

***** OVERVIEW OF CHAPTERS *****

	<u>Pages</u>
Chapter 1 Low Power Microscopy	1-54
Chapter 2 Bright Field Microscopy	55-187
Chapter 3 Polarization Microscopy	189-275
Chapter 4 Fluorescence Microscopy	277-306
Chapter 5 Comparison Microscopy	307-334
Chapter 6 Training in Fibre Microscopy	335-397

*** **USEFUL TABLES** ***

Fibre properties

	<u>Page(s)</u>
Tab. 2-1 Properties and applications of man-made fibres.	74 – 75
Tab. 2-3 Properties of wool, merino wool and angora.	142
Tab. 2-4 Properties of goat hair (Capra).	145
Tab. 2-5 Properties of hair from Old and New World camels (Camelidae).	149

Identification tables

Tab. 6-4 Identification table of man-made fibres.	385-388
Tab. 6-5 Identification table of vegetable fibres.	389-391
Tab. 6-6 Identification table of animal fibres.	392-394

Quality assurance/Training

Tab. 2-13 Checklist for training in bright field microscopy.	185
Tab. 3-5 Checklist for training in polarization microscopy.	271
Tab. 4-5 Checklist for training in fluorescence microscopy.	303
Tab. 5-1 Checklist for training in comparison microscopy.	332

***** CONTENTS *****

* CHAPTER 1	LOW POWER MICROSCOPY *	1-54
1.1	INTRODUCTORY SECTION The size of textile fibres	1-2
1.2	INSTRUMENTAL ASPECTS	3-7
1.2.1	Optics	
1.2.2	Illumination techniques and light sources	
1.2.3	Boom stand	
1.2.4	Important properties	
1.2.5	Applications of low power microscopy	
1.3	PRACTICAL ASPECTS	8-14
1.3.1	Setting up the stereomicroscope	
1.3.2	Focusing	
1.3.3	Optimal magnification	
1.3.4	Searching fibres on tapings	
1.3.5	Counting fibres	
1.3.6	Fibre tufts and pills	
1.3.7	Photomicrography	
1.4	MOUNTING FIBRES	15-23
1.4.1	Types of preparations	
1.4.2	Choice of mounting medium	
1.4.3	Microscope slides and coverslips	
1.4.4	Mounting tools and additional material	
1.4.5	Fibre mounting procedure	
1.4.6	Mounting fibres from small objects	
1.4.7	Mounting control fibres	
1.5	FIBRE MORPHOLOGY	24-50
1.5.1	Natural and man-made fibres	
1.5.2	A remark on photomicrographs	
1.5.3	Fibre colour	
1.5.4	Diameter estimation	
1.5.5	Recognising cross-sections	
1.5.6	Waviness	
1.5.7	Leather and microfibre tufts	
1.5.8	Flock fibres	
1.5.9	Molten endings	
1.5.10	Cotton	
1.5.11	Flax	
1.5.12	Wool	
1.5.13	Angora	
1.5.14	Other animal hair	
1.5.15	Other fibre and textile traces	
1.6	TRAINING AND QUALITY ASSURANCE	51-54
1.6.1	Observation of colour	
1.6.2	Colour discrimination	
1.6.3	Training with fibre search tests	
1.6.4	Quality assurance issues	

* CHAPTER 2	BRIGHT FIELD MICROSCOPY *	55-187
--------------------	----------------------------------	---------------

2.1 INTRODUCTORY SECTION About fibre morphology	55
2.2 THEORETICAL ASPECTS	56-60
2.2.1 Visible light	
2.2.2 The parts of a microscope	
2.2.3 Some useful formulas	
2.3 INSTRUMENTAL ASPECTS	60-62
2.3.1 Objectives	
2.3.2 Eyepieces	
2.3.3 Condenser	
2.3.4 Object stage	
2.3.5 Filters	
2.4 PRACTICAL ASPECTS	63-68
2.4.1 Setting up the microscope	
2.4.2 Observation of fibres	
2.4.3 Measurements	
2.4.4 Photomicrography	
2.5 MAN-MADE FIBRES	69-76
2.5.1 Classification	
2.5.2 Manufacturing	
2.5.3 Properties and textile applications	
2.6 MORPHOLOGY OF MAN-MADE FIBRES	76-113
2.6.1 Delustrants	
2.6.2 Fibre colour	
2.6.3 Dyed fibres	
2.6.4 Ring dyeing	
2.6.5 Zone dyeing	
2.6.6 Pigments	
2.6.7 Fish eyes	
2.6.8 Pigment traces	
2.6.9 Pigmentary and non-pigmentary prints	
2.6.10 Fibre thickness	
2.6.11 Cross-sections and microtomy	
2.6.12 Round or circular cross-section	
2.6.13 Bean cross-section	
2.6.14 Dogbone cross-section	
2.6.15 Irregular cross-section	
2.6.16 Crenate cross-section	
2.6.17 Polygonal cross-section	
2.6.18 Trilobal cross-section	
2.6.19 Multilobal cross-section	
2.6.20 Oblate cross-section	
2.6.21 Bicomponent fibres	
2.6.22 Hollow fibres	
2.6.23 Special cross-sections	
2.6.24 Surface characteristics	
2.6.25 Texturizing	
2.6.26 Aramid fibres	
2.6.27 High tenacity polyethylene	
2.7 MORPHOLOGY OF NATURAL FIBRES	114-158
2.7.1 Classification	
2.7.2 Vegetable fibres	

