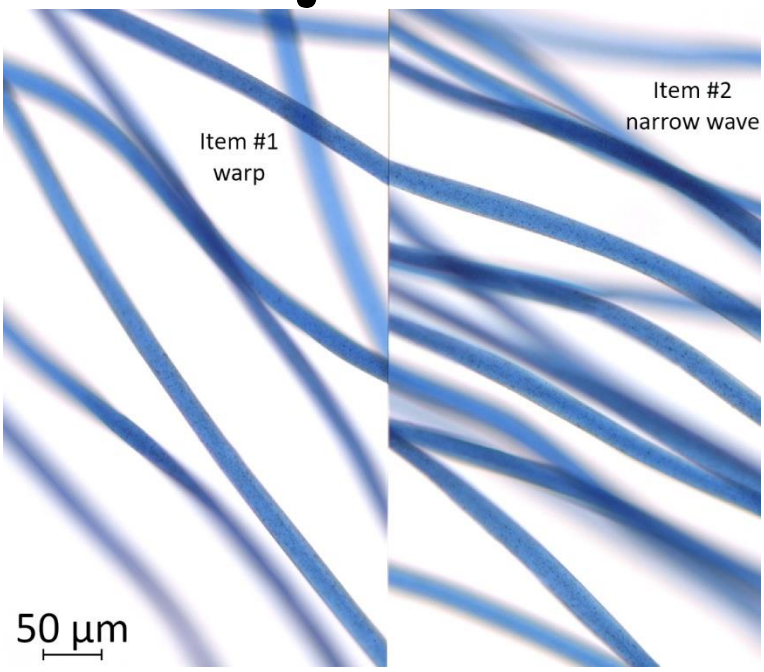
# Washington State Patrol




# Crime Laboratory Division

## Materials Analysis
## Fiber Training Manual

December 2023

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# 1 INTRODUCTION

## 1.1 PURPOSE AND SCOPE

This manual provides the outline for training in Fibers and Textiles. This manual is designed to provide the trainee with the scientific, technical, and other specialized knowledge, skill, and experience required to perform independent casework under this subdisciplines as laid out in the Materials Analysis Technical Procedures (MATP).

## 1.2 MANUAL ORGANIZATION

Each chapter covers core concepts essential for comprehensive polymers casework. These concepts include:

- Fibers as Evidence
- Chemistry, Biology, and Manufacturing
- Microscopy of Manufactured Fibers
- Microscopy of Plant Textile Fibers
- Microscopy of Animal Textile Fibers
- Microscopy of Feathers
- Solubility
- Comparison Microscopy
- Microspectrophotometry
- Infrared Spectroscopy
- Elemental Analysis
- Textile Damage
- Mock Casework

In general, each chapter should be covered in the order presented. Each chapter is organized into the following five parts:

- Objectives – a list of the goals for each chapter.
- Topic Areas – a list of subjects and vocabulary that will be covered during training
- Readings – the list of minimum required readings to complete the training.
- Study Questions – a series of questions to ensure comprehension and encourage discussion
- Practical Exercises – a set of hand-on activities to develop first-hand experience

Modifications to the reading lists, study questions, or practical exercises may be made as needed with the approval of the technical lead.

## 1.3 QUALIFICATIONS

The trainee shall be authorized to perform casework for (1) DNA suitability exams of Hair, and (2) Physical Fit. In addition, the trainee shall have successfully completed the Foundation Training Manual.

The trainee will have successfully completed the following chapters from the Instrument and Techniques Training Manual (or completed prior to the related chapter in this training manual):

- Balances (Non-Seized Drugs or Seized Drugs)
- Chemical and Physical Characterization
- Evidence Recovery,
- Imaging and Visualization
- Infrared Spectroscopy
- Microscopy (Basic)
- Microscopy (Special Applications)
- Microspectrophotometry
- Scanning Electron Microscopy/Energy Dispersive X-ray Spectroscopy
- Screening and Evaluation of Trace Evidence
- X-Ray Fluorescence

A refresher of instruments and techniques may be considered if the trainee does not routinely use these techniques in the current authorized casework subdisciplines.

The trainer must be a qualified analyst in the subdiscipline(s) to be taught. The trainer should have sufficient experience to cover the variety of possible evidence submissions, scenarios that are encountered, and courtroom testimony in the discipline. The trainer must have a thorough understanding of, and follow, the applicable subdiscipline procedures and the policies and procedures of the laboratory/division.

The trainer may delegate specific content to be taught by other instructors. Such instructors must have sufficient experience to cover the variety of possible evidence submissions and scenarios that are encountered in the area that they are going to instruct and a thorough understanding of the applicable procedures and policies of those topics. The technical lead shall approve the qualifications of any instructors.

## 1.4 TRAINING PLAN

A training plan will be developed and approved as outlined in the QOM.

Trainees who demonstrate prior related training and experience may be able to progress through the training program at an accelerated pace or skip certain content based on an evaluation of the trainee. Adjustment of the training plan based upon the trainee's prior related training and/or experience will be left to the technical lead in consultation with the trainer and trainee's supervisor.

The trainee will maintain a notebook (and/or digital equivalent) throughout the duration of the training program and will record notes and observations for each study segment, including answers to study/discussion questions/exercises and documentation of completion of practical and competency exercises. The training notebook should be maintained in a neat, organized, and up to date fashion during training. The training notebook shall be available for review upon request.

The trainee is encouraged to take related outside courses when possible. Notes from such external training events shall be kept as part of the training records.

The trainer should create a learning environment that serves to continuously improve the subdiscipline. Such resources shall include, when feasible, the following:

- Knowledge of all applicable laboratory policies and procedures regarding this discipline
- Training and reference materials available internally and externally
- Organizations and courses that facilitate professional development
- Participation in research, local organization, give a poster presentation, etc.
- Participation in training events for other colleagues, law enforcement partners, etc.

The trainer will continuously evaluate the trainee throughout the training for the trainee's comprehension and competency in their knowledge, practical skills, and critical thinking skills. Training is progressive and continuously builds on and reinforces prior learning. Unacceptable training progress may occur during the course of the training. It is important that any such instances be openly and promptly addressed among the trainee, the trainer, the technical lead, and/or the trainee's supervisor, as appropriate. An appropriate course of action should be developed and implemented to move training progress back to acceptable status.

## 1.5 TRAINING KITS

Training kits may have been created for practical exercises and the mock casework. The technical lead will disperse the kits as needed for training.

## 1.6 TRAINING COMPLETION

In order to successfully complete this training program, the trainee must, after completion of all subject areas required based on the training plan, successfully complete a closed book written exam passed with 80%, a competency exam passed with a pass/fail, and an oral testimony exam with a pass/fail. The content of these exams will be overseen by the technical lead in consultation with the trainer and the trainee's supervisor. The competency exam will take the form of a mock case, which will include a draft report. The oral testimony exam may be either a full moot court or an oral examination of testimony type questions.

The completion of these steps will be documented on a training checklist worksheet that covers the dates completed and the trainers and/or instructors for the content and the exams. An example of a training checklist worksheet is provided at the end of this manual. Electronic versions may be developed and adapted as needed.

Upon satisfactory completion of the above exams, the trainee will be signed off to perform casework in accordance with the QOM. Supervised casework is optional and dependent on the trainee's repertoire of subdisciplines as well as performance on mock casework. The number of supervised case requests shall be determined by the technical lead in consultation with the trainer and the trainee's supervisor. Final approval for independent casework, technical review, and for conducting verifications will be determined by the technical lead in consultation with the trainer and the trainee's supervisor.

## 1.7 TRAINING RECORDS

Training records, including authorizations, will be maintained in accordance with the QOM. Individual scientists are strongly encouraged to maintain copies of their own training records and their training notebook(s).

