

## CHAPTER 6

### TRAINING IN FIBRE MICROSCOPY

#### 6.1 FIBRE COLLECTIONS AND DATABASES

##### 6.1.1 Fibre samples

A fibre collection sounds like something big, and starting to build up a collection of fibre samples feels like a daunting task. This is especially true when casework is the main focus of a fibre lab. While collecting fibre samples is not at all expensive, it can be very time-consuming. Classification of samples and the documentation of the collection takes a lot of time and effort.

There are plenty of possibilities for gathering fibre samples. Here is a non-exhaustive list of ideas for collecting or purchasing fibre samples:

- fibres from commercial reference collections;
- fibres from manufacturers;
- fibres from other fibre labs;
- fibres from collaborative tests, which include fibre identification and description;
- fabric swatches from dye manufacturers;
- fabric swatches from furniture trade;
- fabric swatches from casework garments;
- fabric swatches from donated garments;
- fibre material obtained from specific types of textile materials.

Nowadays, there are only a few **commercial fibre reference collections** available. The Microtrace Forensic Fibre Reference Collection contains 200 samples of man-made fibres coming from 15 generic fibre classes. These include the main generic classes:

- acrylics (3 main subclasses);
- modacrylics;
- polyesters (PET and other sub-classes);
- acetates (di- and triacetates);
- polyamides or nylons (PA 6 and PA 66);
- regenerated cellulose (viscose or rayon, modal, Lyocell);
- polyolefins (polypropylene, HDPE);
- elastane or spandex; and
- chlorofibres.

### 6.1.3 Fibre databases

When our fibre lab started in 1997 with casework, records of examined fibres were kept on paper forms. This was all right for small cases but not practical for cases with over 100 fibres. In due course, we changed to an Excel spreadsheet, and for each new case, a new blank file was utilised. This approach had the advantage that certain lines could be highlighted in colours to define similar fibre types. The different lines could be arranged according to specific described characteristics. Although some macros can be programmed in Excel, the size of such a spreadsheet is somewhat limited.

We found and engaged a brilliant programmer who could translate the needs of the lab into computer code. A first database, Fibre Reference Collection (FRC), was developed in 2000, and this contained fibre samples collected via the various resources described in the previous section. While entering the data for each sample, a lot was learned about fibre morphology.

The next logical step was to develop a database that would contain all fibres encountered in everyday casework. The creation of this casework DB, Analysis Management, was a giant step forward. The fibre characteristics within each sample were entered from now on, and a photomicrograph at 400x magnification was stored too. The casework DB enabled us to scroll quickly through the fibres of a particular case which facilitated also reviewing the case by other examiners.

Through the years, our databases evolved from Access to an SQL server and a .net environment. It is not a goal to discuss the technical details of databases here. We will focus instead on the lessons that were learned in the process of improving our databases.

It is clear that a fibre DB has many advantages over paper forms or even Excel sheets. As the data entry fields in a DB are predefined and their format is fixed, this allows for consistent data entry and fewer errors. Each examiner using a DB would enter the data in exactly the same way. The quality of the data is a weak point for every database, but especially in fibre databases. If several examiners are involved in the interpretation of fibre samples, this can lead to inconsistent data entry. Any flaws in the database should be minimised as much as possible, and the best way is to have a transparent data entry protocol and provide proper training to all database users.

The main incentive for developing a fibre database is that all kinds of helpful information are stored in a structured way and that these data can be searched for at a later moment.

Every database evolves, no matter how good the data entry fields were defined from the start. Some of the initial choices we made in designing the fibre database turned out to be not that good. Here are some of the lessons we learned when trying to describe fibre characteristics in data fields.

#### Delustrants

The presence or absence of delustrants is an essential characteristic of man-made fibres. In the first version of our database, a drop-down list with three possible choices was used to describe "Lustre": *bright*, *semi-dull* and *dull*. At first sight, this seemed the right thing to do, but the only situations for which the user did not doubt was either when there were no delustrants or when plenty of delustrants were present. As the semi-dull choice posed a real problem, the characteristic "Lustre" was altered into a check-box type with only two choices: present (checked) or absent (unchecked). This change involved converting all the records with *semi-dull* and *dull* fibres in the "Lustre" data field to a checked and those with bright fibres to an unchecked check-box.

