and pulled hair samples from a known source; at least 20-25 hairs each from the head and pubic region.

14.5.1.2 Observe with the unaided eye, and then with the stereomicroscope.

14.5.1.3 Mount all of the hairs and examine using the compound light microscope.

14.5.1.4 Note the range of characteristics within the known hair sample set.

14.5.1.5 Evaluate the variation in color, diameter, medullation, and scale features observed along the length of single hairs and among hairs within the sample.

14.5.1.6 Repeat this exercise several times with hairs from other known sources. This ensures that the trainee has a deep understanding about the range of variability within and between hairs of the same somatic origin and ancestry groups.

14.5.2 Performing hair comparisons

14.5.2.1 Select a single hair from each of the known samples collected above, compare this hair to the other hairs from the same source, and compare to all other collected known hair samples.

14.5.2.2 Known hair samples from individuals with similar hair coloring and length should be provided to the trainee for comparison exercises.

14.5.2.3 Perform numerous head hair and pubic hair comparisons from each of the different ancestral groups. Unknown samples should be provided to ensure that the trainee is able to correctly classify the ancestral group of the questioned hair and form appropriate comparison conclusions in each ancestral group.

14.5.2.4 Any errors in the comparisons are reviewed by the trainer, along with the trainee, in order to determine why an incorrect conclusion was made.

14.6 *Competency Evaluation*

14.6.1 Evaluate the trainee's ability to accurately compare hair samples with a challenging practical test that mimics casework, consisting of a series of questioned specimens and known samples for comparison.

15. Hair and DNA

15.1 This section introduces the trainee to the application of DNA technology to hair analysis.

15.1.1 Current technologies make possible the extraction of DNA for analysis from a hair sample.

15.1.1.1 Anagen hairs or other hairs with tissue can be suitable for nuclear DNA (nDNA) analysis.

15.1.1.2 All hairs and hair fragments contain mitochondrial DNA (mtDNA).

15.1.2 Even if not performing DNA analyses, basic knowledge is required for the trainee to understand which type of DNA analysis should be recommended after examining the hairs in a given case.

15.2 Required training topics include:

15.2.1 The basic knowledge of forensic nuclear and mitochondrial DNA analysis.

15.2.2 The criteria for suitability of a hair for nuclear or mitochondrial DNA analysis.

15.2.3 The complementary nature of comparison microscopy and DNA testing.

15.2.4 How to demount a hair.

15.3 Recommended Reading Assignments

1) Wilson, M.R., Polanskey, D., Butler, J., DiZinno, J.A., Replogle, J., and Budowle, B., "The Extraction, PCR Amplification and Sequencing of Mitochondrial DNA from Human Hair Shafts." In: *BioTechniques*, volume 18(4):662-669. 1995.

2) Linch, C.A., Smith, S.L., and Prahlow, J.A. "Evaluation of the Human Hair Root for DNA Typing Subsequent to Microscopic Comparison." *Journal of Forensic Sciences*, volume 43(2):305-314. 1998.

3) Melton, T., Dimick, G., Higgins, B., Lindstrom, L. and Nelson, K., "Forensic Mitochondrial DNA Analysis of 691 Casework Hairs." *Journal of Forensic Sciences*, volume 50(1):73-80. 2005.

4) Houck, M. and Budowle, B., "Correlation of Microscopic and Mitochondrial DNA Hair Comparisons." *Journal of Forensic Sciences*, vol 47(5):964-967. 2002.

5) Houck, M., Bisbing, R., Watkins, T. and Harmon, R. "Locard Exchange: The Science of Forensic Hair Comparisons and the Admissibility of Hair Comparison Evidence: Frye and Daubert Considered." In: *Modern Microscopy Journal, 1-10. 2004.*

6) Robertson, J., *Forensic Examination of Hair*. London: Taylor and Francis. 1999.

7) Houck M. and Bisbing R., "Forensic Human Hair Examination in the 21st Century." *Forensic Science Review*, volume 17(1):51-66. 2005.

8) Yoshino, M., Sato, H. and Seta, S., "Hair: Deoxyribonucleic Acid Typing." In: Siegel, J. and Saukko P.J., eds. *Encyclopedia of Forensic Sciences*, pp 1025-1032. London: Academic Press Ltd., 2000.

15.4 Discussion

15.4.1 Discuss how to determine the suitability of a hair for nDNA or mtDNA analysis. Certain characteristics, such as root type, cellular debris, presence of blood, and hair length affect the suitability for DNA analysis.