## 1.8 QUALITY ASSURANCE

This training manual, including related umbrella documents where applicable, complies with the following external document:

- OSAC 2022-S-0018 (Registry Version) Standard Practice for a Forensic Fiber Training Program, OSAC Proposed Standard sent to ASTM for further development and publication (https://www.nist.gov/organization-scientific-area-committees-forensic-science/osac-registry).

## 1.9 SAFETY

Good chemical safety practices shall be employed.

UV light can damage the eyes. Use UV blocking eye protection when working with UV light.

# 2 FIBERS AS EVIDENCE

## 2.1 OBJECTIVES

- To have a historical perspective concerning fiber and textile evidence
- To understand the value of fiber and textile evidence in criminal investigations
- To become familiar with the types of exams that can be performed on fiber and textile evidence, including an overview of the types of equipment and techniques used
- To become familiar with the specific studies on transference, persistence, and recovery as they apply to fiber and textile evidence.

## 2.2 TOPIC AREAS

1. Transference Methods
    a. Airborne
    b. Contact – touch
    c. Contact – impact
2. Types of Evidence
    a. Fibers
    b. Fabrics
    c. Cordages and Ropes
    d. Textiles
3. Fiber Recovery
4. Types of Exams
    a. Identification/Classification
        i. Fiber type
        ii. Fabric type
        iii. Cordage type
        iv. Textile type
    b. Comparison
        i. Fibers
        ii. Fabric
        iii. Cordage
        iv. Textile
    c. Damage Assessment
        i. Type of weapon
        ii. Scenarios with submitted weapon
5. Evidential Value of Comparisons
    a. Target fiber studies
    b. Discrimination studies
    c. Persistence studies

## 2.3 READINGS


1. Blackledge RD and Gaenzle K (2007) “Characterization of surface-modified fibers” in Blackledge RD (Ed.) Forensic Analysis on the Cutting Edge (chapter 9, pp 221-239) Hoboken, NJ: John Wiley & Sons.
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14. OSAC **2022-N-0018** Standard Practice for a Forensic Fiber Training Program.
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19. Roux C, Langdon S, Waight D, and Robertson J **(1999)** “The transfer and persistence of automotive carpet fibres on shoe soles” in *Science & Justice* 39(4):239-251.
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21. Sheridan KJ, Palmer R, Chalton DA, Bacar JN, Beckett J, Bellerby K, Brown L, Donaghy E, Finlayson A, Graham C, Robertson B, Tayler L, and Gallidabino MD **(2023)** "A quantitative assessment of the extent and distribution of textile fibre transfer to persons involved in physical assault" in *Science & Justice* 63(4):509-516.
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## 2.4 STUDY QUESIONS

1. What types of questions can be answered by fiber evidence?
2. What types of instrumental and technique exams can be performed to compare fibers?
3. Would there be a difference in evidentiary significance between a fiber sitting on the surface of an item versus being caught or adhered to the surface?
4. What are examples of external factors that might influence the type and frequency of fibers in a geographical region?
5. Define "sheddability" as it relates to fiber evidence.
6. Explain what can be done at the laboratory to prevent cross contamination of fiber evidence.
7. Define and explain the importance of the target fiber studies and discrimination studies in determining the evidential value of fiber evidence.
8. What are color block studies, and what is their evidential significance?
9. How does the inter comparison of fibers recovered from unrelated items of evidence support the evidential significance of fibers?
10. How is fiber persistence affected by laundering versus by water immersion?
11. Explain some ways to preserve knotted evidence.
12. Give some examples of surface modifications to fibers and how they might be detected.
13. What are photochromic and thermochromic colorants?
14. What is an example of a type of textile that may use thermochromic colorants?
15. Discuss with your trainer the practical use of 1:1 and zonal tapings.

## 2.5 PRACTICAL EXERCISES

1. None.

# 3 CHEMISTRY, BIOLOGY, AND MANUFACTURING

## 3.1 OBJECTIVES

- To develop knowledge of fiber and textile technology, terminology, and classification schemes.
- To develop knowledge of fiber and textile history, usage, manufacturing, and chemistry.
- To develop knowledge of colorant and polymer chemistry.
- To develop knowledge of textile and cordage construction.

## 3.2 TOPIC AREAS

1. Fiber colorants
    a. Dyes
    b. Pigments
2. Polymers
    a. Monomer vs Polymer
    b. Molecular Mass
    c. Homopolymers
    d. Copolymers
    e. Oligomers
3. Textile Fiber Products Identification Act
4. Classification Schemes
    a. Synthetic (Man-made, Manufactured)
        i. Organic polymers
        ii. Regenerated cellulosics
        iii. Glass
    b. Plant Based (vegetable fibers)
        i. Bast
        ii. Leaf
        iii. Seed
    c. Animal Based (natural protein)
        i. Fur Hairs
        ii. Silk
    d. Mineral Based
        i. Asbestos
5. Textile construction
    a. Fibers
    b. Yarns vs Threads
    c. Fabrics
        i. Knit
        ii. Woven
        iii. Non-Wovens
        iv. Other Construction Methods
    d. Cordage

## 3.3 READINGS


1. Aspland JR **(1981)** "What are dyes? What is dyeing?" in *Dyeing Primer: A Series of Short Papers on the Fundamentals of Dyein*g (part 1, pp 4-6) Research Triangle Park, NC: American Association of Textile Chemists and Colorists.
2. ASTM **E2225-23** Standard Guide for Forensic Examination of Fabrics and Cordage.
3. Brudzyńska P, Sionkowska A, and Grisel M **(2021)** "Plant-derived colorants for food, cosmetic and textile industries: A review" in *Materials* 14:3484.
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12. Nehse K, Koch S, Grieve M, Houck MM, and Robertson J **(2018)** "Future trends in forensic fibre examination" in J Robertson, C Roux, and KG Wiggins (Eds.) *Forensic Examination of Fibres, 3rd Edition* (chapter 11, pp 427-454) Boca Raton, FL: CRC Press.
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16. Taupin JM and Cwiklik C **(2011)** *Scientific Protocols for Forensic Examination of Clothing*. Boca Raton: CRC Press [read chapter 3].
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## 3.4 STUDY QUESTIONS

1. Define and give example(s) for the following terms (using the OSAC Lexicon when possible):
    a. Dye
    b. Pigment
    c. Pigment aggregation
    d. Surface dye
2. What is the difference between a dye and a pigment?
3. Define the following terms:
    a. Monomer
    b. Polymer
    c. Molecular Mass
    d. Homopolymers
    e. Copolymers
    f. Oligomers
4. Compare and contrast step-growth polymerization and chain-growth polymerization (include examples).
5. Define and give example(s) for the following terms (using the OSAC Lexicon when possible):
    a. Plastic
    b. Thermoplastic
    c. Thermoset plastic
6. List the three different groups of natural fibers and give examples.
7. Define and give example(s) the following (using the OSAC Lexicon or OSAC 2022-N-018 when possible):
    a. Fabric
    b. Filament
    c. Synthetic fibers
    d. Manufactured fibers
    e. Natural fibers
    f. Animal fiber
    g. Jute
    h. Technical fibers
    i. Inorganic fibers
    j. Finishing
8. Define acrylic and modacrylic. Name typical end uses.
9. What is the melting point for acrylic? Why?
10. What is the chemical compound typically used as delustrant for synthetic fibers?
11. Why is antimony oxide added to modacrylic?
12. What synthetic fiber class may have pigment rather than dye? Why is it necessary to use pigment for this fiber class?
13. How is acrylic and modacrylic processed?
14. Where are acrylic and modacrylic used?
15. Describe the manufacturing process for acetate.
16. What are the two principal markets for cellulose acetate?
17. Describe the following: wet spinning, dry spinning, melt spinning and spinneret.