- 2.7.3 Cotton
- 2.7.4 Mercerised cotton
- 2.7.5 Pigmentary prints
- 2.7.6 Other seed and fruit fibres
- 2.7.7 Flax and other bast fibres
- 2.7.8 Sisal and other leaf fibres
- 2.7.9 Other characteristics of vegetable fibres
- 2.7.10 Animal fibres
- 2.7.11 Characteristics of mammalian hair
- 2.7.12 Medulla or medullary channel
- 2.7.13 Medulla types
- 2.7.14 Medullary index
- 2.7.15 Cortex
- 2.7.16 Scale pattern
- 2.7.17 Scale count
- 2.7.18 Scale prominence
- 2.7.19 Scale height
- 2.7.20 Wool
- 2.7.21 Merino wool
- 2.7.22 Angora
- 2.7.23 Goat hair
- 2.7.24 Camel hair
- 2.7.25 Other mammalian hair
- 2.7.26 Scale casts of animal hair
- 2.7.27 Silk fibres
- 2.7.28 Leather
- 2.7.29 Feather barbules

2.8 SPECIFIC FIBRES

159-163

- 2.8.1 Microfibres
- 2.8.2 Leather versus microfibres
- 2.8.3 Flock fibres
- 2.8.4 Fibrillated film

2.9 FIBRE TYPE COMBINATIONS

164-166

- 2.9.1 Fibre blends
- 2.9.2 Morphology and fibre type
- 2.9.3 Microtomy

2.10 ACQUIRED AND RARE FEATURES

167-179

- 2.10.1 Features versus artefacts
- 2.10.2 Thermal degradation
- 2.10.3 Photodegradation
- 2.10.4 Chemical degradation
- 2.10.5 Bulbous extremities
- 2.10.6 Mushroom-shaped extremities
- 2.10.7 Transverse striations
- 2.10.8 Microvacuoles
- 2.10.9 Mechanical damage
- 2.10.10 Examples of artefacts

2.11 NATURAL VERSUS MAN-MADE FIBRES

180-183

2.12 TRAINING AND QUALITY ASSURANCE

184-187

- 2.12.1 Training
- 2.12.2 Quality assurance

3.1 THEORETICAL ASPECTS

189-200

- 3.1.1 Light and its polarization states
- 3.1.2 Refractive indices
- 3.1.3 Isotropy and anisotropy
- 3.1.4 Birefringence
- 3.1.5 Elongation
- 3.1.6 Crystallinity
- 3.1.7 Orientation
- 3.1.8 Interference and extinction
- 3.1.9 Michel-Lévy colour chart
- 3.1.10 Compensation

3.2 INSTRUMENTAL ASPECTS

201-204

- 3.2.1 Object stage
- 3.2.2 Polarization optics
- 3.2.3 Polarization filters
- 3.2.4 Lambda plate
- 3.2.5 Quartz wedge

3.3 PRACTICAL ASPECTS

205-207

- 3.3.1 Centring of objectives
- 3.3.2 Adjustment of polars
- 3.3.3 Eyepiece micrometre calibration
- 3.3.4 Photomicrography
- 3.3.5 Conventions

3.4 APPLICATIONS FOR MAN-MADE FIBRES

208-257

- 3.4.1 Fibres with very low birefringence
- 3.4.2 Low birefringent fibres
- 3.4.3 Medium birefringent fibres
- 3.4.4 Highly birefringent fibres
- 3.4.5 Recognizing other generic fibre classes
- 3.4.6 Polarization colours and cross-sections
- 3.4.7 Estimating birefringence using the Michel-Lévy colour chart
- 3.4.8 Quantitative polarization microscopy
- 3.4.9 Observation of dichroism
- 3.4.10 Observation of relative refractive indices
- 3.4.11 Dispersion staining technique
- 3.4.12 Examining damage
- 3.4.13 Examining manufacturing characteristics

3.5 APPLICATIONS FOR NATURAL FIBRES

258-270

- 3.5.1 Vegetable fibres between crossed polars
- 3.5.2 Modified Herzog test
- 3.5.3 Animal fibres between crossed polars
- 3.5.4 Observation of dichroism

