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Standard Practice for a Forensic Fiber Training Program

Trace Materials Subcommittee
Chemistry: Trace Evidence Scientific Area Committee (SAC)
Organization of Scientific Area Committees (OSAC) for Forensic Science

Draft OSAC Proposed Standard

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Prepared by
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Standard Practice for a Forensic Fiber Training Program

1. Scope

1.1. This practice covers training elements and program objectives for use by laboratory personnel responsible for training forensic science practitioners (FSPs) who will perform examinations and comparisons of fibers, fabric, rope, and cordage.

1.2. This standard is intended for use by competent FSPs with the requisite formal education, discipline-specific training (see Practice E2917), and demonstrated proficiency to perform forensic casework.

1.3. This practice outlines the tasks, goals, and objectives that allows the trainee to acquire the requisite knowledge, skills, and abilities to independently perform casework.

1.4. This standard does not purport to address all of the possible 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 requirements prior to use.

1.5. This international standard was developed in accordance with internationally-recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1. ASTM Standards:

D123 Standard Terminology Relating to Textiles
D276 Standard Test Methods for Identification of Fibers in Textiles
D3990 Standard Terminology Relating to Fabric Defects
D4849 Standard Terminology Related to Yarns and Fibers
D4850 Standard Terminology Relating to Fabrics and Fabric Test Methods
D7139 Standard Terminology for Cotton Fibers
E620 Practice for Reporting Opinions of Scientific or Technical Experts
E1459 Standard Guide for Physical Evidence Labeling and Related Documentation
E1492 Practice for Receiving, Documenting, Storing, and Retrieving Evidence in a Forensic Science Laboratory
E1732 Standard Terminology Relating to Forensic Science
E2224 Standard Guide for Forensic Analysis of Fibers by Infrared Spectroscopy
E2225 Standard Guide for Forensic Examination of Fabrics and Cordage
E2227 Standard Guide for Forensic Examination of Non-Reactive Dyes in Textile Fibers by Thin-Layer Chromatography
E2228 Standard Guide for Microscopical Examination of Textile Fibers
E2809 Standard Guide for using Scanning Electron Microscopy/Energy-Dispersive X-ray Spectroscopy (SEM/EDS) in Forensic Polymer Examinations
E2917 Standard Practice for Forensic Science Practitioner Training, Continuing Education, and Professional Development Program
E3255 Practice for Quality Assurance of Forensic Science Service Providers performing Forensic Chemical Analysis
WK78747 Standard Guide for the Forensic Examination of Fibers
WK78749 Microspectrophotometry in Forensic Fiber Analysis

2.2. Other Documents:
AATCC Test Method 20: Qualitative Test Method 20-2013:Fiber Analysis: Qualitative
OSAC 2022-S-0015 Standard Guide for Forensic Physical Fit Examination

3. Terminology

3.1. *Definitions—For definitions of terms used in this guide, refer to Terminology D123, D3990, D4849, D4850, D7139, E1732, and to Standard Guides E2225, E2227, and E2228*.
3.2. *Definitions of Terms Specific to This Standard:*
3.3. *animal fiber, n*—any natural protein-based fiber. (See D7641)
3.4. *bulk sample, n—in the sampling of bulk material,* one or more portions which *(1)* are taken from material that does not consist of separately identifiable units and *(2)* can be identified after sampling separate or composited units. (See D123)
3.5. *charring, n*—the formation of carbonaceous residue as the result of pyrolysis or incomplete combustion. (See D123)
3.6. *fabric, n—in textiles*, a planar structure consisting of yarns or fibers. (See D123)
3.7. *filament, n—in textiles*, a continuous fiber of extremely long length. (See D123)
3.8. *finishing, n*—the process of converting a woven or knitted textile into a usable material; any process performed after dyeing to improve the look, performance, or feel of a textile.
3.9. *flax, n*—the generic name for plants that are botanically classified as *Linum usitatissimum*, which are cultivated for seed and/or fiber.[D.13.17] (See D6798)
3.10. *jute, n*—soft fibers from the inner bark of the round pod jute (*Corchorus capsularis*), the long pod jute (*Corchorus olitorius*), and from the inner bark of other closely related plants, such as kenaf, sometimes referred to as Meshta (*Hibiscus cannabinus*). (See D7641)
3.11. *target fibers, n*—questioned fibers that a forensic science practitioner selects for further examination based on their resemblance to the known sample.

4. Significance and Use

4.1. This practice details a fiber training program to identify the necessary information and guidelines for preparing a trainee to become a qualified FSP. The trainee is under the direct supervision of a qualified FSP throughout their training. Upon successful completion of the program, a trained FSP is capable of independently performing appropriate examinations, interpreting analytical results, writing reports, and testifying in court.
4.1.1. Additional training beyond that listed here should be made available to the trainee. Such training can include off-site courses, tours of manufacturing plants, internships, and specialized training by experienced FSPs. Additional training provides a FSP with the opportunity to remain current in the field.
4.2. This practice identifies a variety of microscopical and instrumental techniques that can be used in the laboratory's training program for the analysis of fibers. Examples of microscopes and instruments used for fiber analysis include the polarized light microscope, comparison microscope, fluorescence microscope, Fourier-transform infrared spectrometer (FTIR), and microspectrophotometer (MSP).
4.3. Fabric or cordage samples may occasionally be evaluated for physical fits of edges. Physical fit comparisons are beyond the scope of this document. Additional training is required to conduct this type of analysis. Refer to *OSAC 2022-S-0015 Standard Guide for Forensic Physical Fit Examination.*
4.4. This document can be adapted to an individual laboratory's training program. Recommendations as to lessons, practical exercises, progress monitoring, and evaluations are included. Reading assignments with full citations are listed in an appendix at the end of this document.

5. Syllabus

5.1. Required topics for fiber training include:

5.1.1. Occurrence, transfer, and persistence of fibers;

5.1.2. Evidence recovery procedures;

5.1.3. Appropriate evidence handling to minimize contamination and loss;

5.1.4. Evidence packaging and documentation;

5.1.5. Fiber and microscopy terminology;

5.1.6. Use and maintenance of microscopes;

5.1.7. Understanding of fiber chemistry, biology, structure, and function;

5.1.8. Identification, classification, and characterization of fibers;

5.1.9. Classification of textiles and cordage;

5.1.10. Comparison of questioned and known fibers;

5.1.11. Comparison of questioned and known fabrics and textiles;

5.1.12. Comparison of questioned and known cordage;

5.1.13. Recognition and characterization of textile and cordage damage;

5.1.14. Recognition of fabric and cordage impressions;

5.1.15. Additional analytical techniques that can be used for fiber analysis;

5.1.16. Interpretation of comparison results;

5.1.17. Preparation of laboratory reports; and

5.1.18. Appropriate testimony of results and interpretations.

6. Responsibilities

6.1. *Trainer Responsibilities*

6.1.1. The trainer is technically qualified in fiber examinations and comparison, including fabric and cordage analysis. The trainer is responsible for:

6.1.1.1. Documenting and reviewing each stage of the training process.

6.1.1.2. Introducing the relevant scientific literature, appropriate procedures, training material, and reference collections.

6.1.1.3. Demonstrating and teaching basic microscopy and instrumental procedures for the analysis and comparison of fiber evidence.

6.1.1.4. Teaching case management, to include: chain of custody documentation; evidence processing, preservation, and storage; decision-making criteria; data interpretation; documentation of analyses; report writing; and laboratory safety protocols.

6.1.1.5. Fostering ethical, unbiased, and appropriate professional conduct.

6.1.1.6. Teaching appropriate quality assurance and quality control procedures.

6.2. *Trainee Responsibilities*

6.2.1. Through completion of this training, the trainee is expected to build on their formal educational background and acquire theoretical knowledge and practical skills in:

6.2.1.1. Equipment and instrumentation use, routine maintenance, and functionality assessment;

6.2.1.2. Fiber and textile history and usage, including common end-uses of different fiber, yarn, fabric and cordage types;

6.2.1.3. Fiber, textile, and cordage terminology (see ASTM documents D3990, D4845, D4849, D4850, D4920, D5219, D5684, D6798, D7022, and D7139);

6.2.1.4. Fiber and textile chemistry

6.2.1.5. Manufacturing processes, including chemical treatments, mechanical treatments, and dyeing and finishing processes;

6.2.1.6. Search, recovery, preservation, and examination techniques, including appropriate sample handling, packaging, and documentation of fibrous materials collected from a variety of

substrates;
6.2.1.7. Classification of natural and manufactured fibers used in textile materials;
6.2.1.8. Identification and comparison of natural and manufactured fibers by optical, chemical and physical property examinations;
6.2.1.9. Examination and comparison of textiles and cordage for physical construction and fiber composition;
6.2.1.10. Fiber and textile physical wear, damage, and manufacturing artifacts assessment;
6.2.1.11. Understanding and interpreting fiber, textile, and cordage examination, identification, and comparison results, including factors affecting (1) the analytical interpretation and (2) the significance of the evidence with respect to fiber transfer and persistence;
6.2.1.12. Appropriate completion of laboratory reports;
6.2.1.13. Appropriate technical assessment of fiber reports for review;
6.2.1.14. Appropriate presentation of testimonial evidence; and
6.2.1.15. Detection and assessment of other types of physical evidence that could be encountered during fiber and textile examinations.