18. Describe the process of dope dyeing. When is it used?
19. Describe the manufacturing process for polyolefins and how they are colored.
20. Name typical end uses for polyolefins.
21. Are polyamides (nylons) melt spun, dry spun or wet spun?
22. Why are some fibers textured?
23. Why is cross section important in fiber design?
24. Why are fibers delustered?
25. What is the difference between bicomponent and biconstituent?
26. What are some of the polymers used for wigs?
27. What is wool?
28. What is the primary factor in determining the quality (grade) of wool?
29. What is felting?
30. Name the principal species cultivated for commercial silk production?
31. How long has silk been used as a textile fiber?
32. Silk can be confused with what other fiber types? Why?
33. When could leather fibers be encountered in a forensic context?
34. Name the hairs from the goat and camel family.
35. How would animal hairs used in textiles differ from those from those not used in textiles but are encountered in daily activities?
36. Describe the difference between bast, leaf, and seed fibers. Include examples.
37. What is the difference between a technical fiber and a fiber ultimate?
38. Describe the mercerization process.
39. Why is the mercerization process used?
40. Describe end uses for the common natural fiber types. Which type is used the most?

## 3.5 PRACTICAL EXERCISES

1. If possible, tour museums and manufacturing plants for fibers, cordage, and textiles.
2. Search on-line for free videos on textile manufacturing. Make a list of the URLs to update the training information on the Portal.
3. Observe a set of yarns visually and with stereomicroscopy. Determine the type of yarn construction (e.g. spun, monofilament, multifilament, core), the number of plies (e.g. single, double, triple), the construction of the plies (e.g. twisted, cabled), the orientation of the yarn as a whole (Z or S), and the orientation of the individual plies (Z or S). Take notes and document your observations with imaging. Include visual color and stereo color of yarns and fibers.
4. Observe a set of knit fabrics visually and with stereomicroscopy. Determine the knit pattern type (e.g. rib knit, interlock, cable). Take notes and document your observations with imaging. Include visual color and stereo color of yarns and fibers.
5. Observe a set of woven fabrics visually and with stereomicroscopy. Determine the woven pattern type (e.g. 1:1 basket weave, satin, twill, etc.). Take notes and document your observations with imaging. Include visual color and stereo color of yarns and fibers.

6. Observe a set of nonwoven fabrics visually and with stereomicroscopy. Take notes and document your observations with imaging. Include visual color and stereo color of yarns and fibers.

7. Observe a set of ropes, cordage, and cables. Determine the types of rope (e.g. braid, etc.) or construction. Practice separating the component parts of each. Take notes and document your observations with imaging. Include visual color and stereo color of yarns and fibers.

# 4 MICROSCOPY OF MANUFACTURED FIBERS

## 4.1 OBJECTIVES

- To prepare slides of fibers from textiles
- To be able to prepare physical cross-sections of fibers using different methods.
- To learn about optical cross sectioning, and to be able to correlate physical cross-sectional shape to optical cross section observations.
- To learn to classify manufactured fibers using PLM

## 4.2 TOPIC AREAS

1. Mounting Media
   a. Entellan
   b. Permount
   c. Xylenes
   d. Xylene Substitute
   e. Cargille 1.520E
2. Interactions between mounting media and fibers
   a. Dye extraction
   b. Solubility (e.g. spandex)
3. Cross Section Methods
   a. Plate (Jolliff)
   b. Sandwich
4. PLM features
   a. Birefringence
   b. Sign of elongation
   c. Refractive indices (n|| and n⊥)
   d. Cross sectional shape
   e. Diameter
   f. Level of Delustrant

## 4.3 READINGS

1. ASTM **E2228-23a** Standard Guide for Microscopical Examination of Textile Fibers.
2. Barna CE and Stoeffler SF **(1987)** “A new method for cross sectioning single fibers” in *Journal of Forensic Sciences* 32(3):761-767.
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## 4.4 STUDY QUESTIONS

1. Define and give example(s) of the following (using the OSAC Lexicon when possible):
    a. Modification Ratio
    b. Lumen
    c. Delustrant
2. When is physical cross sectioning used in fiber casework?
3. What is a modification ratio?
4. How is a modification ratio obtained?

## 4.5 PRACTICAL EXERCISES

### *4.5.1.1 Sample Handling*

1. **Fabric & Cordage Sampling.** Observe a demonstration of sampling from fabrics and cordages. Note what is considered a representative sample and how samples are labeled.
2. **Yarn Sampling & Fiber Slide Preparation.** Observe a demonstration of mounting a representative sample of fibers from a yarn in a temporary mount (e.g. Cargille 1.520E, xylenes, xylene substitute) and in a semi-permanent mount (e.g., Entellan, Permount). Note how much the fibers are separated from each other and how to ensure all fibers within the yarn are represented.
3. **Practice Fiber Removal.** Practice removing fibers from tape lifts and from sticky notes using a xylene substitute. Prepare slides from the removed fibers and observe with PLM. Is there any adhesive still attached to the fibers?
4. **Practice Fiber Cleaning.** Practice removing and cleaning fibers from mounted slides using methanol, xylenes/xylene substitute, and/or acetone.

### *4.5.1.2 Synthetic Fibers*

5. **Basic PLM Observations.** Observe a slide set of common manufactured fibers with PLM. Slide may be part of a collection, a previous exercise, or a new set of slides. Note the mounting medium in your notes. For each fiber type, include:
    a. Color
        i. color and/or intensity differences (pleochroism) based on $n\perp$ and $n\parallel$
        ii. color due to dye or pigment
        iii. uniformity of color along fiber length
    b. Estimated optical cross-sectional shape
    c. Approximate diameter range

i. Use 40X objective lens and a 10x ocular

ii. If the optical cross section is not radially symmetrical (e.g. elliptical, bone shaped), then include a range for the thinnest portion and the thickest portion of the fiber.

d. Relative amount of delustrant (e.g. bright, light, medium, heavy)

e. Present of any inclusions, voids, draw marks, and/or striations

f. Amount of birefringence (low, moderate, high), predominant birefringence colors (e.g. “greens & pinks”, “blue”, “yellow brown”), and number of orders if possible (e.g. 3 orders, 2 orders, 6 orders).

g. Sign of elongation

h. Use the Becke line test to determine the refractive indexes relative to the mounting medium (i.e. n⊥ and n||)

6. **Fiber Identification Scheme – PLM.** Mount a set of different common fiber classes in Cargille 1.520E. Use fibers that are in the typical clothing range (~12-22 μm diameter). Prepare a chart with each row being a different fiber type, and the columns to include birefringence, sign of elongation, relative n⊥, relative n||, and air temperature when relative RI assessed. Make your PLM observations and fill in the chart. Can you distinguish the different classes based on PLM?

7. **RI – Bracketing.** Determine the refractive indices (n⊥ and n||) for two different fiber types of the same fiber class using bracketing. Start with Cargille 1.520E. Use methanol to wash the fibers, then dry the fibers before mounting in a different Cargille liquid.

8. **RI – Dispersion Staining.** Mount fibers from different acrylics on separate slides in Cargille 1.520E. Observe central stop dispersion colors for n⊥ and n||, noting the air temperature.

9. **Practice Physical Cross Sectioning.** Prepare a set of physical cross-sections from a set of fibers. Include (a) preparation of a yarn or yarn ply using the Joliff method, and (b) single fibers using the sandwich method. Observe with PLM and note:

   a. correspondence between physical and estimated optical cross-sectional shape

   b. color due to dye or pigment

   c. uniformity of color throughout the fiber

10. **Modification Ratios.** Prepare a set of physical cross-sections from different trilobal fibers from carpets. Take images and determine the modification ratios.