3.6 TRAINING AND QUALITY ASSURANCE

271-275

- 3.6.1 Training
- 3.6.2 Operator reproducibility
- 3.6.3 Apparatus reproducibility
- 3.6.4 Detection limit
- 3.6.5 Specificity
- 3.6.6 Robustness

*** CHAPTER 4 FLUORESCENCE MICROSCOPY ***

277-306

4.1 THEORETICAL ASPECTS

277-279

- 4.1.1 The origin of fluorescence
- 4.1.2 Fluorescence due to dyestuffs
- 4.1.3 Fluorescence due to finishes
- 4.1.4 Auto-fluorescence

4.2 INSTRUMENTAL ASPECTS

280-284

- 4.2.1 The fluorescence microscope
- 4.2.2 The low power microscope and fluorescence
- 4.2.3 Excitation sources
- 4.2.4 Fluorescence cubes

4.3 PRACTICAL ASPECTS

285-287

- 4.3.1 Examining fluorescence
- 4.3.2 Describing fluorescence
- 4.3.3 Photomicrography

4.4 APPLICATIONS FOR MAN-MADE FIBRES

288-298

- 4.4.1 Fluorescence colours and intensities
- 4.4.2 Pigmented fibres
- 4.4.3 Auto-fluorescence
- 4.4.4 Non-pigmentary prints
- 4.4.5 Pigmentary prints
- 4.4.6 Inclusions
- 4.4.7 High-visibility fibres
- 4.4.8 Colourless fibres
- 4.4.9 Fibre damage
- 4.4.10 Cross-sections

4.5 APPLICATIONS FOR NATURAL FIBRES

299-302

- 4.5.1 Fluorescence colours and intensities
- 4.5.2 Auto-fluorescence
- 4.5.3 Optical brighteners
- 4.5.4 Pigmentary prints
- 4.5.5 Observation of medullar cells
- 4.5.6 Discrimination with fluorescence

4.6 QUALITY ASPECTS

303-306

- 4.6.1 Training
- 4.6.2 Quality assurance
- 4.6.3 Interference

*** CHAPTER 5 COMPARISON MICROSCOPY * 307-334**

5.1 INSTRUMENTAL ASPECTS 307-311

- 5.1.1 The comparison microscope
- 5.1.2 Alternatives to the comparison microscope
- 5.1.3 Optics
- 5.1.4 Light sources
- 5.1.5 Digital camera systems

5.2 PRACTICAL ASPECTS 312-321

- 5.2.1 Background colour adjustment
- 5.2.2 Comparison views
- 5.2.3 Setting up the comparison microscope
- 5.2.4 The comparison process
- 5.2.5 Photomicrography

5.3 CASEWORK EXAMPLES 322-331

- 5.3.1 Case 1: Dark acrylic fibres
- 5.3.2 Case 2: Pink polyester fibres
- 5.3.3 Case 3: Reddish cotton fibres
- 5.3.4 Case 4: Red animal hair
- 5.3.5 Case 5: Bright blue polyester fibres

5.4 QUALITY ASPECTS 332-334

- 5.4.1 Training
- 5.4.2 Quality assurance
- 5.4.3 Remark on fluorescence
- 5.4.4 Checklist of characteristics

*** CHAPTER 6 TRAINING IN FIBRE MICROSCOPY * 335-397**

6.1 FIBRE COLLECTIONS AND DATABASES 335-350

- 6.1.1 Fibre samples
- 6.1.2 The usefulness of fibre collections
- 6.1.3 Fibre databases
- 6.1.4 The usefulness of fibre databases
- 6.1.5 Basics of database design
- 6.1.6 Information content and lessons learned
- 6.1.7 Using photomicrographs
- 6.1.8 Estimating rarity

6.2 MULTIPLE-CHOICE TESTS 351-361

- 6.2.1 MCQ on general fibre knowledge
- 6.2.2 MCQ on bright field microscopy
- 6.2.3 MCQ on polarization microscopy
- 6.2.4 MCQ on fluorescence microscopy
- 6.2.5 Solution key