7. Training Program Objectives

7.1. *Expectations*
7.1.1. Provide a written schedule of expected completion dates for training goals.
7.1.2. Conduct periodic progress assessments between the trainer, trainee, and supervisor.
7.1.2.1. Establish satisfactory/pass criteria prior to beginning the training program, as well as contingencies for not passing a test.
7.1.2.2. Address any deficiencies in performance and make any necessary remediation available in a timely manner through additional readings, training, and re-evaluation of the training program.
7.1.2.3. Recognize that continued deficiencies suggest the unsuitability of the trainee for casework in fiber analysis.
7.1.3. A trainee with experience in other areas of forensic science could have previous knowledge and experience in microscopy, in other areas of trace analysis, and in testimony, and therefore would not require such an extensive training regimen.
7.2. *Instruction*
7.2.1. Select and discuss reading assignments in relevant scientific literature to provide a sound theoretical background and solid foundation in topics necessary for fiber analysis. Other relevant literature or media may supplement the listed assignments.
7.2.1.1. Appendix 1 provides reading assignments to supplement subsequent sections.
7.2.2. Demonstrate and discuss basic and essential skills in sample preparation, microscopy, and instrumental procedures. The trainee practices these skills until they are able to exhibit proficiency in the technique(s) by demonstration to the trainer.
7.3. *Observations*
7.3.1. Enable the trainee to observe (an) experienced FSP(s) in all aspects of casework, including:
7.3.1.1. Record keeping;
7.3.1.2. Evidence processing;
7.3.1.3. Sample preparation;
7.3.1.4. Examination of prepared samples;
7.3.1.5. Characterization, identification, comparison and interpretation of fiber evidence; and
7.3.1.6. Development of a written laboratory report.
7.3.2. Enable the trainee to observe experienced FSPs testifying in court.
7.4. *Practical Exercises*

7.4.1. Design practical exercises to allow the trainee to learn and practice the skills necessary to perform casework.
7.4.1.1. Include analysis of both reference materials and known samples.
7.4.2. Review the exercises with the trainee, with particular attention to development of critical-thinking skills and continual development of practical skills.
7.4.3. Design higher-level exercises to mimic actual casework and to assess practical and critical-thinking skills.
7.4.4. Review performance and documentation during the exercises to evaluate the ability to make determinations based on fiber examinations.
7.4.5. Allow the trainee to assist in or observe casework performed by trained FSPs.
7.4.6. Document completion of the exercises.
7.4.7. Encourage continuous experimentation of skills beyond the required exercises.
7.5. *Tests*
7.5.1. Design tests for each topic of fiber analysis to:
7.5.1.1. Provide focus and continual feedback on comprehension of the topic;
7.5.1.2. Provide documentation on the ability to meet training objectives;
7.5.1.3. Demonstrate the mastery of practical basic skills and theoretical knowledge; and
7.5.1.4. Maintain a record of satisfactory completion of each topic area.
7.5.2. Design practical laboratory tests for each area of fiber analysis to:
7.5.2.1. Enable the trainee to independently perform all aspects (administrative and technical) of the task being tested at simulated casework level.
7.5.2.2. Evaluate the tests at casework level.
7.5.2.3. Document satisfactory completion.
7.5.3. Provide written or oral tests as a means of determining comprehension of the material and to document the training.
7.5.3.1. Questions should be designed to test the trainee's theoretical and practical knowledge.
7.6. *Competency and Moot Court*
7.6.1. Administer a competency test prior to authorizing the trainee to analyze and compare fiber evidence in supervised casework.
7.6.2. The competency test should be designed to mimic actual casework, requiring demonstration of knowledge of the laboratory procedures for (1) handling evidence; (2) case documentation; (3) maintaining chain of custody; (4) examining fiber evidence; (5) comparing fiber evidence; and (6) making determinations and writing reports based on the interpretations made.
7.6.3. The laboratory is responsible for establishing objective criteria for successful completion of a competency test.
7.6.4. If necessary, note any deficiencies or failures and develop a remediation plan.
7.6.5. Conduct a moot court exercise.
7.6.5.1. Evaluate the ability to orally express the appropriate interpretations and significance of fiber analyses.
7.7. *Evaluation of Fiber Training Program*
7.7.1. Allow the trainee to evaluate the fiber training program and the trainer.
7.7.2. Address any perceived deficiencies in the training program and the trainer in a timely manner.
7.8. *Casework Authorization*
7.8.1. Provide the trainee with written approval from designated laboratory personnel (e.g., quality control officer, training manager) to perform supervised casework upon successful completion of the training program and a comprehensive competency test.
7.8.2. Provide the trainee with approval from designated laboratory personnel (e.g., quality

control officer, training manager) to perform independent casework in fiber examinations after successful completion of supervised casework.

7.8.2.1. During this period of supervised casework, discuss and review laboratory results and documentation with the new FSP.

7.8.2.2. Maintain written documentation of this completion.

7.8.3. Provide written approval for the trainee to perform independent casework.

7.9. 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. Introduction to Fibers and Textiles

8.1. Introduce the basic concepts and theoretical knowledge of fiber and textile product manufacture, construction, and use, in addition to commercial and forensic classifications, and provide an overview of forensic examinations for identification and comparisons. This area of training covers both historical and contemporary topics, and provides the foundation upon which practical analytical skills are developed in the subsequent sections.

8.2. Through completion of this module, the trainee will develop the knowledge to be conversant in:

8.2.1. Fiber and textile history, usage and manufacturing;

8.2.2. Fiber and textile technology and terminology;

8.2.3. Chemistry and manufacturing processes of fibers, fabric, cordage, and dyes;

8.2.4. Textile and cordage construction;

8.2.5. Fiber classification schemes; and

8.2.6. Identification versus comparison of fibers and textiles.

8.3. As an option, offer additional training from textile museum or industrial manufacturing plant tours, videos of textile processing, visits to fabric and carpet stores, etc.

8.4. *Textiles*

8.4.1. Instruct in the manufacturing, use, construction, and composition of different types of fibers and fabrics, to include the following:

8.4.1.1. Weaves, knits, and non-woven fabrics;

8.4.1.2. End-use applications of fibers, fabrics, and cordage, incorporating both household and clothing materials;

8.4.1.3. Dyeing and printing of fibers and fabrics;

8.4.1.4. Fiber components of textiles, including yarns, threads, embroidery, and button threads

8.4.1.5. Delustrant and inclusions in fibers; and

8.4.1.6. Bicomponent fibers.

8.4.2. The trainee is required to:

8.4.2.1. Understand textile terminology.

8.4.2.2. Understand the physical construction of household and clothing textiles.

8.4.3. Practical Exercises for the trainee

8.4.3.1. Classify fabrics as to weave, knit, or non-woven.

8.4.3.2. Identify the warp and weft in woven fibers.

8.4.4. Evaluate by an oral or written test and a practical test, incorporating various textiles types.

8.5. *Cordage*

8.5.1. Instruct in the manufacturing and construction of cordage.

8.5.1.1. *Note*—Cordage terminology can vary within the literature.

8.5.2. Instruct in the documentation and handling of knots, to include refraining from altering knots when possible. This section is not intended to instruct in the identification of knots.

8.5.3. The trainee is required to:
8.5.3.1. Understand cordage terminology.
8.5.3.2. Understand how cordage is constructed.
8.5.3.3. Provide a physical description of cordage, to include where applicable: diameter, length, type of structure (e.g., twisted, braided), number of plies/strands, twist directions (S or Z), type of braiding, length and angle of lay (crowns or turns/inch), color, and presence of internal or external marker yarns.
8.5.3.4. Provide a physical description of the plies and yarns from each component, to include if applicable: twist direction of yarns or fibers, number of yarns twisted together, number of filament fibers, length of lay of twisted yarns, type of twisted fibers (e.g., staple, filament, film), and type of core that could be present (mono- or multi-filament).
8.5.4. Practical Exercise for the trainee:
8.5.4.1. Determine the physical construction of cordage samples.
8.5.5. Evaluate by an oral or written test and a practical test, incorporating various cordage types.
8.6. *Overview of Fiber Examinations*
8.6.1. Introduce the basic steps in fiber examinations and how these steps are used (1) to identify and characterize a fiber, textile, or cordage and (2) to conduct comparisons.
8.6.2. Evaluate by an oral or written test.

9. Fiber Evidence

9.1. *Transfer and Persistence*
9.1.1. Introduce the basic concepts and theory of transfer and persistence of fibers. Discuss loss and contamination as it relates to transfer and persistence of fibers.
9.1.2. Instruct in the following concepts:
9.1.2.1. Locard's Exchange Principle;
9.1.2.2. The potential significance of fibers as associative trace evidence in forensic cases;
9.1.2.3. The varying potential for different types of fibers to shed;
9.1.2.4. Fiber transfer mechanisms; and
9.1.2.5. Factors affecting fiber transfer and persistence, e.g., amount of friction, physical characteristics of the fabric, duration of contact, force of contact, damage or lack of damage to material.
9.1.3. Instruct in techniques to prevent or reduce fiber evidence contamination and loss during laboratory examinations, including:
9.1.3.1. Wearing appropriate protective apparel;
9.1.3.2. Appropriate packaging, handling, and labeling;
9.1.3.3. Cleaning equipment and work surfaces;
9.1.3.4. Maintaining a controlled environment; and
9.1.3.5. Separating evidence from different sources by location and time.
9.1.4. Ensure the trainee can demonstrate comprehension of contamination and loss prior to training in basic practical skills.
9.1.5. Practical Exercises for the Trainee
9.1.5.1. Demonstrate knowledge of the types of cases in which fiber evidence is encountered and transferred through an oral or written exercise.
9.1.5.2. Assess the potential for transfer and persistence of fibers by simulating crime scene activity and by varying (1) fabric construction and composition, (2) fabric damage, (3) amount and force of contact, (4) time of collection, and (5) additional activity after the simulation.
9.1.6. Evaluate by an oral or written test.

9.2. *Search, Collection, and Preservation Techniques*

9.2.1. Introduce the basic procedures and processes for appropriately documenting, detecting, collecting, and preserving all types of fiber evidence.

9.2.2. Expose the trainee to practical evidence handling issues such as transfer, persistence, and loss of trace evidence.

9.2.3. Allow the trainee to observe fiber collection in the laboratory and in the field, if possible.

9.2.4. Demonstrate how to maintain control and integrity of fiber evidence throughout collection, examination, and de-mounting.

9.2.5. Complete this training section in conjunction with Section 10, Stereomicroscopy.

9.2.6. The trainee is required to:

9.2.6.1. Recognize fiber evidence.

9.2.6.2. Understand laboratory requirements for documentation of fiber evidence.

9.2.6.3. Coordinate fiber collection with other types of evidence collection.

9.2.6.4. Use picking, taping, scraping, and vacuuming procedures to collect fibers from a variety of surfaces, in conjunction with (1) understanding the benefits and disadvantages of each collection procedure, (2) preventing contamination and loss of fiber evidence, (3) using alternate lighting techniques, and (4) documenting examination and collection.

9.2.6.5. Understand preservation techniques appropriate for various types of fiber evidence.

9.2.7. Practical Exercises for the Trainee

9.2.7.1. Perform collection of several fiber samples from various surfaces using procedures outlined above. Assess the efficiency and discrimination of each collection procedure.

9.2.7.2. Demonstrate appropriate packaging techniques and documentation for trace material collected from items of evidence.

9.2.7.3. Demonstrate the ability to appropriately handle and preserve fiber evidence, from collection and mock examination to de-mounting.