11. **Unknowns.** Analyze a set of unknown manufactured fibers and classify them. Document observations with notes and images.

# 5 MICROSCOPY OF PLANT TEXTILE FIBERS

## 5.1 OBJECTIVES

- To be able to identify plant based natural fibers.

## 5.2 TOPIC AREAS

1. Plant Anatomy Basics
   a. Vascular Tissue
      i. Tracheids
      ii. Fibers
      iii. Vessel elements
      iv. Parenchyma
   b. Monocots vs Dicots
      i. Stems
      ii. Leaves
   c. Technical Fiber vs Fiber Ultimates
   d. Plant cell walls
      i. Primary wall
      ii. Secondary wall
      iii. Cellulose – polymer of beta 1,4 glucose
      iv. Lignin – polymer of polyphenols
2. PLM examination
   a. Maceration of technical fibers
   b. Extinction patterns
      i. Undulose
      ii. Parallel complete
      iii. Parallel incomplete
      iv. Parallel nearly complete
   c. Longitudinal morphology (e.g. smooth, striated, cross-hatching, dislocations, etc.)
   d. Diameter range of single fibers
   e. Lumen diameter range of single fibers
   f. Special features
      i. Crystals (e.g. stegmata, stars)
      ii. Spiral elements
      iii. Vessel elements
   g. Modified Herzog Test
   h. Dispersion staining colors (central stop) in:
      i. Cargille 1.585E
      ii. Cargille 1.590E
      iii. Cargille 1.565E
3. “Distinguishing” Tests – only for excess amount of Q fibers
   a. Phloroglucinol
   b. Herzberg’s Stain

c. Dry Twist Test
d. Modified Billinghame's
e. Nonspecific stains
f. Ashing

## 5.3 READINGS


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## 5.4 STUDY QUESTIONS

1. What is a lumen, and what class of fibers have one?
2. List some morphological features that are important in the identification of vegetable fibers.
3. Describe the Herzog test.
4. Describe the chemical and physical changes to macerated technical fibers.
5. What is the basis for the following tests to distinguish plant fibers?
    a. Billinghame's test

b. Phloroglucinol and hydrochloric acid test
c. Herzberg test
d. Modified Herzog test
e. Dry twist test.

6. What features can be observed within the ash product of various natural fibers? Is ashing a technique that is performed in casework? Why or why not?
7. Create a table that lists the various features and test results (staining, dry twist) used to differentiate between common natural plant fiber types.

## 5.5 PRACTICAL EXERCISES

1. **Basic PLM.** Prepare a set of longitudinal mounts in Cargille 1.540E from as many of the following plant types as possible. Examine each mount with PLM and observe longitudinal morphology (e.g. smooth, striated, cross-hatching, dislocations, etc.), extinction pattern, diameter of single fiber, special features (e.g. crystals, spiral elements, vessel elements), and the modified Herzog test.
    a. Cotton – normal
    b. Cotton – mercerized
    c. Bast fibers – Flax, Ramie, Jute, Hemp
    d. Leaf fibers – Sisal, Abaca/Manila
    e. Other Seed fibers – Kapok, Coir
2. **Cross sections.** Prepare a set of cross sections in Cargille 1.540E from the same samples as the previous exercise. Examine each mount with PLM and observe the following:
    a. how each of the features viewed in longitudinal mount appear in cross section
    b. the thickness of the cell and the cell wall relative to the lumen size and shape
    c. cross-sectional shape of the single fiber cells
    d. presence of any radial cracks in the cell wall
    e. how the ultimate fibers are arranged within the bundles
    f. variation of ultimate fibers within the technical fiber bundles of the same species
3. **Maceration.** Macerate samples of technical fibers and observe under PLM. Compare your observations of the macerated samples to the intact samples.
4. **Dispersion staining.** Prepare a slide of each of Flax, Hemp, Ramie, Jute, Abaca/Manila, and Sisal in Cargille liquids 1.565E, 1.585E, and 1.590E. Observe with central stop lens and record dispersion colors.
    a. Can you distinguish between the different leaf fibers?
    b. Can you distinguish between the different bast fibers?
5. **Other Tests.** Perform the following tests on the supplied natural fibers: Billinghame's test, Phloroglucinol and hydrochloric acid test, Herzberg test, and dry twist test. Create a table of the results.
6. **Kimwipes.** Mount and observe a sample teased out of a Kimwipe. Describe what is present, and its implications for casework.
7. **Unknowns.** Analyze a set of unknown plant fibers and classify them. Document observations with notes and images.

# 6 MICROSCOPY OF ANIMAL TEXTILE FIBERS

## 6.1 OBJECTIVES

- To be able to identify animal based natural fibers.

## 6.2 TOPIC AREAS

1. Wool vs Animal Hair
2. Distinguishing Animal Hairs
   a. Scale Patterns
   b. Medulla patterns
   c. Diameter
3. Scale casting Methods
   a. Clear nail polish on glass slide
   b. Kodak coating film on glass slide
   c. Stamping into a thin polymer film using a heavy weight
4. Types of Silk
   a. Wild/tussah
   b. Cultivated

## 6.3 READINGS

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## 6.4 STUDY QUESTIONS

1. Discuss with your trainer scale counts and how they can be used to distinguish between animal fiber types. What is the practicality of these techniques being performed in casework?
2. What features might lead you to believe that an animal hair is being used as a fiber?

## 6.5 PRACTICAL EXERCISES

1. **Wools & Animal Hairs.** Prepare scale casts, longitudinal mounts, and cross sections of the following taxonomic categories. Examine each mount with PLM and not specifically scale pattern and shape, medulla, and diameter. Include both dyed and undyed samples if available. May also add observations from other slide sets of mounted wools and animal hairs.

    a. Wool from various breeds of sheep
    b. Goats from various breeds (e.g. mohair, cashmere)
    c. Rabbit from various breed (e.g. angora)
    d. Camel family (e.g. camel, alpaca, vicuna, llama)
    e. Commercial furs (e.g. mink, ermine, chinchilla, seal)

2. **Silks.** Examine wild and cultivated silk fibers under PLM. Compare to samples of synthetic fibers of roughly similar RI and/or diameter (e.g. rayon).

3. **Unknowns.** Analyze a set of unknown animal fibers and classify them. Document observations with notes and images.

# 7 MICROSCOPY OF FEATHERS

## 7.1 OBJECTIVES

- To learn the basics of feather classification, especially as it relates to down textiles.
- Understand the limitations of feather evidence.

## 7.2 TOPIC AREAS

1. Laws Protecting Birds
2. Bird Classification
3. Feather Topography
4. Parts of Down Type Feathers
5. Criminalistic Limitations

## 7.3 READINGS

1. Chandler AC **(1916)** “A study of the structure of feathers, with reference to their taxonomic significance” in *University of California Publications in Zoology* 13(11):243-446 [reference source for drawings].
2. Dove CJ **(1997)** “Quantification of microscopic feather characters used in the identification of North American Plovers” in *The Condor* 99:47-57 [reference source for images].
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5. Harwood HP **(2011)** “Identification and description of feathers in Te Papa’s Māori cloaks” in *Tuhinga* 22:125-147 [reference source for images].
6. Robertson J, Harkin C, and Govan J **(1984)** “The identification of bird feathers. Scheme for feather examination” in *Journal of Forensic Science Soc*iety 24:85-98.
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## 7.4 STUDY QUESTIONS

1. What is the goal of identifying feather fragments?
2. What parts of a feather are diagnostic for identifying a taxonomic group of birds?
3. What bird taxonomic group is the most common source for down textiles?
4. Discuss with your trainer the limitations of a feather comparison.