An idea for improvement is to use a tristate check-box instead of the commonly used binary state check-box. In a tristate check-box, the default state of the box is greyed. If the user has examined the characteristic, the box needs to be clicked to change its state to checked (the feature is present) or unchecked (the feature is absent). This is important for the quality of a database search because records with greyed check-boxes are not taken into account.

#### Polarization colours

When viewing the fibres under crossed polars, the interference colours can be described in a drop-down list. This includes some basic choices, such as *grey colours (negative elongation)*, *grey colours (positive elongation)*, *1st order colours*, *bright 2nd - 3rd order colours* and *pale higher-order colours*. The default choice should be set to *undetermined* or to an empty field, hereby indicating that no check of the polarization colours occurred.

#### Fluorescence description

When describing the fluorescence, for each different fluorescence cube, the fluorescence colour and the fluorescence intensity should be entered. The latter is a drop-down list with three choices: *weak*, *medium* and *strong*. For each fluorescence cube, a drop-down list with possible fluorescence colours can be defined. In many cases, there is no fluorescence, and this option should also be included.




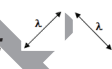

instrumental methods. If infrared is performed, information about the generic fibre class and subclass is available. Raman spectroscopy can also identify some of the dyestuffs. These spectroscopy and microscopy data can be combined and can provide a more precise estimation of the fibre type rarity.

Supplementary tools for training in the microscopy of fibres are provided in the following sections:

- multiple-choice tests on several topics;
- additional fibre images to describe;
- fibre identification tables for man-made, vegetable and animal fibres;
- an index of fibre characteristics.

6.2.3 MCQ on polarization microscopy

A combination of the following symbols is used in this section to describe a particular situation in polarization microscopy:

- the fibre orientation (N-S, NE-SW, E-W or NW-SE): 
- the use of a single polarizer with polarization direction N-S or E-W: 
- the use of crossed polars: 
- the use of a lambda plate with its slow direction oriented NE-SW or NW-SE: 
- the use of a compensator with its slow direction oriented NE-SW or NW-SE: 

**POL1 – A fibre is said to be anisotropic if ...**

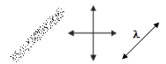
- A)  $n_{//} = 0$
- B)  $n_{//} \neq 0$
- C)  $n_{//} - n_{\perp} = 0$
- D)  $n_{//} - n_{\perp} \neq 0$

**POL2 – If acrylic fibres are viewed under crossed polars, the polarization colours are ...**

- A) 1st order grey
- B) 1st order colours
- C) bright 2nd – 3rd order colours
- D) faint high order colours

**POL3 – Using a combination of crossed polars and a lambda plate as indicated, a fibre turns uniformly blue. This indicates that ...**

- A) this fibre is isotropic
- B)  $n_{//} = n_{\perp}$
- C)  $n_{//} < n_{\perp}$
- D)  $n_{//} > n_{\perp}$



**POL4 – Using a combination of crossed polars and a lambda plate as indicated, a fibre turns uniformly red. This indicates that ...**

- A) this fibre is isotropic
- B)  $n_{//} = n_{\perp}$
- C)  $n_{//} < n_{\perp}$
- D)  $n_{//} > n_{\perp}$



**POL5 – The birefringence of modacrylic fibres is very low and ...**

- A) is almost zero
- B) is always slightly negative
- C) is always slightly positive
- D) can be either slightly negative or positive

**POL6 – The birefringence of diacetate fibres is very low and ...**

- A) is almost zero
- B) is always slightly negative
- C) is always slightly positive
- D) can be either slightly negative or positive

**POL7 – The birefringence of triacetate fibres is very low and ...**

- A) is almost zero
- B) is always slightly negative
- C) is always slightly positive
- D) can be either slightly negative or positive