9.2.7.4. Tape lift or vacuum a “clean” laboratory surface and examine for any fibers.

9.2.7.5. Practice awareness for the potential of fiber transfer and contamination (e.g., place textile items on clean surfaces, remove, and collect from the surface; then place textile items on clean surfaces, remove, place other items on the surface, and then collect from the second item and evaluate results).

9.2.8. Evaluate by an oral or written test as well as a practical test.

10. Microscopy and Fiber Evidence

10.1. *Introduction to Microscopy*

10.1.1. Introduce the theory, basic procedures and techniques, and proper operation of a stereomicroscope, polarized light microscope (PLM), comparison microscope, and fluorescence microscope, to include:

10.1.1.1. Proper illumination;

10.1.1.2. Verification of ocular micrometer;

10.1.1.3. Care and maintenance of microscopes; and

10.1.1.4. Location and function of each microscope component.

10.1.2. The trainee is required to:

10.1.2.1. Understand the optics of the microscope.

10.1.2.2. Properly set up, operate, and maintain each type of microscope and its accessories, including making adjustments, cleaning, and diagnosing problems.

10.1.2.3. Understand the strengths and limitations of each type of microscope.

10.1.2.4. Center microscope stages and objectives.

10.1.2.5. Establish and optimize proper illumination, to include Köhler or modified Köhler

illumination.
10.1.2.6. Perform basic micrometry.
10.1.2.7. Observe samples under brightfield and crossed polars.
10.1.2.8. Observe relative refractive indices of various materials by the Becke line method.
10.1.2.9. Distinguish isotropic and anisotropic materials.
10.1.2.10. Determine extinction positions of various materials.
10.1.2.11. Observe interference colors of various materials.
10.1.2.12. Optimize lighting to achieve and recognize proper color-balancing on a comparison microscope for a similar visual response to color, clarity, and brightness.
10.1.2.13. Observe fluorescence of various materials, noting both color and intensity.
10.1.2.14. Practice taking photomicrographs using each type of microscope with appropriate camera equipment (if possible).
10.1.3. Practical Exercises for the Trainee
10.1.3.1. Become familiar with the stereomicroscope.
10.1.3.2. Become familiar with the compound light microscope, to include performing Kohler or modified Kohler illumination and verifying an ocular micrometer for each objective.
10.1.3.3. Become familiar with the PLM, to include (1) determining refractive indices by the Becke line method; (2) observing samples using the polarizer and analyzer in different positions; (3) observing extinction positions and interference colors under crossed polars; and (4) inserting a compensator or full-wave plate and observing the resulting colors.
10.1.3.4. Become familiar with the comparison light microscope, to include making reference slides for color-balancing and achieving color-balancing.
10.1.3.5. Become familiar with the fluorescence microscope, to include using excitation and barrier filters and observing fluorescent colors and intensity.
10.1.3.6. Take photomicrographs of samples using each type of microscope, if possible.
10.1.4. Evaluate by a written and practical test.
10.2. *Fiber Sample Preparation*
10.2.1. Instruct in handling and mounting of textiles, cordage, and single-fiber samples by:
10.2.1.1. Demonstrating manipulation and sampling of various textiles, cordage, and fibers; and
10.2.1.2. Selecting mounting media and tools appropriate to the evidence.
10.2.2. The trainee is required to:
10.2.2.1. Select the appropriate tools for fiber sample manipulation;
10.2.2.2. Select the appropriate mounting media for sample observation;
10.2.2.3. Prepare slides from various textiles, cordage, and fiber samples for microscopical observation; and
10.2.2.4. Select appropriate microscopes and accessories for the required task.
10.2.3. Practical Exercises for the trainee:
10.2.3.1. Practice retrieving fibers from tape lifts.
10.2.3.2. Practice de-mounting fibers from slides.
10.2.4. Evaluate by a written and practical test.
10.3. *Recognition of Fibers by Microscopy*
10.3.1. Introduce the process of describing and recognizing basic fiber features, including:
10.3.1.1. Color (both macroscopic and microscopic);
10.3.1.2. Natural vs. manufactured;
10.3.1.3. Longitudinal appearance;
10.3.1.4. Cross-sectional shape; and
10.3.1.5. Presence or absence of delustrant/inclusions.
10.3.2. Instruct in the ability to discern:
10.3.2.1. Differences in color using the unaided eye as well as the stereomicroscope and higher-

powered microscopes;
10.3.2.2. Fiber shapes by using various cross-sectioning techniques;
10.3.2.3. Surface features;
10.3.2.4. Internal structure;
10.3.2.5. Dichroism;
10.3.2.6. Fiber diameter (both longitudinal and cross-sectional); and
10.3.2.7. Basic differences between Manufactured, Animal, Mineral, and Vegetable Fibers.
10.3.3. The trainee is required to:
10.3.3.1. Observe fiber samples under brightfield and crossed polars using PLM.
10.3.3.2. Demonstrate an understanding of color and colorimetry.
10.3.3.3. Assess color and dichroism of fiber samples.
10.3.3.4. Understand metamerism and the usage of various light sources in the evaluation and comparison of color.
10.3.3.5. Assess the shape, surface, and internal features by optical cross-sectioning.
10.3.3.6. Prepare and mount cross sections of single fibers, multiple fibers, and fiber tufts using various techniques.
10.3.3.7. Measure fiber dimensions using ocular and stage micrometers.
10.3.3.8. Differentiate general morphological features distinguishing natural and manufactured fibers.
10.3.4. Practical Exercises for the trainee
10.3.4.1. Observe various different types of fibers, textiles, and cordage under the different microscopes, to include (1) different types of woven, non-woven, and knitted textiles; (2) textiles dyed by different methods; (3) textiles with prints, embroidery, etc.; (4) textiles of varying colors, depth of color, texture, and luster.
10.3.4.2. Become familiar with the use of the stereomicroscope for fibers, to include sampling and practicing to recognize "target" fibers.
10.3.4.3. Become familiar with the use of the compound light microscope for fibers, to include (1) determining and comparing fiber diameters at each magnification and (2) observing and comparing fibers mounted in different mounting media,
10.3.4.4. Cross section various fibers using the different techniques learned.
10.3.4.5. Become familiar with the use of PLM for fibers.
10.3.4.6. Observe extinction, interference colors and cross sections of various fibers.
10.3.4.7. Determine refractive indices of various fibers using the Becke line method.
10.3.4.8. Observe and note fiber texture, surface debris, and the presence or absence of pigment particles, inclusions, voids, draw marks, and striations.
10.3.4.9. Observe and note fiber color: uniformity, dyed/pigmented/printed, variation among sample set; and color and intensity under different orientations.
10.3.5. Evaluate by a written and practical test.

11. Microscopy of Vegetable Fibers

11.1. Instruct in the techniques used in the identification of plant fibers commonly used in textile products and cordage (e.g., cotton, flax, jute, sisal, hemp).
11.1.1. The scope of this document does not include other botanical identifications.
11.2. Instruct in the information that can be obtained from cross-sectioning.
11.3. The trainee is required to:
11.3.1. Perform ashing and maceration of fibers for further observation.
11.3.2. Use brightfield and PLM to:
11.3.2.1. Observe (both longitudinally and in cross section) and identify plant tissue and cellular structural features that can be present;

11.3.2.2. Compare and contrast the types and quality of information obtained from optical cross-sectioning versus physical cross-sectioning;
11.3.2.3. Identify and measure cell structures (e.g., entire cell length and width, cell wall, and lumen; spiral thickenings; pits; dislocations; cytoplasmic remnants; crystals; and resins);
11.3.2.4. Identify basic plant tissues, including epidermis, xylem, phloem, seed and leaf hairs;
11.3.2.5. Determine sign of elongation and direction of twist (Herzog test);
11.3.2.6. Examine relative dimensions of the lumens in fiber cross sections; and
11.3.2.7. Observe other optical properties of individual fibers, fiber tissue, and cells.
11.3.3. Determine direction of twist by visual/macroscopical observation.
11.3.4. Perform microchemical tests for degree of lignification (e.g., Graff C, phloroglucinol, Herzberg).
11.3.5. Classify fibers as vegetable, and further classify as bast (stem), leaf, or seed (fruit) fibers.
11.3.6. Determine botanical identification as specifically as possible, using reference sources and comparisons.
11.3.7. Understand the processing, dyeing techniques, and end-use products of various vegetable fibers.
11.3.8. Understand the strengths and limitations of each technique used in the identification process.
11.4. Practical Exercises for the trainee
11.4.1. Use known samples to study textile vegetable fibers (e.g., cotton, coir, flax, hemp, ramie, jute, kapok, sisal, and manila [abaca]).
11.4.2. Perform ashing and maceration to obtain samples for observation.
11.4.3. Prepare and interpret cross sections by the various techniques learned.
11.4.4. Prepare, observe, and characterize longitudinal and cross sections of textile vegetable fibers and note:
11.4.4.1. Presence or absence of transverse dislocations;
11.4.4.2. Variation in cell wall;
11.4.4.3. Lumen dimension and diameter;
11.4.4.4. Degree of cell separation from bundles;
11.4.4.5. Shape of cell tips;
11.4.4.6. Presence or absence of striations, markings, pits, spiral cell wall thickenings, etc.;
11.4.4.7. Presence, shape, and position of crystalline inclusions;
11.4.4.8. Longitudinal appearance versus cross-sectional appearance;
11.4.4.9. Cross-sectional shape; and
11.4.4.10. Variation and arrangement of ultimates.
11.4.5. Observe and interpret optical cross sections.
11.4.6. Compare optical and created cross sections.
11.4.7. Compare and contrast microscopic morphological features of fibers.
11.4.8. Examine and compare dyed or printed fiber samples with untreated samples.
11.4.9. Prepare single-fiber ultimates and determine natural fiber twist using the Herzog Effect.
11.4.10. Perform the Drying Twist test and correlate with results from the Herzog test.
11.5. Evaluate by an oral or written test and a practical test on identification of vegetable fibers.

12. Microscopy of Animal Textile Fibers

12.1. For the purposes of this practice, “animal” refers to non-human mammalian hairs that are

used as fibers.

12.2. Instruct in the techniques used in the identification of animal textile fibers, which could include such products as silk, leather, and animal hairs.