## 7.5 PRACTICAL EXERCISES

1. Examine a set of samples. Describe and document with image the various parts.

# 8 SOLUBILITY

## 8.1 OBJECTIVES

- Understand appropriate use and limitations of solubility of different synthetic fibers.

## 8.2 TOPIC AREAS

1. Solvents
2. Reaction
   a. Soluble (fades, splinters or breaks apart and goes into solution)
   b. Swells
   c. Gels (plasticizes)
   d. Partly soluble (not all portions of a fiber OR not all fibers within a group of like fibers are soluble within 5 minutes)
   e. Fans (forms a fan or mushrooms, damaged areas may swell)
   f. Insoluble
3. Solubility chart for manufactured fibers

## 8.3 READINGS


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## 8.4 STUDY QUESTIONS

1. Define and give example(s) the following (using the OSAC Lexicon when possible):
   a. Solubility
   b. Extraction

2. What are the limitations for using solubility to analyze synthetic fibers.
3. Discuss with your trainer when might you use a solvent to solubilize a fiber in casework.

## 8.5 PRACTICAL EXERCISES

1. Observe the solubility of a set of common synthetic fibers in the available solvents using the steps below. Suggested solvents include glacial acetic acid, acetone, acetonitrile, chloroform, formic acid, conc HCl, HFIP, $HNO_3$, 75% $H_2SO_4$, conc. $H_2SO_4$.
    a. Use freshly prepared solvents
    b. Place dry fiber(s) under small coverslip
    c. Use a Chemistry microscope when possible (to minimize solvent fumes)
    d. Focus on fiber(s) with 20-25X objective lens, with at least one end in view
    e. Keep fiber in focus with one hand while applying the solvent with the other hand
    f. Apply the solvent to the edge of the coverslip with dropper or pipette (solvent should seep under the coverslip until the fiber is completely surrounded)
    g. Note the time the solvent touches the fiber and record all reactions in relation to time
    h. Watch the fiber for at least 5 minutes

# 9 COMPARISON MICROSCOPY

## 9.1 OBJECTIVES

- To learn how to apply comparison microscopy to fibers.

## 9.2 TOPIC AREAS

1. Comparison Microscopy
    a. Transmitted polarization
        i. Single pol
        ii. Cross pol
    b. Reflectance
    c. Fluorescence
    d. Dispersion Staining

## 9.3 READINGS


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## 9.4 STUDY QUESTIONS

1. Describe ways to recognize and combat analyst fatigue that can arise during microscopical comparison.

2. Make a list of the features that are used in fiber comparison. Are any more important than others? Does the fiber type matter?
3. Describe the overall process of a fiber comparison. Describe the levels of comparison (visual, stereoscopic, LM).
4. What are the advantages of characterizing the unknown(s) first? Are there disadvantages?
5. What are the advantages of characterizing the standard(s) first? Are there disadvantages?
6. Are microscopical comparisons more objective or subjective? Why?
7. Are confirmations required or expected for fiber comparisons? When might a confirmation be considered? If performed, what is the necessary documentation?
8. What are reasons why different examiners may come to different conclusions? What instrumental or other technique is in the workflow to combat issues with visual comparison?
9. What can be considered acceptable variation between a Q and a K versus what would be considered an exclusionary difference?

## 9.5 PRACTICAL EXERCISES

1. Mount duplicate sets of brightly dyed cotton fibers from the same source in 1.520E, 1.540E, Entellan, and xylene substitute. Compare cotton fibers from the same mounting medium under brightfield and then again under single pol. Which mounting medium worked best and why? (save samples for MSP)
2. Compare a set of neon fibers by fluorescence microscopy.
    a. Mount duplicate sets on glass slides versus quartz slides. Which works better?
    b. Mount duplicate sets in Cargille 1.520E, xylene substitute, and Entellan. Which works best?
    c. Photo-quench one slide and compare to the other corresponding slide.
3. Compare a set of black polyester fibers with transmitted polarization (single pol and crossed pols).
4. Compare a provided set of unknown fibers by comparison microscopy (transmitted brightfield, transmitted single pol, transmitted crossed pols, fluorescence). Document your observation with notes and images.

# 10 MICROSPECTROPHOTOMETRY

## 10.1 OBJECTIVES

- To understand when MSP is appropriate method for fiber evidence.
- To practice different sample preparations and appropriate mounting medium selection for MSP of fiber evidence.
- To evaluate the number of fibers required within a control sample to yield representative spectra.
- To demonstrate the ability to use the technique to compare spectra from fiber evidence.
- To understand the strengths and limitations of the technique on fiber evidence.

## 10.2 TOPIC AREAS

1. Sample Preparation
   a. Flattening fibers
   b. Mounting medium
   c. Number of fibers
2. Data collection
   a. Fiber orientation in beam path
   b. Transmittance
   c. Reflectance
   d. Fluorescence
3. Data interpretation
   a. Averages and standard deviation
   b. Range overlap

## 10.3 READINGS

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9. OSAC **2022-S-0017** Standard Guide for Microspectrophotometry in Forensic Fiber Analysis.
10. Palenik CS, Beckert JC, and Palenik S **(2016)** "Microspectrophotometry of Fibers: Advances in Analysis and Interpretation". National Criminal Justice Reference Service Document 250437 (Award Number 2012-DN-BX-K040). U.S. Department of Justice.
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12. Reichard EJ, Bartick EG, Morgan SL, and Goodpaster JV **(2017)** "Microspectrophotometric analysis of yellow polyester fiber dye loadings with chemometric techniques" in *Forensic Chemistry* 3:21-27.
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16. Was-Gubala J and Starczak R **(2015)** "UV-VIS microspectrophotometry as a method of differentiation between cotton fibre evidence coloured with reactive dyes" in *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 142:118-125.
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## 10.4 STUDY QUESTIONS

1. None.

## 10.5 PRACTICAL EXERCISES

1. Collect a VIS spectra a known pleochroic sample using different orientations. Is there a pattern to the spectra?

2. Collect VIS spectra from a sets of brightly dyed cotton fibers from the same source in 1.520E, 1.540E, Entellan, and xylene substitute (same samples from comparison microscopy if feasible). Compare spectra from the same samples mounted in the same and different mounting media. Which mounting media distinguished the samples the best?
3. Collect UV Vis spectra from the same set of neon fibers mounted on quartz slides mounted in different mounting media. Which media worked best?
4. Collect VIS spectra from a set of black polyester fibers and compare.
5. Examine sets of spectra and determine if they Q and K are similar, dissimilar, or inconclusive.

# 11 INFRARED SPECTROSCOPY

## 11.1 OBJECTIVES

- To understand the use of IR spectroscopy in fiber polymer identification and comparison.
- To understand the limitations of IR spectroscopy for cellulosic fibers and animal fibers.
- To understand the limitations of IR spectroscopy for dyes and pigments in a fiber.
- To understand the appropriate use of IR for fibers in the analytical scheme.
- To practice methods for preparing fiber samples for IR analysis
- To practice acquiring spectra from single fibers, performing spectral library searches of fibers, interpretation of fiber spectra, and comparison of spectra between samples.