**FLUO13 – In biological fluorochrome labelling techniques, the excitation and emission filters are ...**

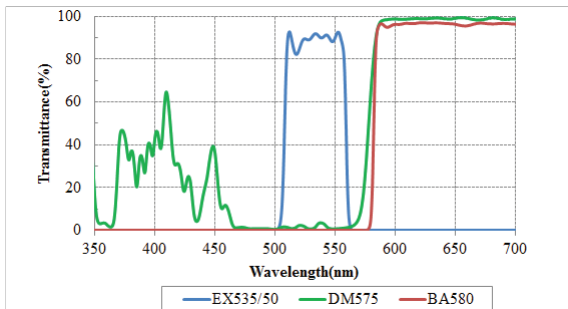
- A) both longpass filters
- B) a longpass filter for excitation, a bandpass filter for emission
- C) a bandpass filter for excitation, a longpass filter for emission
- D) both bandpass filters

**FLUO14 – Which filter block corresponds with the near-UV excitation block used in fibre examinations?**

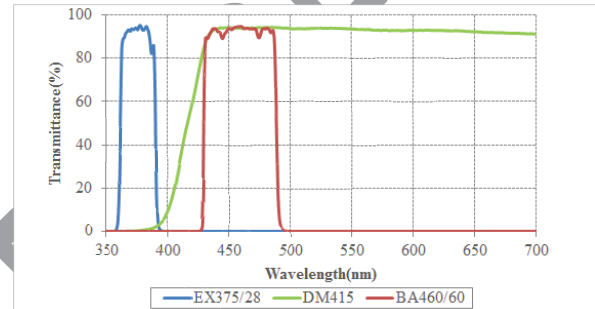
- A) filter block 1
- B) filter block 2
- C) filter block 3
- D) filter block 4

**FLUO15 – Which filter block corresponds with the green excitation block used in fibre examinations?**

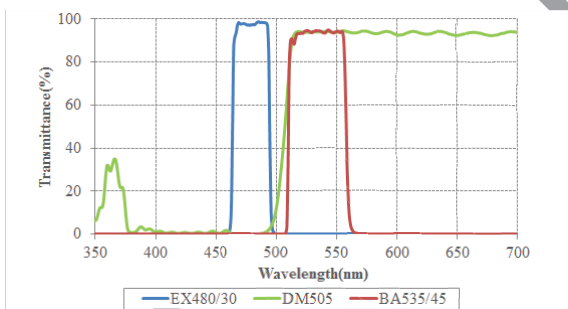
- A) filter block 4
- B) filter block 5
- C) filter block 6
- D) neither of these