12.2.1. The scope of this document does not include animal hair species identification.

12.2.2. Introduce:

12.2.2.1. Microscopic features of animal hairs;

12.2.2.2. Various domestic and local wild animal hairs that can be encountered in casework; and

12.2.2.3. Differences among domestic animal hairs (cat, dog) and animal textile fibers.

12.3. The trainee is required to:

12.3.1. Characterize optical and physical properties of animal textile fibers.

12.3.1.1. Make scale casts.

12.3.1.2. Identify and distinguish “wild” and “cultivated” types of silk.

12.3.1.3. Identify and describe the major morphological and structural features of animal hairs, including, but not limited to: root, cortex, medulla, scales, and shield, as appropriate for fur or guard hairs.

12.3.2. Distinguish human from animal hairs.

12.3.3. Identify the animal hairs and hides most commonly used in textile products:

12.3.3.1. Wool;

12.3.3.2. Goat family (Mohair, Cashmere);

12.3.3.3. Camel family (Camel, Alpaca, Vicuna);

12.3.3.4. Rabbit (Angora); and

12.3.3.5. Fur-bearing (Mink, Ermine, Chinchilla).

12.3.4. Understand the processing, grading, finishing, and dyeing techniques for animal hairs, as well as the end uses.

12.3.5. Understand appropriate animal taxonomy and morphological terminology.

12.3.6. Understand the strengths and limitations of identifying animal textile hairs by microscopy.

12.4. Practical Exercises for the trainee:

12.4.1. Examine human hairs and animal hairs to distinguish them from each other.

12.4.1.1. Animal hairs that are more difficult to distinguish from human hairs, such as cattle, horse, and bear, should be emphasized.

12.4.2. Identify and characterize the structures in various types of animal-based textiles.

12.4.3. Perform scale casts on various animal hairs used in textiles.

12.4.4. Determine scale margin distances.

12.4.5. Examine silk.

12.4.6. Examine leather.

12.5. Evaluate by an oral or written test and a practical test, with emphasis on identification of animal hairs used in the textile industry.

13. Microscopy of Mineral Fibers

13.1. Instruct in the history and use of mineral fibers.

13.1.1. Manufactured textile products that could also fall under the classification of mineral fibers, such as glass wool, certain anti-static fibers, and metallic fibers, are addressed in Section 14.

13.1.2. Naturally-occurring mineral fibers such as asbestos can be encountered as fibrous evidence, although their use has declined significantly due to health risks. These types of fibers could be encountered as evidence from sources such as building insulation, old

textile products, and current textile products containing chrysotile. Additional training regarding health and safety issues may be necessary if handling such evidence.

13.1.3. The emerging use of basalt fibers in fireproof textiles can be studied in this section of training as well.

13.2. The trainee is required to:

13.2.1. Understand the historical and current processing practices and end uses of the asbestos minerals, including:

13.2.1.1. Chrysotile;

13.2.1.2. Amosite;

13.2.1.3. Crocidolite;

13.2.1.4. Fibrous tremolite/actinolite; and

13.2.1.5. Fibrous anthophyllite.

13.2.2. Understand the crystalline nature, chemistry, and differences between layer and chain silicates.

13.2.3. Determine the optical properties of asbestos fibers by PLM and by dispersion staining.

13.2.4. Identify and classify asbestos by optical properties, particularly chrysotile.

13.2.5. Understand the applicability of instrumental techniques (e.g., infrared spectroscopy, X-ray diffraction, and elemental analytical techniques) to this type of fiber identification.

13.2.6. Understand the strengths and limitations of identification of asbestos by microscopy.

13.3. Practical Exercises for the trainee

13.3.1. Use authenticated samples of asbestos, other natural fibers, and building materials to compare and contrast morphological features. Exercise caution when handling samples of asbestos.

13.3.2. Practice judging dispersion staining colors with known materials.

13.3.3. Examine and learn to identify the different types of asbestos using microscopy and dispersion staining techniques. Exercise caution when handling samples of asbestos.

13.3.4. Examine pulped polyethylene, pulped Kevlar, and leather to learn to differentiate from asbestos.

13.4. Evaluate by an oral or written test and a practical test.

14. Microscopy of Manufactured Fibers

14.1. Manufactured fibers include fibers that are:

14.1.1. Made by chemical synthesis, such as thermoplastics, glass, and steel;

14.1.2. Made by regenerating natural polymers, such as rayon and bamboo; and

14.1.3. Derived from chemically-modified natural polymers, such as cellulose acetates.

14.2. Include manufactured fibers such as fiberglass; metal-coated decorative threads; and anti-static, ceramic, and metal fibers in the training.

14.3. *Optical properties*

14.3.1. Instruct in the appropriate techniques and observations for determining the optical properties of manufactured fibers.

14.3.2. The trainee is required to:

14.3.2.1. Determine refractive indices, sign of elongation, and birefringence of various manufactured fibers using the immersion method, and by using compensators and a quartz wedge.

14.3.2.2. Use appropriate mounting media to reveal internal structures in fibers.

14.3.2.3. Obtain optical property values of reference materials (from literature and reference collections).

14.3.2.4. Classify manufactured fibers into the appropriate generic class based on optical properties.

14.3.3. Practical Exercises for the trainee:

14.3.3.1. Determine sign of elongation using a first-order red compensator.

14.3.3.2. Determine sign of elongation using a quartz wedge.

14.3.3.3. Measure the birefringence of various fibers using a compensator or wedge.

14.3.3.4. Measure the refractive indices of various fibers using the immersion method.

14.3.3.5. Observe the amount of contrast and determine the relative refractive indices of multiple fibers in various mounting media.

14.3.3.6. Observe and note pigment particles, inclusions, voids, draw marks, and striations, and the amount, size, and shape of each.

14.3.4. Evaluate by an oral or written test and a practical test.

14.4. *Cross Sections*

14.4.1. Instruct in the information that can be obtained from each of the cross-sectional techniques learned. Cross sections can reveal:

14.4.1.1. The physical shape of the fiber;

14.4.1.2. The distribution of internal structures; and

14.4.1.3. Dye penetration into the fiber.

14.4.2. The trainee is required to:

14.4.2.1. Measure fiber dimensions in cross section and determine the modification ratio of multi-lobed fibers.

14.4.2.2. Describe and compare observed fiber features, such as: shape, delustrant, pigment particle distribution, presence and size of spherulites or voids, dye penetration depth, and bi-component fibers/biconstituent fibers in both cross- and longitudinal-sections.

14.4.2.3. Determine fiber diameter and shape (optical cross sections) from longitudinal sections.

14.4.2.4. Compare and contrast the types and quality of information obtained from optical cross-sectioning versus physical cross-sectioning.

14.4.2.5. Observe the relationship of fiber cross-sectional shape to generic class and end-usage.

14.4.3. Practical Exercises for the trainee

14.4.3.1. Interpret cross sections made by the various techniques learned.

14.4.3.2. Observe and interpret optical cross sections.

14.4.3.3. Compare optical and created cross sections.

14.4.3.4. Determine the modification ratio of multi-lobed fibers.

14.4.4. Evaluate by an oral or written test and a practical test.

14.5. *Solubility*

14.5.1. Instruct in solubility testing and the judicious use of this destructive technique. Advise as to the applicability of solubility testing, and how it can provide information for fiber identification of manufactured fibers or distinctions between manufactured fibers that cannot easily be provided by other techniques.

14.5.2. The trainee is required to:

14.5.2.1. Understand the procedure and applications of solubility testing.

14.5.2.2. Micro-sample appropriately-sized fiber segments.

14.5.2.3. Observe and describe solubility test reactions (e.g., swelling, gelling, color change, soluble, insoluble).

14.5.2.4. Use solubility testing to determine fiber generic class distinctions.

14.5.2.5. Recognize the situations in which solubility testing is appropriate and select appropriate tests.

14.5.2.6. Recognize solvent reactions indicative of bi-component/bi-constituent fiber compositions.
14.5.3. Practical Exercises for the trainee
14.5.3.1. Perform solvent testing on a variety of manufactured fibers.
14.5.3.2. Perform solubility testing on acetate and triacetate fibers specifically.
14.5.3.3. Practice re-using minimal fiber samples by solvent washing.
14.5.3.4. Compare fiber types in side-by-side solubility reactions.
14.5.4. Evaluate by an oral or written test and a practical test.
14.6. *Thermal Microscopy*
14.6.1. Instruct in the use of PLM equipped with a hot stage to observe the effect of heat on thermoplastic fibers and to determine fiber melting point.
14.6.2. Advise as to the applicability and judicious use of this destructive technique.
14.6.3. The trainee is required to:
14.6.3.1. Properly set up, operate and calibrate a hot stage apparatus attached to a microscope.
14.6.3.2. Perform micro-sampling on appropriately-sized fiber segments.
14.6.3.3. Use the hot stage for melting point determinations.
14.6.3.4. Observe, describe, and evaluate thermal reactivity in fibers (e.g. softening, charring, melting, etc.).
14.6.3.5. Identify those situations in which thermal microscopy is appropriate.
14.6.3.6. Obtain and compare melting point values from reference materials and from the literature.
14.6.3.7. Understand alternative procedures of melting point determination.
14.6.4. Practical Exercises for the trainee
14.6.4.1. Determine melting range of various manufactured fibers.
14.6.4.2. Identify and discriminate Nylon 6 and 6,6 by melting points.
14.6.4.3. Observe and describe thermal reactions in bi-component and bi-constituent fibers.
14.6.4.4. Compare fiber types in side-by-side thermal reactions.
14.6.5. Evaluate by an oral or written test and a practical test.
14.7. Evaluate the trainee in all the microscopical techniques for the identification of manufactured fibers by an oral or written test and a practical test.

15. Comparative Microscopy

15.1. Instruct in the microscopical comparison of fibers.
15.2. *Compound Comparison Microscope*
15.2.1. Instruct in the use of and proper setup of the comparison microscope/comparison polarized microscope for fiber comparisons.
15.2.2. Discuss the necessity of using the comparison microscope/comparison polarized microscope for the comparison of physical and optical properties of fibers.
15.2.2.1. If the laboratory does not possess a comparison polarized microscope, a polarized light microscope is used to assess the optical properties of the fibers being compared.
15.3. *Fluorescence Microscopy*
15.3.1. Instruct in the use of the fluorescence microscope for comparison, for both natural and manufactured fibers.
15.3.2. Discuss the various filters or filter cubes (wavelength ranges, excitation, barrier filter, and dichromatic mirror) that are available to observe fluorescence in fibers.
15.3.3. Discuss sample variability, mounting media, sample handling, photobleaching, quenching, and case circumstances that affect the fluorescence of fibers, as well as the

significance and limitations for discriminating between samples.