6.3 ADDITIONAL PHOTOMICROGRAPHS 362-381

- 6.3.1 Photomicrographs
- 6.3.2 Fibre descriptions

6.4 SUGGESTED FURTHER READING 382-383

6.5 FIBRE IDENTIFICATION TABLES 384-394

6.6 INDEX OF FIBRE CHARACTERISTICS 395-397

***** INDEX OF FIGURES, TABLES AND PHOTOMICROGRAPHS *****

Chapter 1 Low power microscopy

Figures

	Page
Fig. 1-1 The size of microtraces.	2
Fig. 1-2 The components of a stereomicroscope.	5
Fig. 1-3 Woven fabric at different magnifications.	7
Fig. 1-4 A visual mnemonic for focusing.	8
Fig. 1-5 Optimal magnification.	10
Fig. 1-6 Screening of tapings using a search grid.	11
Fig. 1-7 A colony counter.	12
Fig. 1-8 Fibre tufts and fibre pills.	13
Fig. 1-9 Target grid used in photography at low magnifications.	14
Fig. 1-10 Refraction of light.	16
Fig. 1-11 Microscope slides and coverslips.	18
Fig. 1-12 Mounting tools and additional material.	19
Fig. 1-13 Fibre mounting procedure.	21
Fig. 1-14 Mounted fibres.	22
Fig. 1-15 A simplified classification of natural fibres.	24
Fig. 1-16 A simplified classification of man-made fibres.	25
Fig. 1-17 Comparison scale for fibre diameter estimation.	28
Fig. 1-18 Example of a fibre search test.	52

Tables

	Page
Tab. 1-1 Properties of the Leica MZ12 stereomicroscope.	6
Tab. 1-2 Commonly used mounting media for microscopy.	18

Photomicrographs

	Page
Ph. 1-1 Man-made fibres with regular diameter, viewed at various magnifications.	27
Ph. 1-2 Red bean-shaped acrylic fibres, viewed at different magnifications.	29
Ph. 1-3 Fibres with flattened section, viewed at various magnifications.	30
Ph. 1-4 Regular undulations of fibre filaments.	31
Ph. 1-5 A leather tuft, viewed at various magnifications.	32
Ph. 1-6 Flock fibres, viewed at various magnifications.	34
Ph. 1-7 Man-made fibres with molten endings, viewed at various magnifications.	35
Ph. 1-8 Cotton morphology.	36
Ph. 1-9 Indigo dyed cotton fibres from a jeans fabric, viewed at various magnifications.	37
Ph. 1-10 Flax morphology.	39
Ph. 1-11 Wool morphology.	40
Ph. 1-12 Fine wool fibres, viewed at various magnifications.	41
Ph. 1-13 Medium-sized wool, viewed at various magnifications.	42
Ph. 1-14 Merino wool fibres, viewed at various magnifications.	43
Ph. 1-15 Angora morphology.	44
Ph. 1-16 Angora, viewed at various magnifications.	45
Ph. 1-17 Wool and angora, viewed at various magnifications.	46
Ph. 1-18 Cashmere, viewed at various magnifications.	47
Ph. 1-19 Other textile-related microtraces.	49

Chapter 2 Bright field microscopy

Figures

	Page
Fig. 2-1 The main components of the microscope in bright field mode.	57
Fig. 2-2 A low power versus a high power objective.	58
Fig. 2-3 A series of microscope objectives.	60
Fig. 2-4 Eyepieces with dioptre adjustment.	61
Fig. 2-5 Obtaining Köhler illumination.	63
Fig. 2-6 Effect of opening the condenser diaphragm.	64
Fig. 2-7 A visual aid for focusing.	65
Fig. 2-8 The use of an ocular micrometer.	66
Fig. 2-9 The use of an object micrometer.	67
Fig. 2-10 The use of a photomicrography aid.	68
Fig. 2-11 Classification of man-made fibres.	69
Fig. 2-12 Schematical representation of fibre production.	71
Fig. 2-13 Orientation of the polymer chains during drawing.	72
Fig. 2-14 Fibre cross-sectional shapes.	108
Fig. 2-15 Classification scheme of natural fibres.	114
Fig. 2-16 Classification scheme of vegetable fibres.	116
Fig. 2-17 Classification scheme of animal fibres.	130
Fig. 2-18 Structural elements found in animal fibres.	131
Fig. 2-19 Description of the medulla of animal hair.	133
Fig. 2-20 Natural flow of wool, illustrating its crimp.	137
Fig. 2-21 Morphology of man-made fibres.	182
Fig. 2-22 Morphology of natural fibres.	183

Tables

	Page(s)
Tab. 2-1 Properties and applications of man-made fibres.	74-75
Tab. 2-2 Cross-sectional shapes of man-made fibres.	108
Tab. 2-3 Properties of wool, merino wool and angora.	142
Tab. 2-4 Properties of goat hair (Capra).	145
Tab. 2-5 Properties of hair from Old and New World camels (Camelidae).	149
Tab. 2-6 Morphology differences between leather and microfiber tufts.	160
Tab. 2-7 Thermal characteristics of the main generic fibre classes.	168
Tab. 2-8 UV resistance of the main generic fibre classes.	170
Tab. 2-9 Chemical resistance of the main generic fibre classes.	171
Tab. 2-10 Resistance to wear of the main generic fibre classes.	175
Tab. 2-11 Microbiological resistance of the main generic fibre classes.	179
Tab. 2-12 Differences between man-made and natural fibres in bright field microscopy.	180
Tab. 2-13 Checklist for training in bright field microscopy.	185