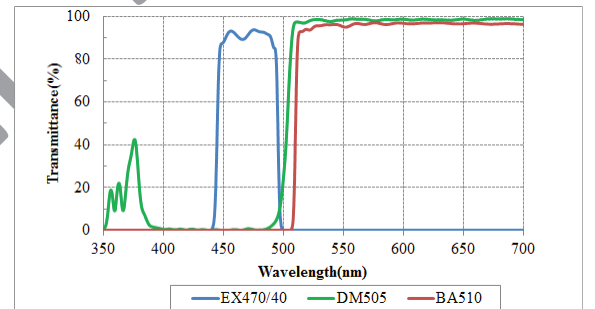
**Filter block 1**



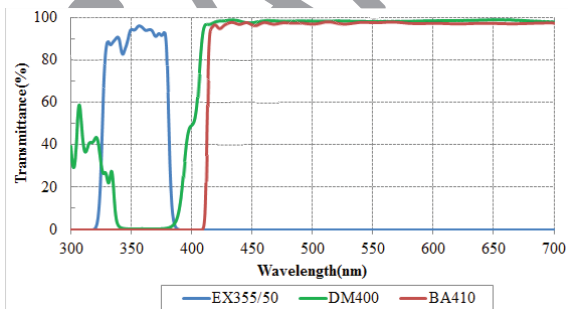
**Filter block 4**



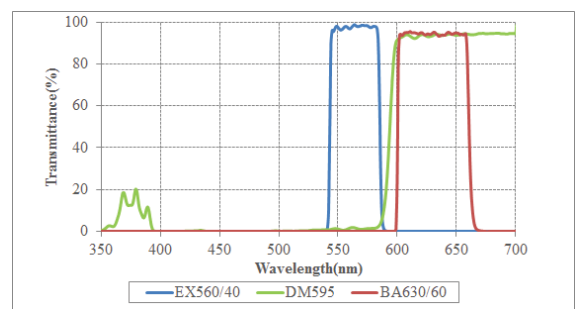
**Filter block 2**



**Filter block 5**



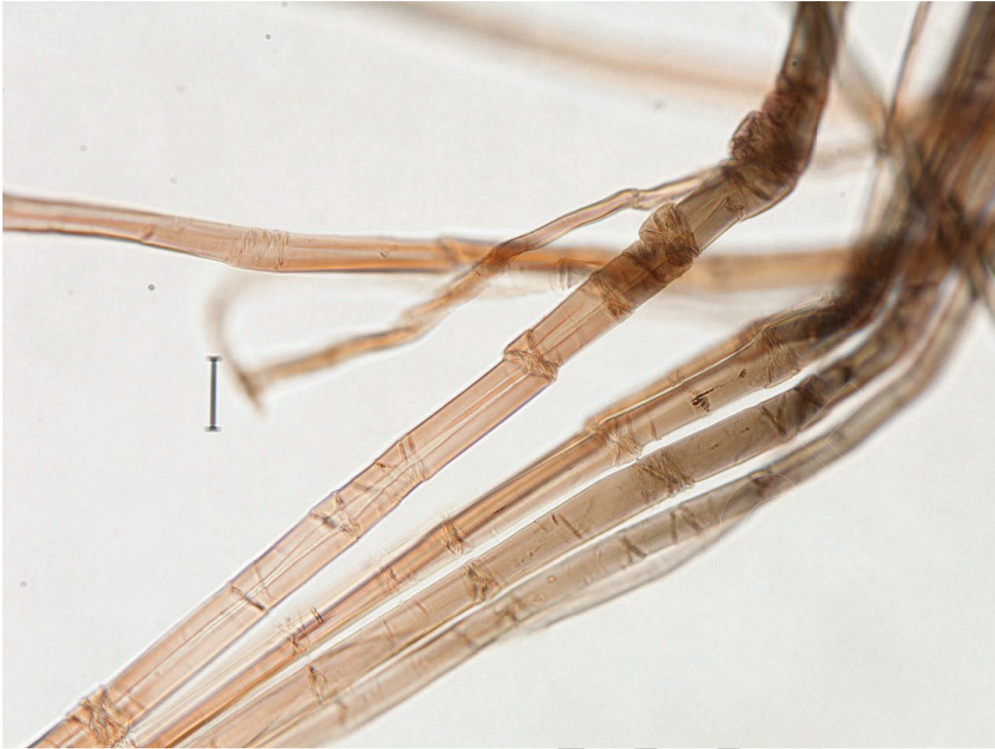
**Filter block 3**



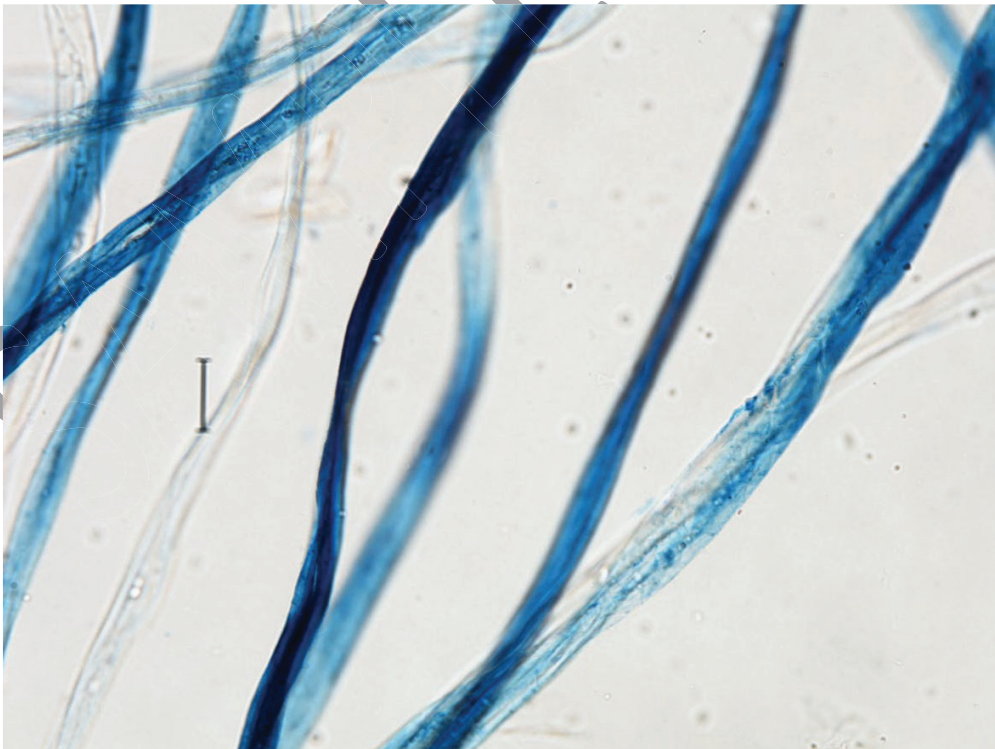