15.4. The trainee is required to:

15.4.1. Perform comparisons of fiber features under the stereomicroscope (e.g, color, diameter, luster).

15.4.2. Perform comparisons of fiber features under PLM (e.g, birefringence).

15.4.3. Perform side-by-side comparison of fiber features under the comparison microscope (e.g., color, diameter, delustrant, cross-sectional shape).

15.4.4. Perform visual examinations and comparisons to assess the presence/absence of fluorescence and its dependence on various excitation conditions.

15.4.4.1. Distinguish between fluorescence originating from dyes and that originating from optical brighteners.

15.4.4.2. Recognize fluorescence from adherent material.

15.4.4.3. Understand the factors which could affect fluorescence.

15.4.5. Interpret the significance of the compared fiber features under each type of microscope.

15.4.6. Sample fabric standards to represent the textile as a whole.

15.5. Practical Exercises for the trainee

15.5.1. Examine and compare various fibers to determine whether each sample can be distinguished by stereomicroscopy and PLM.

15.5.2. Select and characterize fiber standard samples that represent the textile in its entirety.

15.5.3. Conduct a performance check of the comparison microscope to ensure that lighting, color, background color, and magnification are balanced.

15.5.4. Perform color comparisons of fibers under the comparison microscope.

15.5.5. Perform comparisons of morphological features of fibers under the comparison microscope.

15.5.6. Perform comparisons of optical features of fibers under the comparison microscope/comparison polarized microscope.

15.5.7. Mount fibers in different media (e.g., methanol, xylene, Entellan, Permount, Cargille) and observe any fluorescence.

15.5.8. Wash unbleached cotton in detergent to observe optical brighteners under fluorescence.

15.5.9. Expose textiles to products that can fluoresce (e.g., watercolor paint, oil, lubricants, wallboard particles), sample the fibers and observe.

15.5.10. Observe fibers longitudinally and in cross section under fluorescence.

15.5.11. Perform comparisons of fibers based on their fluorescent properties.

15.6. Evaluate by an oral or written test and a practical test.

15.6.1. Include analytical procedures learned to this point.

15.6.2. Include identification in addition to comparison on the test(s).

15.6.3. Include both natural and manufactured fibers on the test(s).

15.6.4. Evaluate the trainee's critical-thinking skills as to selection of examination processes and sequence of procedures.

16. Fourier-Transform Infrared Spectroscopy (FTIR)

16.1. Introduce the use of Infrared (IR) spectroscopy as a valuable technique in fiber polymer identification and comparison.

16.1.1. IR spectroscopy can provide additional compositional information to what is obtained from the use of PLM.

16.1.2. The IR spectrometer is primarily used in the identification of manufactured fibers.

16.1.3. While cellulosic and animal fibers are indistinguishable from one another using IR, the trainee will find it useful to analyze natural fibers by IR to gain experience from the spectral information obtained by this technique.

16.2. Advise on the appropriate use of IR analysis for fibers in the analytical scheme.
16.2.1. IR should follow visible and fluorescence comparison microscopy and PLM. IR analysis should also follow ultraviolet (UV)/visible spectroscopy, if sample preparation (e.g., flattening) irreversibly changes fiber morphology. If fibers have been differentiated by a previous analytical technique, IR analysis is not necessary.
16.2.2. IR spectroscopy should be conducted before dye extraction for chromatography due to the semi-destructive nature of the extraction technique.
16.2.3. Examination of acrylic and modacrylic fibers is likely to significantly benefit from IR spectral analysis due to the large number of sub-generic classes. Sub-types of nylon and polyester fibers can also be differentiated by IR spectroscopy.
16.2.4. Fiber dyes and pigments are difficult to discern by IR as they are often present at concentrations below the detection limits of the instrument and the polymer composition of the fiber often masks their absorption information.
16.3. The trainee is required to:
16.3.1. Properly operate and maintain an IR spectrometer and its accessories.
16.3.2. Understand the theory of infrared absorption and FTIR.
16.3.3. Understand the strengths and limitations of the instrument and its accessories.
16.3.4. Identify those situations in which infrared analysis is appropriate.
16.3.5. Prepare samples by a variety of techniques.
16.3.6. Acquire spectra from various samples.
16.3.7. Perform spectral library searches.
16.3.8. Interpret the spectral data.
16.3.9. Compare spectral data between samples.
16.4. Practical Exercises for the trainee:
16.4.1. Set up, operate, and do a performance check on the bench and microscope.
16.4.2. Adjust apertures, objectives and condensers for optimum performance.
16.4.3. Practice sample handling and preparation.
16.4.4. Achieve sample alignment with the aperture.
16.4.5. Run several different types and sizes of fibers on the IR.
16.4.5.1. Run samples of cellulosic fibers for informational purposes.
16.4.5.2. Run samples of animal textile fibers for informational purposes.
16.4.5.3. Run samples of a wide variety of manufactured fibers, to include a variety of acrylics, modacrylics, nylons, and polyesters.
16.4.6. Examine the effects of fiber thickness, flattening, and orientation.
16.4.7. Examine a variety of fibers using the various techniques and sample preparation procedures available on the laboratory instrument (such as transmission IR, diamond cell, KBr salt plate, and ATR) and by using different detectors, if available.
16.4.8. Interpret spectra and search spectral libraries.
16.4.9. Identify the fiber type by IR.
16.4.10. Perform spectral comparisons between fibers.
16.5. Evaluate by an oral or written test and a practical test.

17. Microspectrophotometry

17.1. Instruct in the use of UV and visible light as a qualitative, quantitative and objective process of color analysis.
17.1.1. Color analysis by spectrophotometry is applicable to both natural and manufactured fibers.
17.2. The trainee is required to:
17.2.1. Properly operate, maintain, and conduct performance checks on the MSP and its

accessories.
17.2.2. Understand the theory of microspectrophotometry.
17.2.3. Understand and optimize the optical properties of the MSP.
17.2.4. Identify those situations in which microspectrophotometry is appropriate.
17.2.5. Prepare samples for analysis by microspectrophotometry and select appropriate mounting media.
17.2.6. Select appropriate parameters and apertures for the sample and acquire spectra.
17.2.7. Evaluate the number of fibers required within a control sample to yield representative spectra.
17.2.8. Interpret spectra.
17.2.9. Demonstrate the ability to use the technique to compare spectra.
17.2.10. Understand the strengths and limitations of the technique.
17.3. Practical Exercises for the trainee
17.3.1. Do performance checks using certified filters.
17.3.2. Acquire spectra from various samples of fibers.
17.3.2.1. Vary the parameters to obtain maximum absorbance values.
17.3.2.2. Compare reproducibility in uniformly-dyed fibers.
17.3.2.3. Vary fiber orientation and compare reproducibility.
17.3.2.4. Vary fiber sample area on a single fiber and compare reproducibility.
17.3.2.5. Vary fiber sample area on a set of fibers and compare reproducibility.
17.3.2.6. Acquire and compare spectra from samples that exhibit variable dye uptake (e.g., cotton).
17.3.3. Acquire and compare spectra from metameric fibers.
17.3.4. Acquire and compare spectra from multiple MSP instruments, if available.
17.3.5. Acquire spectral sets of known and questioned samples and compare spectral curves between samples.
17.4. Evaluate through an oral or written test and a practical test.

18. Thin-Layer Chromatography (TLC)

18.1. Instruct in the appropriate application of thin-layer chromatography (TLC) to fiber dye analysis and comparison.
18.1.1. Dye analysis by TLC is applicable to both natural and manufactured fibers.
18.2. The trainee is required to:
18.2.1. Understand the physical and chemical principles of TLC.
18.2.2. Identify those situations in which TLC analysis is appropriate.
18.2.3. Use standard dye mixtures for testing eluent, extraction chemical, and system performance.
18.2.4. Classify dyes based on fiber type and extraction reactions in various solvents.
18.2.5. Successfully extract dye from both bulk samples and single fibers.
18.2.6. Effectively apply samples to a TLC plate.
18.2.7. Select optimum eluent system(s) and develop TLC plates using the appropriate eluent(s).
18.2.8. Develop and evaluate chromatograms for colors, fluorescence, position and intensity of bands under both UV and visible light.
18.2.9. Compare TLC results between samples.
18.2.10. Interpret the significance of the observed chromatogram.
18.3. Practical Exercises for the trainee
18.3.1. Extract and classify fiber dyes.
18.3.2. Perform TLC on various dyed fibers and textiles.
18.3.3. Using different eluent systems, extract fibers from known dye classes and compare.
18.3.4. Using different solvent systems, perform TLC on fibers from known dye classes and

compare.

18.3.5. Perform TLC on similarly-colored fibers and compare.

18.3.6. Perform TLC on basic-dyed acrylic fibers (bulk samples).

18.3.7. Perform TLC on basic-dyed acrylic fibers of differing lengths.

18.4. Evaluate through a written or oral test and a practical test, covering sample application, plate development, and interpretation of bands.

19. Comparison

19.1. Instruct in the classification and comparison of a variety of fibers, both natural and manufactured, based on their physical, optical, and chemical characteristics.

19.2. Instruct in the appropriate sampling of textiles and cordage to obtain a known fiber standard, including the use of alternate lighting techniques for sample selection.

19.3. Instruct in the comparison of cordage and textiles, including yarns, threads, fabrics, embroidery, and button threads.

19.4. Instruct in the application of fiber examination to mock casework scenarios.

19.5. The trainee is required to:

19.5.1. Learn to select known samples representative of the variation within a textile, including color, pattern, fiber-type, and texture.

19.5.2. Understand and apply the techniques learned for the examination and comparison of the physical construction and composition of textiles, including yarns, threads, fabrics, embroidery, and button threads.

19.5.3. Understand and apply the techniques learned for the examination and comparison of the physical construction and composition of cordage.

19.5.4. Appropriately apply processes and techniques learned throughout the training period for fiber analysis and comparison.