Photomicrographs

	Page
Ph. 2-1 Delustrants.	77
Ph. 2-2 Delustrants viewed at different focal planes.	78
Ph. 2-3 Antimony trioxide as delustrant.	79
Ph. 2-4 Delustrants in streaks.	80
Ph. 2-5 Dyed versus pigmented fibres.	81
Ph. 2-6 Fibre colours obtained within a range of pure acid dyes.	82
Ph. 2-7 Ring dyeing.	83
Ph. 2-8 Zone dyeing.	84
Ph. 2-9 Tiger tail acrylics.	85
Ph. 2-10 Some examples of pigmented fibres.	86
Ph. 2-11 Pigments viewed at different focal planes.	87
Ph. 2-12 Fish eyes.	89
Ph. 2-13 Variation of fish eye size.	90
Ph. 2-14 Traces of blue pigments in a delustred polyester fibre type.	90
Ph. 2-15 Pigmentary versus non-pigmentary prints.	91
Ph. 2-16 Fibre titer versus thickness.	92
Ph. 2-17 Cross-sectioned fibres.	93
Ph. 2-18 Circular versus bean cross-section.	94
Ph. 2-19 Bean cross-section in acrylic fibres.	95
Ph. 2-20 Dogbone cross-section in acrylic fibres.	96
Ph. 2-21 Irregular cross-section in a viscose fibre.	97
Ph. 2-22 Crenate cross-section in an acetate fibre.	98
Ph. 2-23 Examples of fibres with a polygonal cross-section.	99
Ph. 2-24 Examples of fibres with a trilobal cross-section.	100
Ph. 2-25 Optical sectioning.	101

Ph. 2-26	Fibre with a multilobal cross-section.	102
Ph. 2-27	Examples of fibres with an oblate cross-section.	103
Ph. 2-28	Side-by-side bicomponent fibre types.	104
Ph. 2-29	Example of a core/sheath bicomponent fibre type.	105
Ph. 2-30	Optical sectioning in a core/sheath bicomponent fibre.	106
Ph. 2-31	Example of a mushroom type bicomponent fibre.	106
Ph. 2-32	Examples of hollow fibres.	107
Ph. 2-33	Surface striations in an acrylic fibre.	109
Ph. 2-34	Elbows due to the stuffer-box texturizing process.	110
Ph. 2-35	Kevlar fibres.	112
Ph. 2-36	Nomex fibres.	112
Ph. 2-37	High tenacity polyethylene fibres.	113
Ph. 2-38	Cotton fibre morphology.	117
Ph. 2-39	Indigo dyed cotton fibres.	118
Ph. 2-40	Mercerised cotton.	119
Ph. 2-41	Examples of pigmentary prints on cotton.	120
Ph. 2-42	Kapok morphology.	121
Ph. 2-43	Coir morphology.	122
Ph. 2-44	The morphology of flax, hemp and ramie.	123
Ph. 2-45	The morphology of jute.	124
Ph. 2-46	The morphology of kenaf.	125
Ph. 2-47	The morphology of sisal.	126
Ph. 2-48	The morphology of abaca (Manila hemp).	127
Ph. 2-49	Cross-sections of bast and leaf fibre bundles.	129
Ph. 2-50	Cortical fusi in a coarse wool fibre.	134
Ph. 2-51	Preparation effects.	135
Ph. 2-52	The morphology of wool.	138
Ph. 2-53	The morphology of merino wool.	139
Ph. 2-54	The morphology of angora.	140
Ph. 2-55	Angora sample (reference collection).	141
Ph. 2-56	Mohair sample (reference collection).	143
Ph. 2-57	Cashmere sample (reference collection).	144
Ph. 2-58	Camel sample (reference collection).	146
Ph. 2-59	Llama sample (reference collection).	147
Ph. 2-60	Alpaca sample (reference collection).	148
Ph. 2-61	Scale casts of coarse and fine wool, merino wool and angora.	150
Ph. 2-62	Scale casts of mohair and cashmere goat hair.	151
Ph. 2-63	Scale casts of camel, llama and alpaca.	152
Ph. 2-64	Scale casts of yak down, musk ox guard hair and musk ox down (Quiviut).	153
Ph. 2-65	Pearl beads in a silk fibre.	155
Ph. 2-66	Silk fibres (reference collection).	156
Ph. 2-67	Leather morphology.	157
Ph. 2-68	Down barbule morphology.	158
Ph. 2-69	Microfibre filaments in a yarn.	160
Ph. 2-70	Morphology of microfibre and leather tufts.	161
Ph. 2-71	Fibrillated film.	163
Ph. 2-72	Some examples of cross-sectioned acrylic fibres.	166
Ph. 2-73	Thermoplastic fibres deformed due to heat exposure.	169
Ph. 2-74	Bulbous extremities in polyester fibres.	171
Ph. 2-75	Mushroom endings.	172
Ph. 2-76	Transverse striations.	173
Ph. 2-77	Microvacuoles.	174
Ph. 2-78	Splitting in a tetra-channel polyester fibre.	175
Ph. 2-79	Axial splitting in man-made fibres.	176
Ph. 2-80	Soot particles at the fibre surface.	177
Ph. 2-81	Diatoms between the lobes of a polyamide fibre.	178
Ph. 2-82	Blood at the surface of a wool fibre.	178
Ph. 2-83	Some examples of texturized fibres with a polygonal section.	187