## 11.2 TOPIC AREAS

11.2.1 FIBERS AND TEXTILES

1. Analytical Scheme
    a. After all microscopies and MSP
    b. Before semi-destructive techniques (if used)
2. Methodology
    a. Flattening sample
        i. Roller
        ii. Diamond anvil cell
        iii. Diamond compression cell
    b. Setup
        i. Microscope
            1. KBr plate
            2. Open disk
            3. ATR objective
            4. Diamond Anvil Cell (DAC) – open face
            5. Diamond Compressions Cell (DCC)
        ii. Bench
            1. Diamond Anvil Cell – open face
            2. ATR
3. Interpretation
    a. Functional group assignments for peaks
        i. Acrylic and modacrylic subtypes
        ii. Nylon subtypes
        iii. Polyester subtypes
    b. Polymer classification (type/subtype)

## 11.3 READINGS

1. ASTM **E2224-23a** Standard Guide for Forensic Analysis of Fibers by Infrared Spectroscopy.

2. Carraher CE Jr **(2003)** *Seymour/Carraher's Polymer Chemistry, 6th Edition*, Marcel Dekker, Inc. [read section on Infrared Spectroscopy in chapter 4].
3. Causin V, Marega C, Guzzini G, and Marigo A **(2004)** "Forensic analysis of poly(ethylene terephthalate) fibers by infrared spectroscopy" in *Applied Spectroscopy* 58(11):1272-1276.
4. Causin V, Marega C, Schiavone S, and Marigo A **(2005)** "A quantitative differentiation method for acrylic fibers by infrared spectroscopy" in *Forensic Science International* 151:125-131.
5. Cho L, Reffner JA, and Wetzel DL **(1999)** "Forensic classification of polyester fibers by infrared dichroic ratio pattern recognition" in *Journal of Forensic Sciences* 44(2):283-291.
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12. Kirkbride KP **(2018)** "Infrared microspectroscopy of fibres" in J Robertson, C Roux, and KG Wiggins (Eds.) *Forensic Examination of Fibres, 3rd Edition* (chapter 7, pp 245-288) Boca Raton, FL: CRC Press.
13. Kisler-Rao AE **(2015)** "Comparison of nylon, polyester, and olefin fibers using FTIR and melting point analysis" in *Journal of the American Society of Trace Evidence Examiners* 6(1):3-20.
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15. Meleiro P and García-Ruiz C **(2016)** "Spectroscopic techniques for the forensic analysis of textile fibers" in *Applied Spectroscopy Reviews* 51(4):258-281.
16. Ohta Y and Kajiwara K **(2009)** "High performance fibers: Structure, characteristics and identification" in MM Houck (Ed.) *Identification of Textile Fibers* (chapter 5, pp 88-110) Boca Raton, FL: CRC Press [read sections 5.3.2 (pp 97-98)].
17. Takematsu MM, Diniz MF, Mattos EC, Dutra RCL **(2018)** "Sheath-core bicomponent fiber characterization by FT-IR and other analytical methodologies" in *Polimeros* 28(4):339-347.
18. Tungol MW, Bartick EG, and Montaser A **(1990)** "The development of a spectral database for the identification of fibers by infrared microscopy" in *Applied Spectroscopy* 44:543–549.
19. Tungol MW, Bartick EG, and Montaser A **(1991)** "Analysis of single polymer fibers for Fourier transform infrared microscopy: The results of case studies" in *Journal of Forensic Sciences* 36(4):1027-1043.
20. Tungol MW, Bartick EG, and Montaser A **(1991)** "Spectral data base for the identification of fibers by infrared microscopy" in *Spectrochimica Acta* 46B(11):1535E-1544E.
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## 11.4 STUDY QUESTIONS

1. How much variation is allowed between spectra being compared? Give examples of known instances where variation is expected.
2. What is considered an exclusionary difference when comparing spectral data taken from a Q and a K?
3. What are the documentation expectations and requirements for IR as it relates to all aspects of analysis (e.g., sample prep, instrumental spectra, and data interpretation/comparison)?
4. How are samples typically prepared within the MA workflow?
5. Discuss rejection of data regarding IR data. When does it occur and how is it documented?

## 11.5 PRACTICAL EXERCISES

1. Observe a demonstration of preparing a synthetic fiber sample and a refresher of collecting spectra. The spectra collected shall be from the same fiber source (e.g. a polyester or a nylon) and used in the next exercise. The demonstration should include:
    a. How to adjust apertures, objectives, and condensers for optimum performance.
    b. How to flatten samples using a roller, a DAC, and a DCC.
    c. How to collect spectra from a single fiber using an IR microscope with a KBr disk, a hole punched through an adhesive tape, an open face DAC, an ATR objective, and a DCC.
    d. How to collect spectra from the different available detectors.
    e. How to collect spectra from multiple fibers using an IR bench with open face DAC in a beam condenser and from a bench ATR.
    f. How to print out a spectrum with all the MATP required information.
2. Compare spectra from the same synthetic fiber type (e.g. polyester or a nylon) from the previous exercise.
    a. How do the different methods effect the appearance of the spectrum?
    b. What are the effects of fiber thickness, flattening, and orientation?
3. Run samples of different types of manufactured fibers.
    a. What peak(s) distinguish nylon 6 from 6,6?
    b. What subtypes of acrylic and modacrylics can you distinguish?
    c. What subtypes of polyester can you distinguish?
4. Run samples of cellulosic fibers for informational purposes, including rayons, cellulose acetates, and natural cellulosics (e.g. cotton, linen, ramie, hemp, etc.).
    a. Can you distinguish the natural cellulosics?
5. Run samples of animal textile fibers for informational purposes, including animal hairs (e.g. mohair, cashmere, etc.) and silk fibers (both wild and cultivated if possible).
    a. Can different species of animal hairs be distinguished?
    b. Can animal hairs be distinguished from silk fibers?
    c. Can wild silk be distinguished from cultivated silk?
6. Practice interpreting manufactured fiber spectra (assigning functional groups to different peaks) and searching spectral libraries.

a. How close is a polyester fiber spectrum to a polyester resin (polymer library) versus a polyester fiber (fiber library)?

7. Compare fibers of the same fiber type (subtype) from different sources.
8. Compare spectra from fibers of different colors that share the same type/subtype.
9. Examine a set of unknown spectra and identify the polymer class and subtype.

# 12 ELEMENTAL ANALYSIS

## 12.1 OBJECTIVES

- Demonstrate the appropriate use and limitations of SEM-EDS to compare elements present in fibers.
- Demonstrate the appropriate use and limitations of XRF to compare elements present in fibers.

## 12.2 TOPIC AREAS

1. Uses of Elemental Analysis of Fibers
   a. Metallic Fibers
   b. Fiber Additive Types
2. Limitations of SEM-EDS for Fibers
3. Limitations of XRF for Fibers

## 12.3 READINGS

1. Blackledge RD and Gaenzle K **(2007)** “Characterization of surface-modified fibers” in Blackledge RD (Ed.) *Forensic Analysis on the Cutting Edge* (chapter 9, pp 221-239) Hoboken, NJ: John Wiley & Sons [read 9.4.1 (pp 225-234)].
2. Cartier J, Roux C, and Grieve M **(1997)** "A study to investigate the feasibility of using x-ray fluorescence microanalysis to improve discrimination between colorless synthetic fibers" in *Journal of Forensic Sciences* 42(6):1019-1026.
3. Koons R **(1996)** "Comparison of individual carpet fibers using energy dispersive x-ray fluorescence" in *Journal of Forensic Sciences* 41(2):199-205.
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5. Roux C, Morison R, and Maynard P **(2018)** “Other instrumental approaches to fibre examination” in J Robertson, C Roux, and KG Wiggins (Eds.) *Forensic Examination of Fibres, 3rd Edition* (chapter 9, pp 309-344) Boca Raton, FL: CRC Press [read section 9.4.2 (pp 322-328)].
6. Sano T and Suzuki S **(2009)** “Basic forensic identification of artificial leather for hit-and-run cases” in *Forensic Science International* 192(1-3):e27-e32.