19.5.5. Assess comparison results and understand the significance of the results.

19.5.6. Define and recognize exclusionary differences.

19.5.7. Understand and discuss the discrimination power of the analytical protocol(s) used.

19.5.8. Evaluate the appropriate process of analysis, based on casework scenarios.

19.6. Practical Exercises for the trainee

19.6.1. Perform fiber comparisons.

19.6.2. Identify the types of fibers present in a textile, including both clothing and household textiles.

19.6.3. Compare the physical construction of textiles.

19.6.4. Determine the composition of various natural-fiber and manufactured-fiber cordages.

19.6.5. Compare the physical construction of cordages.

19.6.6. Interpret the completed exercises.

19.6.7. Assess the processes of fiber analysis that should be used in mock scenarios.

19.7. Evaluate by an oral or written test and a practical test, including:

19.7.1. Determination of textile content, incorporating both natural and manufactured fibers.

19.7.2. Comparison of textile construction and composition, incorporating both natural and manufactured products.

19.7.3. Determination of fiber content of cordage, incorporating both natural and manufactured fibers.

19.7.4. Comparison of cordage construction and composition, incorporating both natural and manufactured products.

19.7.5. Evaluation of the trainee's critical-thinking skills as to selection of examination techniques and sequence of procedures.

20. Damage and Impressions

20.1. Instruct in the recognition, examination, and possible cause(s) of damage to textile and cordage materials.

20.2. Instruct in the recognition and documentation of fabric and cordage impressions. The analysis of fabric and cordage impressions is outside the scope of this practice.

20.3. Instruct in the recognition, documentation, potential composition, and examination of fiber-plastic (thermoplastic) fusions. The analysis of the non-fiber (such as paint or other polymer) portions of a thermoplastic fusion is outside the scope of this practice.

20.4. Instruct in the recognition of when a physical fit could be pursued, if relevant. Physical fitting of textile materials and cordage is beyond the scope of this document.

20.5. The trainee is required to:

20.5.1. Identify and characterize the possible causes of physical, chemical, mechanical and environmental damage to textile and cordage materials.

20.5.2. Recognize and characterize the types of damage that can occur from normal wear (e.g., seam separation, stains, snags, runs, pills, holes, fraying).

20.5.3. Examine and identify different types of textile damage and identify characteristics commonly associated with each type (e.g., cuts, tears, burned material, gunshots) by visual, stereomicroscopical, and microscopical procedures.

20.5.3.1. Imaging by Scanning Electron Microscopy (SEM) can be useful in the recognition and characterization of textile damage. See Section 21.8.

20.5.4. Examine airbags and identify singe marks on textiles caused by airbags.

20.5.5. Reproduce different types of damage (e.g., cuts, tears, gunshots) and understand how simulations are useful in examinations.

20.5.6. Understand how laundering can affect the characteristics of damage.

20.5.7. Identify and document fabric impressions.

20.5.7.1. Understand different procedures by which fabric impressions can be collected from a crime scene (e.g., photography, tape lifts, gel lifts).

20.5.8. Identify, examine, and collect material from fiber-plastic fusions.

20.6. Practical Exercises for the trainee:

20.6.1. Expose various textiles and cordage to environmental damage (e.g., weathering such as sunlight and rain, burial, submersion), observe resulting characteristics, and compare to each other and to the original textile.

20.6.2. Expose various textiles and cordage to chemical damage (e.g, acids, bases, ignitable liquids, household chemicals), observe resulting characteristics, and compare to each other and to the original textile.

20.6.3. Expose various textiles and cordage to mechanical damage (e.g., laundering, crushing, burning, abrading), observe resulting characteristics, and compare to each other and to the original textile.

20.6.4. Subject various textiles and cordage to damage by weapons or other implements (e.g, serrated knife, key, scissors, ice pick, double-edged knife, bullet, screwdriver, knitting needle) that can be used in stabbing, slashing, tearing, and projectile damage; observe resulting characteristics, and compare to each other and to the original textile.

20.6.5. Simulate fabric impressions using various types of textiles and cordage, including airbags.

20.6.6. Obtain exemplars of fiber-plastic fusions and fiber-airbag fusions (e.g., from junkyards); examine, collect and characterize material from these samples.

20.7. Evaluate by an oral or written test and a practical test, including:

20.7.1. Assessment and characterization of textile damage, to include physical, chemical, mechanical, and environmental damage, and damage by weapons;
20.7.2. Assessment of fabric impressions;
20.7.3. Assessment of damage vs. wear;
20.7.4. Assessment of fiber-plastic fusions, to include collection and comparison of material from such fusions;
20.7.5. Assessment of fiber-airbag fusions, to include collection and comparison of material from such fusions; and
20.7.6. Evaluation of critical-thinking skills as to selection of examination techniques and sequence of procedures.

21. Fiber Examination - Additional Techniques

21.1. Familiarize the trainee with a variety of additional instrumental techniques that can be applied to fiber and textile examinations.
21.2. This section is intended to develop the trainee's theoretical knowledge of these techniques. If the laboratory uses any of these procedures for fiber analysis, amend this module to include:
21.2.1. Specifically-stated learning objectives;
21.2.2. Additional reading assignments;
21.2.3. Basic skills demonstrations;
21.2.4. Practical exercises; and
21.2.5. Oral or written tests and a practical test.
21.3. Upon satisfactory completion of this training module, the trainee will have developed theoretical knowledge in the applicability and use of alternative procedures in fiber examinations including, but not limited to, the use of:
21.3.1. Raman spectroscopy;
21.3.2. Pyrolysis-gas chromatography and pyrolysis-gas chromatography/mass spectrometry;
21.3.3. Capillary electrophoresis and high-performance liquid chromatography for dye analysis;
21.3.4. Scanning electron microscopy/energy dispersive x-ray spectroscopy; and
21.3.5. X-ray fluorescence.
21.4. *Raman Spectroscopy*
21.4.1. Introduce the comparison of a variety of fibers and fiber dyes, based on their chemical composition, using Raman spectroscopy.
21.4.2. Trainee objectives:
21.4.2.1. Prepare samples for analysis by Raman spectroscopy.
21.4.2.2. Perform appropriate computer searches of spectral libraries, if available.
21.4.2.3. Demonstrate the ability to use Raman to chemically classify components found in fibers using typical case-size samples.
21.4.2.4. Understand the strengths and limitations of the technique.
21.4.3. Practical Exercises for the trainee:
21.4.3.1. Prepare and analyze a series of fiber samples having a variety of composition and dyes.
21.4.3.2. Search a series of spectra against a spectral library.
21.4.3.3. Perform dye component classifications for the spectra of a series of unknowns.
21.4.3.4. Perform spectral comparisons between fibers.
21.4.4. Evaluate by an oral or written test and a practical test.
21.5. *Pyrolysis Gas Chromatography/Mass Spectrometry (PGC and PGC/MS)*
21.5.1. Introduce the comparison of a variety of fibers, based on their chemical composition,

using pyrolysis gas chromatography with flame ionization detection (PGC) or pyrolysis gas chromatography/mass spectrometry (PGC/MS).

21.5.2. Trainee objectives:

21.5.2.1. Understand the theory of PGC or PGC/MS.

21.5.2.2. Prepare samples for analysis by PGC or PGC/MS.

21.5.2.3. Perform computer searches of spectral libraries, if available.

21.5.2.4. Use PGC or PGC/MS to classify and compare fibers.

21.5.2.5. Understand the strengths and limitations of the technique.

21.5.3. Practical Exercise for the trainee

21.5.3.1. Classify and compare polymers found in types of fiber using PGC or PGC/MS.

21.5.4. Evaluate by an oral or written test and a practical test.

21.6. *Capillary Electrophoresis (CE)*

21.6.1. Introduce the comparison of a variety of fiber dyes using capillary electrophoresis (CE).

21.6.2. Trainee objectives:

21.6.2.1. Understand the theory of CE.

21.6.2.2. Prepare samples for analysis by CE.

21.6.2.3. Use CE to classify and compare fiber dyes.

21.6.2.4. Understand the strengths and limitations of the technique.

21.6.3. Practical Exercise for the trainee

21.6.3.1. Classify and compare dyes in various types of fibers using CE.

21.6.4. Evaluate by an oral or written test and a practical test.

21.7. *High-Performance Liquid Chromatography (HPLC)*

21.7.1. Introduce the comparison of a variety of fiber dyes using high-performance liquid chromatography (HPLC).

21.7.2. Trainee objectives:

21.7.2.1. Understand the theory of HPLC.

21.7.2.2. Prepare samples for analysis by HPLC.

21.7.2.3. Use HPLC to classify and compare fiber dyes.

21.7.2.4. Understand the strengths and limitations of the technique.

21.7.3. Practical Exercise for the trainee

21.7.3.1. Classify and compare dyes in various types of fibers using HPLC.

21.7.4. Evaluate by an oral or written test and a practical test.

21.8. *Scanning Electron Microscopy/Energy Dispersive X-ray Spectroscopy (SEM/EDS)*

21.8.1. Introduce the comparison of a variety of fibers, based on their elemental components, using SEM/EDS.

21.8.2. Introduce the imaging of textile samples by SEM/EDS.

21.8.3. Trainee objectives:

21.8.3.1. Understand the theory of SEM/EDS.

21.8.3.2. Prepare samples for analysis by SEM/EDS.

21.8.3.3. Know the types of SEM detectors and understand when each detector can be used.

21.8.3.4. Perform computer searches of spectral libraries, if available.

21.8.3.5. Demonstrate the ability to use the technique to compare samples based upon their elemental components.

21.8.3.6. Demonstrate the ability to use the instrument to observe the surface features of textile samples.

21.8.3.7. Understand the strengths and limitations of the techniques.

21.8.4. Practical Exercises for the trainee

21.8.4.1. Compare the elemental components in a variety of fiber samples using SEM/EDS.
21.8.4.2. Observe and characterize the surface features of various textiles.
21.8.4.3. Observe and characterize the surface features of damaged textiles, and compare to undamaged textiles from the same source.
21.8.5. Evaluate by an oral or written test and a practical test.
21.9. *X-Ray Fluorescence (XRF)*
21.9.1. Introduce the comparison of a variety of fibers, based on their elemental components, using XRF.
21.9.2. Trainee objectives:
21.9.2.1. Understand the theory of XRF.
21.9.2.2. Prepare samples for analysis by XRF.
21.9.2.3. Perform computer searches of spectral libraries, if available.
21.9.2.4. Demonstrate the ability to use the technique to compare samples based upon their elemental components.
21.9.2.5. Understand the strengths and limitations of the technique.
21.9.3. Practical Exercise for the trainee
21.9.3.1. Compare the elemental components in a variety of fiber samples using XRF.
21.9.4. Evaluate by an oral or written test and a practical test.