15.4.2 Discuss the complementary nature of microscopical hair comparisons and DNA analysis.

15.5 Practical Exercises

15.5.1 Examine numerous hairs and discuss their suitability for DNA analysis.

15.5.2 Practice photographing the root area for documentation purposes.

15.5.3 Practice demounting hairs from slides and preparing the hairs for nDNA or mtDNA analysis, or both.

15.5.4 If available, review results of DNA analyses and microscopical conclusions that have been reached on the same hairs in prior cases in order to gain experience in determining which hairs are most suitable for DNA analysis.

15.6 Competency Evaluation

15.6.1 Evaluate the trainee's ability to describe the types of DNA used for hair comparisons, the suitability of hair for DNA analysis, and how nDNA and mtDNA differ with an oral, practical, or written examination, or any combination thereof.

16. Interpretation and Reporting

16.1 This section helps the trainee to bring all analytical results together in a report and understand the significance and limitations of the analytical results.

16.2 The knowledge, training and experience required for the trainee to complete this section include the ability to:

16.2.1 Look at the circumstances of the incident and consider what information can contribute to the investigation from the analysis of hair.

16.2.2 Reach scientifically supportable, impartial, and informative conclusions based upon analytical results and appropriate case context that are not tailored to support the claims of one party over another.

16.2.3 Understand what types of background and contextual information are relevant and irrelevant to various tasks performed.

16.2.4 Write reports with appropriate limitations, interpretations, conclusions and statements according to laboratory protocols.

16.2.5 Understand how conclusions can be interpreted or misinterpreted by readers not familiar with hair evidence.

16.3 Recommended Reading Assignments

Any of the below-listed literature regarding statistical studies are intended for historical purposes and for an understanding of the ongoing conversation regarding the use of statistics in forensic hair examination but should not be used in the reporting of conclusions or testimony.

1) Aitken, C.G.G. and Robertson, J., "The Value of Microscopic Features in the Examination of Human Head Hairs, 1: Statistical Analysis." *Journal of Forensic Sciences,* 31(2):546-562. 1986.

2) Bisbing, R., "Hair Comparison: Microscopic." In: Siegel, J. and Saukko P.J., eds. *Encyclopedia of Forensic Sciences*, pp 1002-1016. London: Academic Press Ltd., 2000.

3) Barnett, P.D. and Ogle, R.R., "Probabilities and Human Hair Comparison." *Journal of Forensic Sciences,* volume 27(2):272-278. 1982.

4) Cole, Simon A., and Troy Duster. "Microscopic Hair Comparison and the Sociology of Science." *Contexts* 15.1: 28-35. 2016.

5) Deedrick, D. and Koch, S., "Microscopy of Hair Part 1: A Practical Guide and Manual for Human Hairs." *Forensic Science Communications*, vol 6, no. 1, 2004.

6) Gaudette, B., "Hair: Overview." In: Siegel, J. and Saukko P.J., eds. *Encyclopedia of Forensic Sciences*, pp 999-1002. London: Academic Press Ltd., 2000.

7) Gaudette, B., "Hair Comparison: Other." In: Siegel, J. and Saukko P.J., eds. *Encyclopedia of Forensic Sciences*, pp 1016-1018. London: Academic Press Ltd., 2000.

8) Gaudette, B., "Hair Comparison: Significance of Hair Evidence." In: Siegel, J. and Saukko P.J., eds. *Encyclopedia of Forensic Sciences*, pp 1018-1024. London: Academic Press Ltd., 2000.

9) Gaudette, B., "Hair: Hair Transfer, Persistence and Recovery." In: Siegel, J. and Saukko P.J., eds. *Encyclopedia of Forensic Sciences*, pp 1032-1034. London: Academic Press Ltd., 2000.

10) Gaudette, B., "Hair: Identification of Human and Animal Hair." In: Siegel, J. and Saukko P.J., eds. *Encyclopedia of Forensic Sciences*, pp 1034-1041. London: Academic Press Ltd., 2000.

11) Gaudette, B.D., "A Supplementary Discussion of Probabilities and Human Hair Comparisons." *Journal of Forensic Sciences*, volume 27(2):279-289. 1982.

12) Gaudette, B.D. and Tessarolo, A.A., "Secondary Transfer of Human Scalp Hair." *Journal of Forensic Sciences*, volume 32(5):1241-1253. 1987.