## 12.4 STUDY QUESTIONS

1. List possible inorganic additive types used in the textile industry, including possible elements that may be present due to those additives.
2. Discuss with your trainer when SEM-EDS and/or XRF are used in fiber comparisons.

## 12.5 PRACTICAL EXERCISES

1. SEM-EDS
   a. Compare the SEM-EDS elemental profile from the same fiber type prepared in different ways (e.g. cross sections, longitudinally flattened, longitudinally neat). Use the same fiber source as used for XRF.

b. Compare the elemental components in a variety of fiber types using SEM-EDS. Use the same fiber sources as used for XRF.

2. XRF

a. Compare the XRF elemental profile from the same fiber type prepared in different ways (e.g. cross sections, longitudinally flattened, longitudinally neat). Use the same fiber source as used for SEM-EDS.

b. Compare the elemental components in a variety of fiber types using XRF Use the same fiber sources as used for SEM-EDS.

3. Comparison of SEM-EDX vs XRF data

a. Compare the SEM-EDS and XRF data from the same sample preparations.

b. Compare the SEM-EDS and XRF data from the same fiber types.

# 13 TEXTILE DAMAGE

## 13.1 OBJECTIVES

- To recognized and characterize physical, chemical, mechanical, environmental, and thermal damage to textiles
- To recognize possible cause(s) of damage to textile and cordage materials.
- To examine airbags and identify singe marks on textiles caused by airbags.
- To learn how to develop different case scenarios and related testing
- To familiarize the trainee with the types of damage that may occur to clothing and/or other items of forensic significance.
- To have the trainee demonstrate a basic understanding of how to assess clothing for damage.

## 13.2 TOPIC AREAS

1. Types of damage
    a. normal wear
    b. mechanical
        i. cuts
        ii. tears
        iii. stabs / puncture
        iv. abrasion
        v. blunt force
        vi. gunshot
        vii. explosion
        viii. insect
    c. thermal and chemical
        i. heat source, open flame, etc.
        ii. acid / base
2. Age of damage
    a. old vs. new
    b. laundered vs. unlaundered
3. Mechanism of damage
    a. origin
    b. motion / direction
    c. tears: one handed vs. two handed
4. Sample collection / preparation
5. Data interpretation and report writing

## 13.3 READINGS

1. Boland CA **(2007)** “Clothing damage analysis in alleged sexual assaults – The need for a systematic approach” in *Forensic Science International* 167:110-115.
2. Cao W, Peng EL, Ruffo HE, Doucette CM, and Zhou YR **(2023)** “Damage characteristics of fabrics created by TASER probes” in Journal of Forensic Sciences 68:647-654.

3. Carr DJ and Mabbott AJ **(2017)** “Ballistic damage” in Carr D (Ed.) *Forensic Textile Science* (chapter 9, pp 181-199) Cambridge: Woodhead Publishing.
4. Carr DJ and Wainwright A **(2011)** “Variability of simulants used in recreating stab events” in *Forensic Science International* 210:42-46.
5. Costello PA and Lawton ME **(1990)** “Do stab-cuts reflect the weapon which made them?” in *Journal of the Forensic Science Society* 30:89-95.
6. Cowper EJ, Carr DJ, Horsfall I, and Fergusson SM **(2015)** “The effect of fabric and stabbing variables on severance appearance” in *Forensic Science International* 249:214-224.
7. Daly DJ, Lee-Gorman MA, and Ryan J **(2009)** “Distinguishing between damage to clothing as a result of normal wear and tear or as a result of deliberate damage: A sexual assault case study” in *Journal of Forensic Sciences* 54(2):400-403.
8. Dann T and Malbon C **(2017)** “Tearing or ripping of fabrics” in Carr D (Ed.) *Forensic Textile Science* (chapter 8, pp 169-180) Cambridge: Woodhead Publishing.
9. Daroux FY **(2017)** “Forensic analysis of blunt impact damage to textiles” in Carr D (Ed.) *Forensic Textile Science* (chapter 6, pp 99-125) Cambridge: Woodhead Publishing.
10. Duerden IJ **(1998)** “Automobile seat belts” in Hearle JWS, Lomas B, and Cooke WD (Eds.) *Atlas of Fibre Fracture and Damage to Textiles, 2nd Edition* (chapter 37, 320-322) Boca Rotan: Woodhead Publishing.
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13. Jason A **(2014)** “Bullet entry holes in fabric: Fibers, facts, and fallacies” in *Association of Firearm and Tool Mark Examiners Journal* 46(2):133-137”
14. Kemp SE **(2017)** “Forensic analysis of sharp weapon damage to textile products” in Carr D (Ed.) *Forensic Textile Science* (chapter 5, pp 71-97) Cambridge: Woodhead Publishing.
15. LaVigne M, Cavaleri JJ, and Roberts K **(2019)** “Time and temperature dependent analysis of bleach degradation residues on textile fabrics by presumptive chemical analysis and ion chromatography-mass spectrometry” in *Journal of the American Society of Trace Evidence Examiners* 9(1):64-87.
16. Leung EH and Halliday DX **(2010)** “’Flashburning’ – Interpreting the presence of heat damage to a suspect’s clothing and footwear in the investigation of fires” in *Science and Justice* 50:187-191.
17. Masakowski S, Enz B, Cothern JE, and Rowe WF **(1986)** “Fiber-plastic fusions in traffic accident reconstruction” in *Journal of Forensic Sciences* 31(3):903-912.
18. Molina G, De Luca S, and Scarso F **(2022)** “Analysis and identification of damage caused by canine (*Canis lupus familiaris*) manipulation of woven textiles as cultural evidence in forensic cases” in *Forensic Anthropology* 5(3):228-238.
19. Monahan DL and Harding HWJ **(1990)** “Damage to clothing – Cuts and tears” in *Journal of Forensic Sciences* 35(4):901-912.
20. Nolan G, Hainsworth SV, Nutty GN **(2013)** “Forces required for a knife to penetrate a variety of clothing types” in *Journal of Forensic Sciences* 58(2):372-379.
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22. Schubert GD **(2007)** “Forensic analysis of automotive airbag contact – Not just a bag of hot air” in Blackledge RD (Ed.) *Forensic Analysis on the Cutting Edge* (chapter 2, pp 33-56) Hoboken, NJ: John Wiley & Sons.
23. Sloan K, Ferguson M, and Robertson J **(2022)** “Textile damage science – Is it a reliable science?” in *WIRES Forensic Science* 4:e1468.
24. Sloan K, Fergusson M, and Robertson J **(2018)** “Textile damage examinations on the cutting edge – an Australian perspective” in *Australian Journal of Forensic Sciences* 50(6):682-688.
25. Sloan K, Robertson J, Fergusson M, Spratford W **(2020)** “An evaluation of human stabbing performance to inform the standardization of textile damage examinations: Do simulation trial correlate to reported stabbings?” in *Forensic Science International* 312:110305.
26. Smith MJ and Thompson K **(2017)** “Forensic analysis of textile degradation and natural damage” in Carr D (Ed.) *Forensic Textile Science* (chapter 4, pp 41-69) Cambridge: Woodhead Publishing.
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28. Taupin JM **(1998)** “Damage to a wire security screen: Adapting the principles of clothing damage analysis” in *Journal of Forensic Sciences* 43(4):897-900.
29. Taupin JM **(1998)** “Testing conflicting scenarios – A role for simulation experiments in damage analysis of clothing” in *Journal of Forensic Sciences* 43(4):891-896.
30. Taupin JM **(1999)** “Comparing the alleged weapon with damage to clothing: The value of multiple layers and fabrics” in *Journal of Forensic Sciences* 44(1):205-207.
31. Taupin JM and Cwiklik C **(2011)** *Scientific Protocols for Forensic Examination of Clothing*. Boca Raton: CRC Press [read chapters 5, 6, and 9 and appendix 1].
32. Wakefield D **(2011)** “Cut window and door screens: Which side were they cut from?” in *Association of Firearm and Tool Mark Examiners Journal* 43(2):168-171.
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34. Wąs-Gubała J and Krauß W **(2004)** “Textile damage caused by vapour cloud explosions” in *Science & Justice* 44(4):209-215.
35. Wąs-Gubała J and Krauß W **(2006)** “Damage caused to fibres by the actions of two types of heat” in *Forensic Science International* 159:119-126.
36. Wightman G, Wark K, and Thomson J **(2015)** “The interaction between clothing and air weapon pellets” in *Forensic Science International* 246:6-16.
37. Williams GA **(2018)** “Forensic textile damage analysis: Recent advances” in Research and Reports in *Forensic Medical Science* 8:1-8.