22. Interpretation and Report Writing

22.1. *Interpretation*
22.1.1. Instruct in integrating the factors that affect evidence interpretations and the significance of fiber evidence.
22.1.2. Practical Exercise for the trainee
22.1.2.1. Interpret technically-reviewed, completed laboratory casefiles on fiber evidence.
22.1.2.2. Review and interpret previously-completed practical exercises.
22.1.2.3. Understand the strengths and limitations of different fiber types, fabrics, and cordage, based upon factors such as color, commonness or uncommonness of fiber type; number of comparable characteristics; texture of material.
22.2. *Report Writing*
22.2.1. Instruct in writing technically- and administratively-accurate reports for fiber examinations.
22.2.2. The trainee is required to:
22.2.2.1. Provide appropriate interpretations from analytical data.
22.2.2.2. Understand the factors affecting analytical data.
22.2.2.3. Understand the factors affecting the interpretation of analytical data.
22.2.2.4. Understand the significance of fiber evidence.
22.2.2.5. Understand the current literature on the formal application of statistics and be able to discuss when it would be appropriate for the interpretation of fiber evidence.
22.2.2.6. Write complete and unbiased analytical reports with appropriate results and interpretations.
22.2.3. Practical Exercise for the trainee
22.2.3.1. Write practice reports on completed, technically-reviewed laboratory reports on fiber evidence.
22.2.3.2. Write a report communicating the results and interpretations of previously-completed practical exercises.
22.2.4. Evaluate by reviewing and discussing the trainee's interpretations and practice case

reports.

22.3. *Interpretive Exercise*

22.3.1. Provide a number of mock cases for analysis, either composed of analytical data or simulated evidence. Simulated evidence is handled as evidence according to laboratory protocols.

22.3.2. Based on the provided or generated information, the trainee prepares an analytical report for each case.

22.3.3. Evaluate and discuss the reports with the trainee.

23. Testimony and Competency

23.1. *Testimony*

23.1.1. Allow observation of experienced FSPs testifying in court as often as possible.

23.1.1.1. A variety of FSPs testifying on a range of offenses and examinations is recommended.

23.1.1.2. Determine the number and frequency of testimony observations based on the testimony experience of the trainee and the depth of the testimonies observed.

23.1.1.3. Discuss the courtroom experience after each observation. If available, review the testimony transcript with the trainee.

23.1.1.4. Consider supplementing testimony observations with trial transcripts when an adequate number of testimony reviews is logistically difficult for the laboratory.

23.1.2. Practical Exercises for the trainee

23.1.2.1. Observe general courtroom procedures, witness appearance and demeanor, and the presentation of technical or expert knowledge in testimony; document observations.

23.1.2.2. Prepare a list of suggested questions on a mock case.

23.1.2.3. Prepare a list of questions and answers for educating the court on forensic fiber analysis.

23.1.2.4. Review relevant materials for an admissibility hearing.

23.1.3. Review and discuss the documents and questions prepared by the trainee.

23.2. *Competency*

23.2.1. Evaluate the knowledge, skills, and abilities of the trainee in fiber examinations.

23.2.2. The trainee:

23.2.2.1. Completes a final, comprehensive, written or oral examination on fiber examinations;

23.2.2.2. Conducts mock case(s) for evaluation of competency; and

23.2.2.3. Participates in a mock trial using one of the mock cases completed during training. An oral review can replace the mock trial if there is previous experience in this area.

23.2.3. Competency is achieved by:

23.2.3.1. Receiving a passing grade on the written examination;

23.2.3.2. Successful completion of the competency evaluation; and

23.2.3.3. Successful completion of the mock trial or oral review.

23.3. *Supervised Casework and Peer Reviews*

23.3.1. Subsequent to achieving competency, and prior to performing independent casework, the trainee performs supervised casework.

23.3.2. Practical Exercises for the trainee:

23.3.2.1. Observe (an) experienced FSP(s) perform fiber analysis casework.

23.3.2.2. Perform actual casework under the supervision of a qualified FSP.

23.3.3. Review, evaluate and discuss the supervised casework with the trainee.

23.3.3.1. Independency is achieved when there are no technical errors and minimal administrative errors in the supervised casework, based on a determined amount of cases completed.

23.3.4. *Peer Review*

23.3.4.1. The trainee completes mock technical and administrative review exercises.
23.3.4.2. Review, evaluate, and discuss the mock reviews with the trainee.
23.3.4.3. Competency in review is achieved when there are no technical errors and there are minimal administrative errors in mock review.

APPENDIX I: Reading Assignments

1. Section 8: Introduction to Fibers and Textiles

1.1. Apsell P, "What are dyes? What is dyeing?," *Dyeing Primer*. Aspland JR, editor. Research Triangle Park, NC: American Association of Textile Chemists and Colorists, 1981: 4-7.
1.2. Fergusson SM and Hemmings J, "Fibres, Yarns and Fabrics: An Introduction to Production, Structure and Properties," *Forensic Examination of Fibres, 3rd edition*. Robertson J, Roux C, and Wiggins KG, editors. Boca Raton: CRC Press, 2018: 1-59.
1.3. Joseph ML, *Joseph's Introductory Textile Science, 6th edition*. New York: International Thomson Publishing, 1992.
1.4. Koch SL and Nehse K, "Fibers," *Handbook of Trace Evidence Analysis*. Desiderio VJ, Taylor CE, and Nic Daéid N, editors. Hoboken, NJ: John Wiley & Sons, 2020: 322–339.
1.5. Patnaik A and Patnaik S, *Fibres to Smart Textiles: Advances in Manufacturing, Technologies, and Applications, 1st edition*. Boca Raton: CRC Press, 2020.
1.6. Review various textile manufacturing websites (e.g., www.ncto.org)
1.7. Scientific Working Group for Materials Analysis (SWGMAT) "Introduction to Fibers Chapter," *Forensic Fiber Examination Guidelines*, https://www.asteetrace.org/static/images/pdf/02%20Introduction%20to%20Fibers%20Chapter%20%282011%20Update%29.pdf

2. Section 8.4: Introduction to Fibers and Textiles-*Textiles*

2.1. Fergusson SM and Hemmings J, "From Fibre to Fabric," *Forensic Examination of Fibres, 3rd edition*. Robertson J, Roux C, and Wiggins KG, editors. Boca Raton: CRC Press, 2018: 39-59.
2.2. Taupin JM and Cwiklik C, *Scientific Protocols for Forensic Examination of Clothing*. Boca Raton: CRC Press, 2010.
2.3. Van Amber RR, "Apparel and household textiles and their role in forensics," *Forensic Textile Science*. Carr D, editor. Cambridge: Woodhead Publishing, 2017: 15-26.

3. Section 8.5: Introduction to Fibers and Textiles-*Cordage*

3.1. Himmelfarb D, *The Technology of Cordage Fibres and Rope*. London: Leonard Hill, 1957.
3.2. McKenna HA, Hearle JWS, and O'Heare N, *Handbook of Fibre Rope Technology*. Boca Raton: CRC Press, 2004.
3.3. Wiggins KG, "Ropes and Cordages," *Forensic Examination of Fibres, 3rd edition*. Robertson J, Roux C, and Wiggins KG, editors. Boca Raton: CRC Press, 2018: 89-98.

4. Section 8.6: Introduction to Fibers and Textiles-*Overview of Forensic Fiber Examinations*

4.1. Carr D, *Forensic Textile Science*. Cambridge: Woodhead Publishing, 2017.
4.2. Gaudette B, "The forensic aspects of textile fiber examination," *Forensic Science Handbook, Volume II*. Saferstein R, editor. Englewood Cliffs, NJ: Prentice-Hall Inc., 1988: 209-214.

4.3. Grieve MC, "Fibers and their Examination in Forensic Science," *Forensic Science Progress, Volume 4*. Maehly A and Williams RL, editors. New York: Springer, 1990: 41-125.
4.4. Grieve MC and Wiggins KG, "Fibers under fire: suggestions for improving their use to provide forensic evidence," *Journal of Forensic Sciences*, 2001; 46(4): 835-843.
4.5. Koch SL and Nehse K, "Fibers," *Handbook of Trace Evidence Analysis*. Desiderio VJ, Taylor CE, and Nic Daéid N, editors. Hoboken, NJ: John Wiley & Sons, 2020: 322–376.
4.6. Robertson J and Roux C, "From Crime Scene to Laboratory," *Forensic Examination of Fibres, 3rd edition*. Robertson J, Roux C, and Wiggins KC, editors. Boca Raton: CRC Press, 2018: 99-143.
4.7. Trejos T, Koch S, and Mehltretter A, "Scientific foundations and current state of trace evidence—a review," *Forensic Chemistry*, 2020: 100223.
4.8. Wiggins K, "Forensic textile fiber examination across the USA and Europe," *Journal of Forensic Sciences*, November 2001; 46(6): 1303-1308.

5. Section 9.1: Fiber Evidence-*Transfer and Persistence*

5.1. Akulova V, Vasiliauskienė D, and Talalienė D, "Further insights into the persistence of transferred fibres on outdoor clothes," *Science & Justice - Journal of the Forensic Science Society*, 2002; 42:165-171.
5.2. Annis PA, Bresee RR, and Cooper TR, "Influence of textile structure on single fiber transfer from woven fabrics," *Textile Research Journal*, 1992; 65(2):293-301.
5.3. Bennett S, Roux CP, and Robertson J, "The significance of fibre transfer and persistence - a case study," *Australian Journal of Forensic Science*, 2010; 42:221–228.
5.4. Bruschweiler W and Grieve MC, "A study on the random distribution of a red acrylic target fibre," *Science & Justice*, 1997; 37: 85-89.
5.5. Chewning D, Deaver K, and Christensen A, "Persistence of Fibres on Ski Masks During Transit and Processing," *Forensic Science Communications*, July 2008; 10(3).
5.6. Coxon A, Grieve M, and Dunlop J, "A method of assessing the fibre shedding potential of fabrics," *Journal of the Forensic Science Society*, 1992; 32(2):151-158.
5.7. DeBattista R, Tidy H, Thompson TJU, and Robertson P, "An investigation into the persistence of textile fibres on buried carcasses," *Science & Justice*, July 2014; 54(4): 288-291.
5.8. DeWael K, Lepot L, Lunstroot K, and Gason F, "Evaluation of the shedding potential of textile materials," *Science & Justice*, 2010; 50: 192-194.
5.9. Gaudette B, "The forensic aspects of textile fiber examination," *Forensic Science Handbook, Volume II*. Saferstein R, editor. Englewood Cliffs, NJ: Prentice-Hall Inc., 1988: 214-221, 255-259.
5.10. Grieve MC, Dunlop J, and Haddock PS, "Transfer experiments with acrylic fibres," *Forensic Science International*, 1989; 40:267-277.
5.11. Kidd C and Robertson J, "The transfer of textile fibers during simulated contacts," *Journal of the Forensic Science Society*, 1982; 3: 301-308.
5.12. Koch SL and Nehse K, "Fibers," *Handbook of Trace Evidence Analysis*. Desiderio VJ, Taylor CE, and Nic Daéid N, editors. Hoboken, NJ: John Wiley & Sons, 2020: 339–342.
5.13. Lepot L, Vanden Driesse T, Lunstroot K, et al., "Fibre persistence on immersed garments--influence of knitted recipient garments," *Science & Justice*, 2015; 55(4): 248-253.
5.14. Lowrie CN and Jackson G, "Secondary transfer of fibres," *Forensic Science International*, 1994; 64: 73-82.