Chapter 3 Polarization microscopy

Figures

	Page
Fig. 3-1	190
Fig. 3-2	190
Fig. 3-3	192
Fig. 3-4	193

Fig. 3-5 Crystalline and amorphous zones in a drawn textile fibre.	193
Fig. 3-6 Fibre crystallinity and orientation.	194
Fig. 3-7 A system with crossed polars.	195
Fig. 3-8 Extinction and interference positions.	196
Fig. 3-9 The origin of polarization colours.	197
Fig. 3-10 Michel-Lévy colour chart.	198
Fig. 3-11 Specific parts of the polarization microscope.	201
Fig. 3-12 Conventions for polarizer and analyzer.	203
Fig. 3-13 Lambda plate or first-order red plate.	204
Fig. 3-14 Quartz wedge.	204
Fig. 3-15 Centring of a microscope objective.	205
Fig. 3-16 A system with crossed polars.	206
Fig. 3-17 Conventions in polarization microscopy.	207
Fig. 3-18 Addition of one order for low birefringent fibres with positive elongation.	208
Fig. 3-19 The effect of a lambda plate on a low birefringent fibre with positive elongation.	209
Fig. 3-20 Addition of one order for low birefringent fibres with negative elongation.	209
Fig. 3-21 The effect of a lambda plate on a low birefringent fibre with negative elongation.	210
Fig. 3-22 Polarization colours of acrylic fibres.	211
Fig. 3-23 Polarization colours of diacetate.	213
Fig. 3-24 Polarization colours of viscose.	215
Fig. 3-25 Polarization colours of nylon - PA 6.6.	217
Fig. 3-26 Polarization colours of nylon - PA 6.	217
Fig. 3-27 Polarization colours of polyester (PET).	219
Fig. 3-28 Two types of tilting compensators.	234
Fig. 3-29 Conditions for birefringence measurement using a K- and B-compensator.	236
Fig. 3-30 Graphical method for determining the birefringence.	238
Fig. 3-31 Observation of dichroism using one polar and a circular stage.	240
Fig. 3-32 Alternative observation of dichroism.	240
Fig. 3-33 Activation of a single refractive index.	245
Fig. 3-34 The central illumination method.	246
Fig. 3-35 Refractive index chart.	249
Fig. 3-36 Dispersion staining technique.	249
Fig. 3-37 Twist direction in some vegetable fibres.	261
Fig. 3-38 Modified Herzog test according to this work.	262
Fig. 3-39 Modified Herzog test according to other authors.	263

Tables

Tab. 3-1 Refractive indices of some gasses, liquids and solids.	Page 191
Tab. 3-2 Birefringence categories and ranges for man-made fibres.	221
Tab. 3-3 Observed dichroic effects in man-made fibres.	243
Tab. 3-4 Dichroic effects occurring in some natural fibre classes.	269
Tab. 3-5 Checklist for training in polarization microscopy.	271
Tab. 3-6 Generic fibre classes with overlapping birefringence ranges.	274