## 13.4 STUDY QUESTIONS

1. What are the differences between new damage and laundered damage?
2. How are cuts differentiated from tears? What indicators are used to determine if the “weapon” was sharp or dull? How is directionality determined?
3. How is a scissor cut differentiated from a knife cut?
4. How can one determine what side of a material the damage has originated?
5. What differences are there between tears made with one hand versus two hands?
6. What are characteristics of burnt nylon? Silk?

7. What characteristics are indicative of insect damage and how are they observed?

## 13.5 PRACTICAL EXERCISES

1. Procure a number of used/worn fabrics and other textiles which may commonly be encountered in forensic casework. The samples should include, but are not limited to, woven clothing items and knit clothing items. If possible, used/worn furniture or vehicle upholstery and carpet samples should be included. Using notes, sketches, and photos characterize the defects observed in the provided samples.
2. Prepare test damage by using various “weapons” (to include but not limited to; single edged knives, double edged knives, scissors, box cutters, ice picks, screw drivers, etc.) on the fabrics and textiles collected for exercises 1 and 2. The damage should include cuts, tears, punctures, stabs, slashes, etc. In addition, gunshot damaged articles obtained from the firearms section should be evaluated. Using notes, sketches, and photos characterize the provided samples and articulate the following:
    a. All information derived from the examination of the defect (type of weapon, how used, etc.)
    b. The class and individual characteristics encountered in the samples examined.
    c. The problems encountered in the examinations of the materials and how they can be overcome.
    d. The best methods for documenting the examinations.
    e. The significance of their findings.
    f. Additional analysis that can be/should be performed.
    g. The wording of their report.
3. Obtain several t-shirts. Using a volunteer, tear a t-shirt by pulling with one hand, and tear another t-shirt using two hands. Observe and record the damage.
4. Place the damaged articles from exercises 3 and 4 in the laundry and reexamine them after they have been dried, documenting and noting differences between the pre- and post-laundered damage.
5. Procure a number of fabrics and other textiles of known composition which are commonly encountered in forensic casework. The samples should include the following fiber types: cotton, rayon, silk, linen, wool, acetate, acrylic, olefin, nylon, and polyester.
    a. Expose small sections (~5mm x 5mm) of the material to an open flame by holding it approximately ¼ to ½ inch from the flame of an alcohol burner.
    b. Expose the known materials to a variety of chemicals including sulfuric acid, acetic acid (vinegar), sodium hydroxide (lye), and ammonia.
    c. Obtain insect damaged items if available.
    d. Record observations of both visual and stereomicroscopic examination of the materials.

# 14 MOCK CASEWORK

## 14.1 OBJECTIVES

- To demonstrate the ability to perform and properly document Fiber casework
- To demonstrate appropriate report writing skills
- To successfully apply all previously acquired skills and abilities in this training program and demonstrate the ability to perform all tasks expected in normal casework
- To understand and successfully perform the technical review procedure

## 14.2 TOPIC AREAS

1. Type of Exam
    a. Identification/Classification of Textile types
    b. Identification/Classification of Fiber types
    c. Comparison of textile/fiber types
    d. Damage Assessment
2. Assessment of Submitted Evidence
3. Technical Manual Requirements for Notes
4. Limitations
5. Report writing
6. Court Testimony

## 14.3 READINGS

1. Current chapter(s) on Fiber analyses and Damage Assessment in the Materials Analysis and Technical Procedures (MATP).
2. ASTM **E2224-23a** Standard Guide for Forensic Analysis of Fibers by Infrared Spectroscopy.
3. ASTM **E2225-23** Standard Guide for Forensic Examination of Fabrics and Cordage.
4. OSAC **2022-N-0018** Standard Practice for a Forensic Fiber Training Program.
5. OSAC **2022-S-0017** Standard Guide for Microspectrophotometry in Forensic Fiber Analysis.
6. OSAC **2022-S-0019** Standard Guide for Forensic Examination of Fibers.

## 14.4 STUDY QUESTIONS

1. What is the minimum requirement to report out that a fiber is green cotton?
2. What exam results must be in your notes to report out that two pieces of braided rope are similar and could have originated from the same source?
3. What conclusions may be reached in a damage assessment examination?
4. Explain a fiber identification to a jury.
5. Explain a fabric comparison to a jury.
6. Explain a damage assessment examination to a jury.
7. Explain the scientific support (i.e. validation studies) for physical fit analysis to a jury.

## 14.5 PRACTICAL EXERCISES

1. Review at least 5 case files. A representative file from each analyst should be included in the mix. Note the wording of observations and the images taken. Note how the conclusion(s) and any limitations were documented.
2. Work at least 5 mock cases as if they were real cases, including following the Technical Procedures Manual requirements and preparation of a draft report. These cases should be realistic in the type of evidence submitted. At least one of the mock cases should include:
    a. A fiber comparison
    b. A fabric comparison
    c. A cordage comparison
    d. Two damage assessments
    e. A negative comparison (e.g., exclusion or non-association)
    f. A positive comparison (e.g. an association)
3. Perform at least 5 practice technical reviews. Two of these reviews must be on a damage assessment examination. These reviews may be on copies of active case files prior to the actual case files undergoing technical review by a qualified analyst or on mock case files created for this exercise.
4. Discuss with your trainer and other analysts any unusual casework they have had. Document your conversation with notes.
5. Discuss with your trainer and other analysts any court testimony experiences they have had. Document your conversations with notes.
6. Observe court testimony if possible. Document your observations with notes.
7. Participate in an oral practice session to practice giving verbal answers to court type questions for this subdiscipline. Documentation will include a written list of questions asked provided by your trainer after the practice session.

# 15 FIBER TRAINING CHECKLIST

| **Trainee Name:**<br>**Trainer(s) Name(s):** | Trainee Initials/Date | Trainer Initials/Date | Time for Completion |
|---|---|---|---|
| Chapter 2 – Fibers as Evidence | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |
| Chapter 3 – Chemistry, Biology, and Manufacturing | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |
| Chapter 4 – Microscopy of Manufactured Fibers | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |
| Chapter 5 – Microscopy of Plant Textile Fibers | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |
| Chapter 6 – Microscopy of Animal Textile Fibers | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |
| Chapter 7 – Microscopy of Feathers | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |
| Chapter 8 – Solubility | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |
| Chapter 9 – Comparison Microscopy | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |

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| Chapter 10 – Microspectrophotometry | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |
| Chapter 11 – Infrared Spectroscopy | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |
| Chapter 12 – Elemental Analysis | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |
| Chapter 13 – Textile Damage | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |
| Chapter 14 – Mock Casework | | | |
| Readings | | | |
| Study Questions | | | |
| Practical Exercises | | | |
| Written Test | | | |
| Competency Exam | | | |
| Oral Testimony Exam | | | |