**Filter block 6**

Nikon fluorescence filters

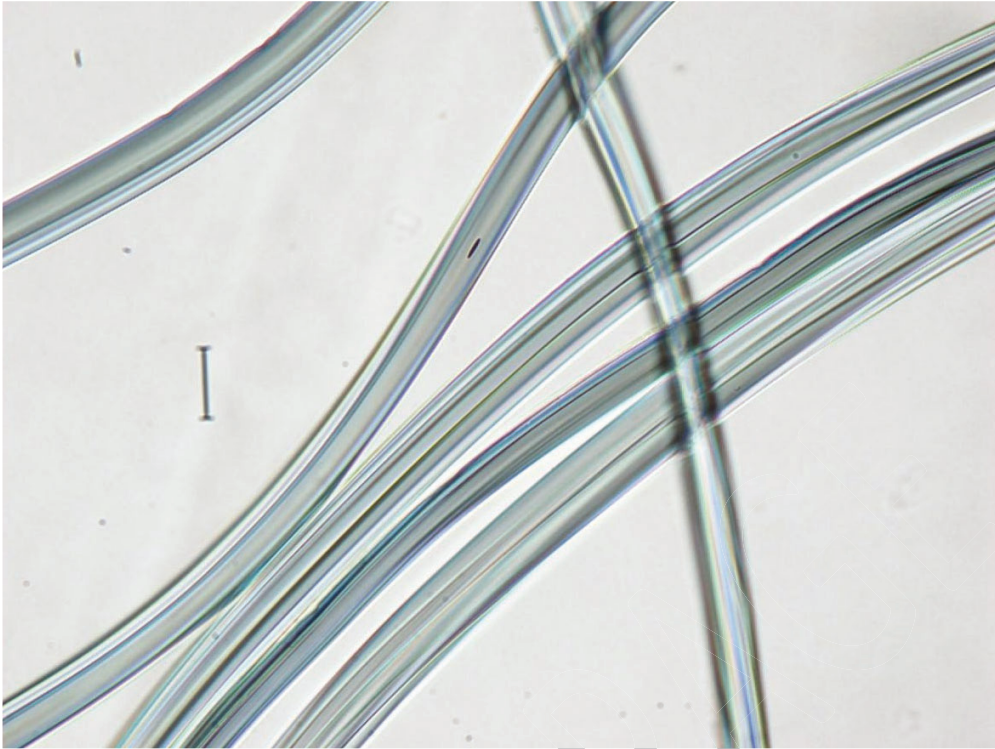
[https://www.microscope.healthcare.nikon.com/en\\_EU/products/accessories/fluorescent-filter-cubes-row](https://www.microscope.healthcare.nikon.com/en_EU/products/accessories/fluorescent-filter-cubes-row)