Photomicrographs

Ph. 3-1 Acrylic fibre viewed in bright field and with polarized light.	Page 211
Ph. 3-2 Modacrylic fibre (Dyneel) viewed in bright field and with polarized light.	212
Ph. 3-3 Modacrylic fibre (Verel) viewed in bright field and with polarized light.	212
Ph. 3-4 Diacetate fibre viewed in bright field and with polarized light.	213
Ph. 3-5 Triacetate fibre viewed in bright field and with polarized light.	214
Ph. 3-6 Viscose viewed in bright field and with polarized light.	215
Ph. 3-7 Polypropylene fibre viewed in bright field and with polarized light.	216
Ph. 3-8 Nylon fibre (PA 6) viewed in bright field and with polarized light.	218
Ph. 3-9 Polyester (PET) fibre viewed in bright field and with polarized light.	219
Ph. 3-10 Inidex, a polyacrylate fibre, viewed in bright field and with polarized light.	222
Ph. 3-11 Elastane viewed in bright field and with polarized light.	222
Ph. 3-12 Lyocell viewed in bright field and with polarized light.	223
Ph. 3-13 Kevlar mixed with PES viewed in bright field and with polarized light.	223
Ph. 3-14 A polyamide-imide (Kermel) viewed in bright field and with polarized light.	224
Ph. 3-15 A fibre with polygonal cross-section viewed with crossed polars.	225
Ph. 3-16 A fibre with trilobal cross-section viewed with crossed polars.	226
Ph. 3-17 Trilobal nylon fibre (PA 6) viewed in bright field and with polarized light.	226
Ph. 3-18 Galaxy (viscose) viewed in bright field and with polarized light.	227
Ph. 3-19 A polyimide fibre (P84, Inspec) viewed in bright field and with polarized light.	227
Ph. 3-20 PET fibres with different cross-sectional shapes.	228
Ph. 3-21 The use of a fixed compensator.	229
Ph. 3-22 The use of a quartz wedge to determine the order.	230

Ph. 3-23	Estimating the birefringence of a polypropylene fibre using the Michel-Lévy colour chart.	232
Ph. 3-24	Estimating the birefringence of a polyamide fibre using the Michel-Lévy colour chart.	233
Ph. 3-25	Correct fibre orientation leads to compensation.	235
Ph. 3-26	Incorrect fibre orientation does not lead to compensation.	235
Ph. 3-27	Determination of the birefringence using a tilting compensator.	237
Ph. 3-28	Regular dichroism in a polyester fibre.	241
Ph. 3-29	Regular dichroism in a polyamide fibre.	241
Ph. 3-30	Inversed dichroism in a polyamide fibre.	242
Ph. 3-31	Pronounced hue change in a polyester fibre.	242
Ph. 3-32	Inversed dichroism and hue change in a pigmented fibre.	242
Ph. 3-33	Very slight dichroic effect in an acrylic fibre.	243
Ph. 3-34	Weak regular dichroism in a diacetate fibre.	244
Ph. 3-35	Determining the relative magnitude of $n_{//}$ of a polyamide fibre mounted in Histomount.	247
Ph. 3-36	Determining the relative magnitude of $n_{//}$ of a chlorofibre mounted in water.	247
Ph. 3-37	Dispersion staining in a PA 6.6 fibre.	250
Ph. 3-38	Deformed fibre between crossed polars.	251
Ph. 3-39	Cut fibre end between crossed polars.	251
Ph. 3-40	Fibres exposed to heat.	252
Ph. 3-41	Bulbous fibre ending due to singeing.	253
Ph. 3-42	Bamboo-like nodes in HTPE (Certran) between crossed polars.	253
Ph. 3-43	Characteristic pattern of Nomex between crossed polars.	254
Ph. 3-44	Fibrillation in Kevlar fibres.	254
Ph. 3-45	Microfibres viewed between crossed polars and lambda plate.	255
Ph. 3-46	Elbow in a polyamide fibre texturized with the stuffer-box method.	255
Ph. 3-47	Mushroom end in a polyester fibre.	256
Ph. 3-48	Different aspects of a Kevlar fibre, viewed with polarized light.	257
Ph. 3-49	Cotton viewed in bright field and with polarized light.	258
Ph. 3-50	Mercerized cotton viewed in bright field and with polarized light.	259
Ph. 3-51	Kapok viewed in bright field and with polarized light.	260
Ph. 3-52	Modified Herzog test on flax: S twist.	263
Ph. 3-53	Modified Herzog test on hemp: Z twist.	264
Ph. 3-54	Modified Herzog test on ramie: S twist.	264
Ph. 3-55	Modified Herzog test on jute: Z twist.	265
Ph. 3-56	Modified Herzog test on kenaf: Z twist.	265
Ph. 3-57	Modified Herzog test on sisal: Z twist.	266
Ph. 3-58	Modified Herzog test on abaca: Z twist.	266
Ph. 3-59	Wool viewed in bright field and with polarized light.	267
Ph. 3-60	Angora viewed in bright field and with polarized light.	268
Ph. 3-61	Silk viewed in bright field and with polarized light.	269
Ph. 3-62	Some hue changes observed in cotton fibres.	270
Ph. 3-63	Differences in polarization colours observed with two different microscopes.	272
Ph. 3-64	Surface dyed fibre.	273
Ph. 3-65	Small changes in fibre orientation under crossed polars.	275