13) Gaudette, B.D., "Strong Negative Conclusions in Hair Comparisons – A Rare Event." *The Canadian Society of Forensic Sciences Journal*, volume 17(1):32-37. 1985.

14) Gaudette, B.D. and Keeping, E.S., "An Attempt at Determining Probabilities in Human Scalp Hair Comparison." *Journal of Forensic Sciences*, volume 19(3):599-606. 1974.

15) Gaudette, B.D., "Probabilities and Human Pubic Hair Comparisons." In: *The Journal of Forensic Sciences*, volume 21(3):514-517. 1976.

16) .

17) Gaudette, B.D., "Some Further Thoughts on Probabilities and Human Hair Comparisons." *Journal of Forensic Sciences*, volume 23(4):758-763. 1978.

18) Gaudette, B.D. "Evaluation of Associative Physical Evidence." *Journal of Forensic Science Society*, volume 26(3):163-167. 1986.

19) Gaudette, B.D., "The Use of Statistics in Forensic Science." *The Journal of Forensic Science Society*, volume 27(2):117-118. 1987.

20) Gaudette, B.D., "Evidential Value of Human Hair Examination." In Robertson, J., *Forensic and Microscopic Examination of Human Hair,* pp 243-260. London: Taylor and Francis. 1999.

21) Giannelli, P.C., "Hair Comparison Evidence." Faculty Publications. Paper 231, 2001.

22) Houck, M., "Is Microscopic Hair Comparison a Legitimate Science?" In: Koen, W. and Bowers, C., eds., *Forensic Science Reform*, pp 34-53. London: Academic Press Ltd., 2017.

23) Houck, M. M., "Forensic Human Hair Examination and Comparison in the 21st Century." *Forensic science review*, *17*(1), 51-66, 2005.

24) Kaye, David H. "Ultracrepidarianism in Forensic Science: The Hair Evidence Debacle." *Washington & Lee Law Review Online,* 72. 2015.

25) Lanning, K.A., Michaud, A.L., Bisbing, R.E., Springer, F.A., Tridico, S.R., "Scientific Working Group on Materials Analysis Position on Hair Evidence." *Journal of Forensic Sciences*, volume 54(5): 1198-1202. 2009.

26) Mann, M.J., "Hair Transfers in Sexual Assault: A Six Year Case Study." *Journal of Forensic Sciences,* volume 35(4): 951-955. 1990.

27) National Research Council, "Strengthening Forensic Science in the United States: A Path Forward." National Academy Press, pg 151-166. 2009.

28) Rowe, Walter F. "The Current Status of Microscopical Hair Comparisons." *The Scientific World Journal,* 1: 868-878. 2001.

29) Taupin, J. M. "Forensic hair morphology comparison–a dying art or junk science?" *Science & Justice,* 44.2: 95-100. 2004.

30) Wickenheiser, R.A. and Hepworth, D.G., "Further Evaluation of Probabilities in Scalp Hair Comparison." *Journal of Forensic Sciences*, volume 35(6):1323-1329. 1990.

31) Department of Justice, Uniform Language for Testimony and Reports for the Forensic Hair Discipline (2019)
https://www.justice.gov/olp/page/file/1083686/download

16.4 Discussion

16.4.1 Discuss how to determine what type of analysis is appropriate in a given case, based upon the circumstances of the incident. For example, in an assault, finding victim's hairs with

telogen roots on the clothing of a defendant could be insignificant if the victim and defendant lived together. However, finding a clump of victim's hairs with anagen roots on the clothing of this defendant can be meaningful. Context is essential in defining the problem being addressed scientifically.

16.4.2 Discuss and understand the conclusions from a hair comparison.

16.4.3 Discuss and understand how the meanings and limitations of conclusions from a hair comparison differ (e.g., similarities, dissimilarities, and inconclusive).

16.4.4 Discuss factors that affect the strengths and weaknesses of an association.

16.4.5 Discuss and understand the difference and significance between false positives and false negatives that can occur in hair comparisons and their impact on case outcomes.

16.4.6 Discuss publications reflecting critical perspectives of the field.

16.4.7 Discuss the scientific limitations of hair examinations.

16.4.7.1 Microscopical hair comparisons cannot source a hair to a single person to the exclusion of all others.

16.4.7.2 It is unknown how many people share the same microscopic hair characteristics.

16.4.7.3 Mitochondrial DNA is shared among maternal relatives (and others more distantly related) and is also not able to identify a single person to the exclusion of all others.