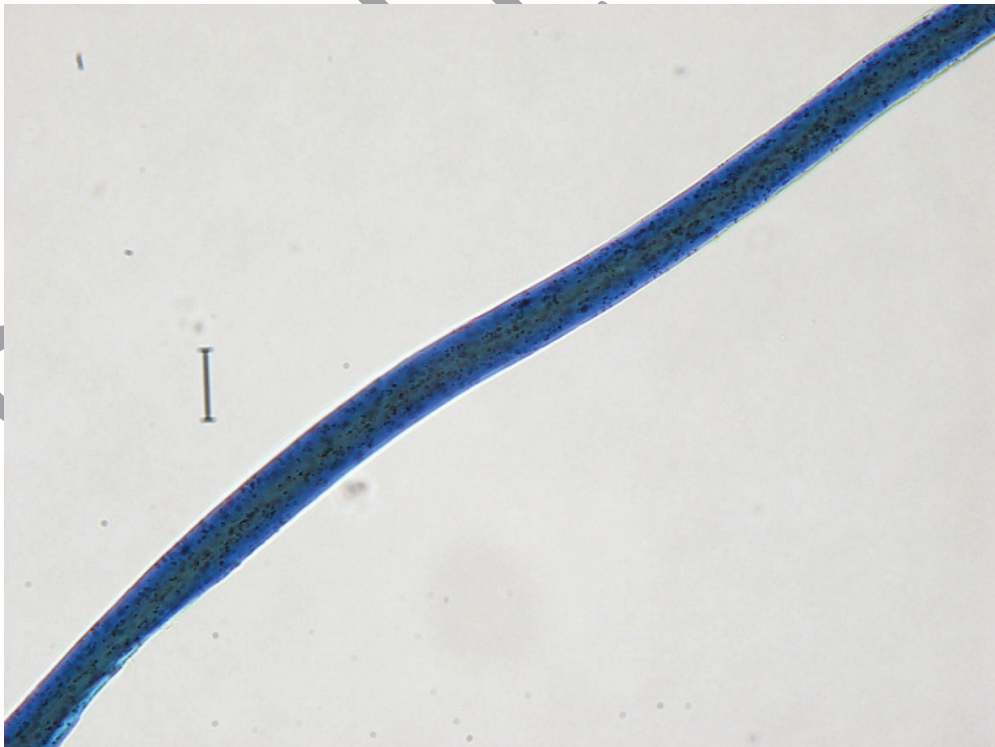
Ph. 6-6



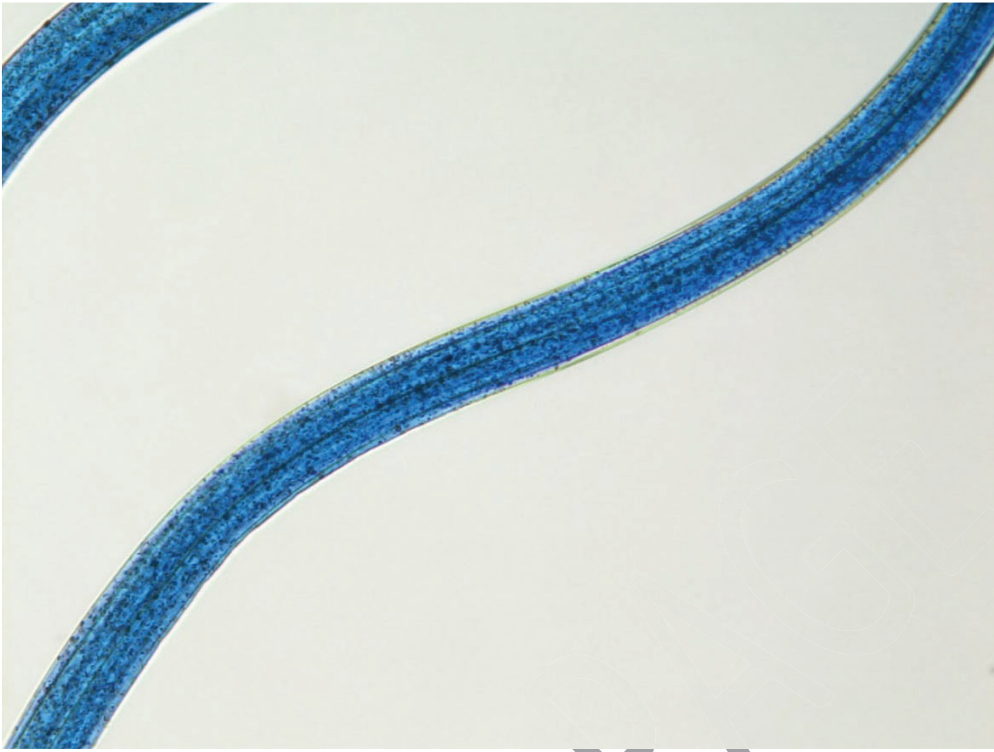
Ph. 6-7