5.15. Marname R, Elliot D, and Coulson S, "A pilot study to determine the background population of foreign fibre groups on a cotton/polyester T-shirt," *Science & Justice,* 2006; 46(4): 215-220.
5.16. Merciani P, Monard FS, Buzzini P, et al., "A study of the cross transfer of fibers," *Forensic Science International*, 136(1): 123.
5.17. Palmer R, "The retention and recovery of transferred fibers following the washing of recipient clothing," *Journal of Forensic Sciences*, 1997; 43(3):502-504.
5.18. Palmer R and Banks M, "The secondary transfer of fibres from head hair," *Science & Justice-Journal of the Forensic Science Society*, 2005; 45:123–128.
5.19. Palmer R and Burch HJ, "The population, transfer, and persistence of fibres on the skin of living subjects," *Science & Justice,* 2009; 49(4): 259-264.
5.20. Palmer R and Polworth G, "The persistence of fibers on skin in an outdoor deposition crime scene scenario," *Science & Justice*, 2011; 51(4): 187-189.
5.21. Palmer R, Sheridan K, Puckett J, Richardson N, and Lo W, "An investigation into secondary transfer--the transfer of textile fibres to seats," *Forensic Science International,* 2017; 278: 334-337.
5.22. Pounds CA and Smalldon KW, "The transfer of fibres between clothing materials during simulated contacts and their persistence during wear, Part I," *Journal of the Forensic Science Society,* 1975;15:17-27.
5.23. Pounds CA and Smalldon KW, "The transfer of fibres between clothing materials during simulated contacts and their persistence during wear, Part II," *Journal of the Forensic Science Society,* 1975;15:29-37.
5.24. Pounds CA and Smalldon KW, "The transfer of fibres between clothing materials during simulated contacts and their persistence during wear, Part III," *Journal of the Forensic Science Society,* 1975;15:197-207.
5.25. Robertson J, Kidd CBM, and Parkinson HMP, "The persistence of textile fibres transferred during simulated contacts," *Journal of the Forensic Science Society,* 1982; 22: 353-360.
5.26. Robertson J and Roux C, "Transfer, Persistence and Recovery of Fibers," *Forensic Examination of Fibres, 3rd edition*. Robertson J, Roux C, and Wiggins KG, editors. Boca Raton: CRC Press, 2018: 109-119.
5.27. Robertson J and Lloyd AK, "Redistribution of textile fibres following transfer during simulated contacts," *Journal of the Forensic Science Society*, 1984; 24:3-7.
5.28. Roux C, Robertson J, and Palmer R, "Persistence and Recovery," *Encyclopedia of Forensic Sciences, 2nd edition*. Saukko PJ and Houck MM, editors. Waltham: Academic Press, 2013: 117-123.
5.29. Roux C, Langdon S, Waight D, and Robertson J, "The transfer and persistence of automotive carpet fibres on shoe soles," *Science & Justice*, 1999; 39(4): 239-251.
5.30. Salter MT, Cook R, and Jackson AR, "Differential shedding from blended fabrics," *Forensic Science International* 1987; 33:155-164.
5.31. Scientific Working Group for Materials Analysis (SWGMAT), "Trace Evidence Recovery Guidelines," *Forensic Science Communications*, October 1999; 1(3).
5.32. Scott H, "The persistence of fibers transferred during contact of automotive carpets and clothing fabrics," *Canadian Society of Forensic Science Journal,* 1985; 18(4):185-199.
5.33. Sheridan K, et al., "A study on contactless airborne transfer of textile fibres between different garments in small compact semi-enclosed spaces," *Forensic Science International,* August 2020; 315: 110432.
5.34. Skokan L, Tremblay A, and Muehlethaler C, "Differential shedding: A study of the fiber transfer mechanisms of blended cotton and polyester textiles," *Forensic Science*

International, March 2020; 308: 110181.
5.35. Slot A, et al., "Tracers as invisible evidence — the transfer and persistence of flock fibres during a car exchange," *Forensic Science International*, 2017; 275: 178–186.
5.36. Trejos T, Koch S, and Mehltretter A, "Scientific foundations and current state of trace evidence—a review," *Forensic Chemistry*, 2020: 100223
5.37. Watt R, Roux C, and Robertson J, "The population of coloured textile fibres in domestic washing machines," *Science & Justice*, 2005; 45: 75-83.
5.38. Wiggins K, Drummond P, and Champod TH, "A study in relation to the random distribution of four fibre types on clothing (incorporating a review of previous fibre studies)," *Science & Justice-Journal of the Forensic Science Society*, 2004; 44: 141-148.

6. Section 9.2: Fiber Evidence-*Search, Collection, and Preservation Techniques*

6.1. Gaudette B, "The forensic aspects of textile fiber examination, " *Forensic Science Handbook, Volume II*. Saferstein R, editor. Englewood Cliffs, NJ: Prentice-Hall Inc., 1988: 218-272.
6.2. Grieve MC and Garger BS, "An improved method for rapid and accurate scanning of fibers on tape," *Journal of Forensic Sciences*, 1981; 26(3):560-563.
6.3. McKenna FJ and Sherwin JC, "A simple and effective method for collecting contact evidence," *Journal of the Forensic Science Society*, 1985; 30:485-493.
6.4. Palenik S, "Microscopy and Microchemistry of Physical Evidence," *Forensic Science Handbook, Volume II*. Saferstein R, editor. Englewood Cliffs, NJ:Prentice-Hall, 1988: 164-171.
6.5. Dignan SJ and Murphy KJ, "Fibre evidence from fingernail clippings," *Canadian Society Forensic Science Journal*, 2002; 35(1):17-21.
6.6. Koch SL and Nehse K, "Fibers," *Handbook of Trace Evidence Analysis*. Desiderio VJ, Taylor CE, and Nic Daéid N, editors. Hoboken, NJ: John Wiley & Sons, 2020: 342–344.
6.7. Moore JE, Jackson G, and Firth M, "Movement of fibres between working areas as a result of routine examination of garments," *Journal of the Forensic Science Society*, 1986; 26:433-440.
6.8. Robertson J and Roux C, "Crime Scene Considerations," *Forensic Examination of Fibres, 3rd edition*. Robertson J, Roux C, Wiggins KG, editors. Boca Raton: CRC Press, 2018: 101-109.
6.9. Robertson J and Roux C, "Protocols for Fibre Examination and Initial Examinations," *Forensic Examination of Fibres, 3rd edition*. Robertson J, Roux C, and Wiggins KG, editors. Boca Raton: CRC Press, 2018: 119-126.
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6.11. Scotman TG and van der Weerd J, "On the recovery of fibres by tape lifts, tape scanning, and manual isolation," *Science & Justice*, December 2015; 55(6): 415-421.
6.12. Schwartz TR, Rothenberg DS, and Clark BL, "Trace Evidence Recognition, Collection and Preservation," *Handbook of Trace Evidence Analysis.* Desiderio VJ, Taylor CE, and Nic Daéid N, editors. Hoboken, NJ: John Wiley & Sons, 2020: 1-30.
6.13. Scientific Working Group for Materials Analysis (SWGMAT), "Trace Evidence Recovery Guidelines," *Forensic Science Communications*, October 1999; 1(3).

7. Section 10.1: Microscopy and Fiber Evidence-*Introduction to Microscopy*

7.1. Abramowitz M, "Fluorescence Microscopy, The Essentials," *Basics and Beyond Series, Volume 4*. Melville, NY: Olympus America Inc., 1993: 1-22.

7.2. Bowen AB, "Polarized Light Microscopy for the Trace Evidence Examiner," *Handbook of Trace Evidence Analysis*. Desiderio VJ, Taylor CE, and Nic Daéid N, editors. Hoboken, NJ: John Wiley & Sons, 2020: 32-156.
7.3. DeForest PR, "Foundations of forensic microscopy," *Forensic Science Handbook, Volume I, 2nd edition*. Saferstein R, editor. Englewood Cliffs, NJ: Regents/Prentice-Hall Inc., 2002: 215-319.
7.4. Goldberg O, "Kohler Illumination," *The Microscope*, 1980; 28:15-20.
7.5. Gray P, *The Encyclopedia of Microscopy and Microtechnique*. Malabar, FL: Krieger Publishing Company, 1982.
7.6. McCrone WC, "Checklist for True Kohler Illumination," *American Laboratory*, 1980; 12(1): 96-98.
7.7. McCrone WC, McCrone LB, and Delly JB, *Polarized Light Microscopy*. Chicago: McCrone Research Institute, 2002.
7.8. Nesse WD, *An Introduction to Optical Mineralogy, 4th edition*. Cambridge: Oxford University Press, 2013.
7.9. Siegel JI, "Fluorescence Microscopy," *American Laboratory*, 1982; 14(3): 65-69.
7.10. Stoiber RE and Morse SA, *Crystal Identification with the Polarizing Microscope*. New York, NY: Chapman and Hall, 1994.
7.11. Wheeler BP, *Practical Forensic Microscopy: A Laboratory Manual, 2nd edition*. Chichester, England: John Wiley & Sons Ltd., 2021.

8. **Section 10.2: Microscopy and Fiber Evidence-*Fiber Sample Preparation***

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9. **Section 10.3: Microscopy and Fiber Evidence-*Recognition of Fibers by Microscopy***

9.1. Barna CE and Stoeffler SF, "A New Method for Cross-sectioning Single Fibers," *Journal of Forensic Sciences*, 1987; 32: 761-767.
9.2. De Wael K and Vanden Driessche T, "Dichroism measurements in forensic fibre examination. Part 2 - dyed polyamide, wool and silk fibres," *Science & Justice*, December 2011; 51(4):163-72.
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