16.4.7.4 Nuclear DNA could be absent in a hair root and probative information (artificial treatment, hair color, damage, decomposition, etc.) can be lost if nDNA is attempted prior to microscopical analysis.

16.5 Practical Exercises

16.5.1 Write reports on simulated hair cases according to laboratory guidelines.

16.5.2 Discuss the testimony that would be given for each of the simulated cases.

16.6 *Competency Evaluation*

16.6.1 Evaluate the trainee's ability to correctly interpret given data sets, form conclusions, and write reports with properly qualified results with a written or oral examination, or both.

17. Moot Court and Competency Examination

17.1 This section introduces the trainee to courtroom policies and procedures and includes a review of historical cases and challenges to hair examinations.

17.1.1 This module should include observation of the testimony of a senior analyst and practice by the trainee in a simulated courtroom situation.

17.2 The knowledge, training and experience required for the trainee to complete this section include the ability to:

17.2.1 Explain the results of the examinations as related in the written report.

17.2.2 Properly qualify the results within the limitations of the science.

17.2.3 Respond to questions from both prosecution and defense in a scientifically sound and unbiased manner.

17.2.4 Understand the importance of a pretrial conference with the attorneys.

17.2.5 Discuss the legal and ethical obligations of an expert witness.

17.2.6 Understand that the weight that hair evidence carries in court is influenced by the testimony given by the analyst. Discuss why the analyst should be careful when explaining a hair examination and why it is important to always include the limitations of a microscopical comparison.

17.2.7 Understand the laboratory procedures regarding the monitoring of courtroom testimony.

17.3 Recommended Reading Assignments

1) Deedrick, D. and Koch, S., "Microscopy of Hair Part 1: A Practical Guide and Manual for Human Hairs." In: *Forensic Science Communications*, vol 6, no. 1. 2004.

2) Eastwood, J. and J. Caldwell., "Educating Jurors about Forensic Evidence: Using an Expert Witness and Judicial Instructions to Mitigate the Impact of Invalid Forensic Science Testimony." Journal of Forensic Sciences, vol 60, no.6. 2015.

3) Giannelli, P.C., "Hair Comparison Evidence." Faculty Publications. Paper 231, 2001.

4) Houck, M., Bisbing, R., Watkins, T. and Harmon, R. "Locard Exchange: The Science of Forensic Hair Comparisons and the Admissibility of Hair Comparison Evidence: Frye and Daubert Considered." In: *Modern Microscopy Journal, 1-10. 2004.*

5) Houck, M., "Statistics and Trace Evidence: The Tyranny of Numbers." In: *Forensic Science Communications,* vol 1, no. 3. 1999.

6) Oien, C.T., "Forensic Hair Comparison: Background Information for Interpretation." *Forensic Science Communications,* vol 1, no.2. 2009.

7) Department of Justice, Uniform Language for Testimony and Reports for the Forensic Hair Discipline (2019) https://www.justice.gov/olp/page/file/1083686/download

17.4 Practical Exercises

17.4.1 Review transcripts of hair testimonies (if available). From these transcripts, critique the testimony given and formulate answers to the direct and cross-examination questions asked by the attorneys. Review and discuss with the trainer both the original testimony and the trainee's answers.

17.4.1.1 Review cases of wrongfully convicted individuals where hair evidence was presented and discuss with the trainer.

17.4.2 Formulate a series of qualifying and technical court questions and explain to a mock attorney the results of the hair examination.

17.4.3 Participate in practice moot courts and be evaluated by the trainer.

17.4.4 Observe the pretrial conference and testimony of senior hair examiners. Afterward, discuss the various aspects of testifying, to include:

17.4.4.1 Appearance and demeanor.

17.4.4.2 Presenting credentials in a voir dire.

17.4.4.3 Addressing chain of custody issues.

17.4.4.4 Jury education on hair evidence.

17.4.4.5 Presenting results accurately in layman's terms.

17.4.4.6 Cross-examination.

17.4.4.7 Jury's reaction.

17.5 Competency Evaluation

17.5.1 Provide a competency test to the trainee as required by the laboratory. The test should be a comprehensive test encompassing the entire process of hair examination.

17.5.2 Upon successful completion of the competency test, the trainee should be subjected to a moot court, conducted in as realistic a manner as possible. Critique the trainee's performance with the goal of helping the trainee improve. Special attention should be given to the trainee's appearance, demeanor, knowledge, and ability to present the results and limitations of the science in an understandable and unbiased manner to the jury.