Chapter 4 Fluorescence microscopy

Figures

	Page
Fig. 4-1 Jablonski energy diagram depicting the pathway to fluorescence.	277
Fig. 4-2 Total fluorescence emission of a fibre.	279
Fig. 4-3 Specific parts of the fluorescence microscope.	280
Fig. 4-4 Specific parts of the fluorescence stereomicroscope.	281
Fig. 4-5 Schematic representation of a fluorescence cube.	283
Fig. 4-6 Fluorescence cubes used for fibre examination.	283
Fig. 4-7 Fluorescence cubes in the filter carousel.	285
Fig. 4-8 Standard presentation of fluorescence images.	287
Fig. 4-9 Image analysis of fibre fluorescence.	305

Tables

	Page
Tab. 4-1 Main fluorescence systems in forensic fibre examination.	284
Tab. 4-2 Fluorescence observed in man-made fibres.	288
Tab. 4-3 Fluorescence observed in cotton fibres.	299
Tab. 4-4 Fluorescence observed in wool fibres.	299
Tab. 4-5 Checklist for training in fluorescence microscopy.	303

Photomicrographs

	Page
Ph. 4-1 Fluorescence in an evenly dyed yellow polyester fibre.	287
Ph. 4-2 Strong even fluorescence in a mauve polyester fibre.	289
Ph. 4-3 Uneven fluorescence in a green acrylic fibre.	289
Ph. 4-4 Fluorescence in an acrylic fibre containing finely dispersed pigments.	290
Ph. 4-5 Auto-fluorescence in a polyester fibre.	291
Ph. 4-6 Uneven fluorescence in a printed polyamide fibre.	292
Ph. 4-7 Fluorescence in the polyamide fibre "Footlights".	293
Ph. 4-8 Four different hi-viz fibre types.	294
Ph. 4-9 Testing the fluorescence of colourless fibres with stereomicroscopy.	295
Ph. 4-10 Fluorescence in a colourless fibre type.	296
Ph. 4-11 Fluorescence in a damaged fibre.	297
Ph. 4-12 Fluorescence microscopy on a cross-section of yarn.	298
Ph. 4-13 Auto-fluorescence of cotton and flax.	300
Ph. 4-14 Discrimination of fibre samples with fluorescence microscopy.	302
Ph. 4-15 Fluorescence of glue residues.	306

Chapter 5 Comparison microscopy

Figures

	Page
Fig. 5-1 Specific components of the comparison microscope.	309
Fig. 5-2 The controller of a comparison microscope.	309
Fig. 5-3 Colour correction buttons.	312
Fig. 5-4 Different views in comparison microscopy.	313

Tables

	Page
Tab. 5-1 Checklist for training in comparison microscopy.	332

Photomicrographs

	Page
Ph. 5-1 Two comparisons with split repositioning.	310
Ph. 5-2 Two comparisons using a transparent split.	310
Ph. 5-3 Different degrees in background compensation.	313
Ph. 5-4 Comparison of zone dyed polyester fibres.	315
Ph. 5-5 Comparison of viscose fibres.	316
Ph. 5-6 Comparison of dip-dyed acrylic fibres.	317
Ph. 5-7 Comparison of matching polyester fibres.	318
Ph. 5-8 Comparison of thick polyester fibres from a scouring sponge.	319
Ph. 5-9 Comparison of two non-matching fibres.	320
Ph. 5-10 Comparison of damaged acrylic fibres.	323
Ph. 5-11 Comparison of pink polyester fibres.	325
Ph. 5-12 Comparison of faintly dyed pink polyester fibres.	326
Ph. 5-13 Comparison of orange-red cotton fibres.	327
Ph. 5-14 Comparison of red animal hair.	328
Ph. 5-15 Comparison of red animal hair (2).	329
Ph. 5-16 Comparison of red animal hair (3).	330
Ph. 5-17 Comparison of bright blue polyester fibres.	331

Chapter 6 Training in fibre microscopy

Figures

	Page
Fig. 6-1 Commercially available forensic fibre reference collections.	336
Fig. 6-2 A ring binder containing samples of a fibre reference collection.	338
Fig. 6-3 Fibre collection terminology and fibre database equivalents.	343
Fig. 6-4 Venn diagrams illustrating the rarity of three specific fibre types.	348
Fig. 6-5 Some characteristics of man-made and natural fibres.	393

Tables

	Page(s)
Tab. 6-1 Some examples of data formats.	344
Tab. 6-2 Current data from a reference database and a casework database.	347
Tab. 6-3 Information obtained from DB queries.	349
Tab. 6-4 Identification table of man-made fibres.	385-388
Tab. 6-5 Identification table of vegetable fibres.	389-391
Tab. 6-6 Identification table of animal fibres.	392-394
Tab. 6-7 Index of fibre characteristics.	395-396

Photomicrographs

	Pages
Ph. 6-1 →	362-
Ph. 6-32	378

SAMPLE PAGE