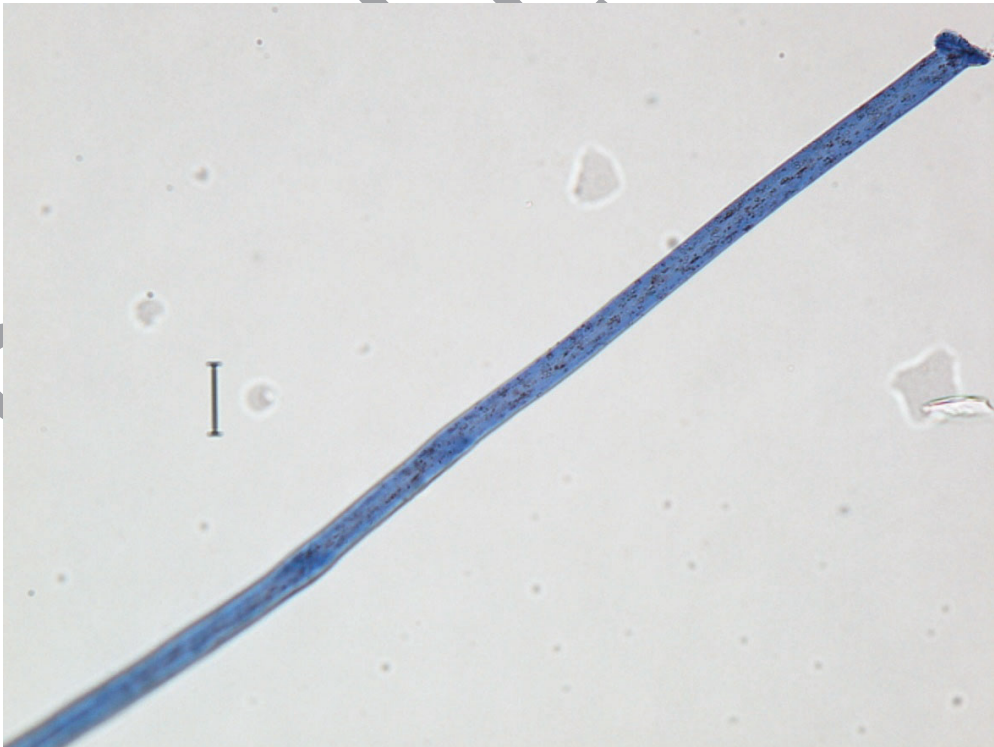
Ph. 6-16



Ph. 6-17




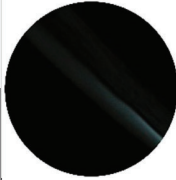




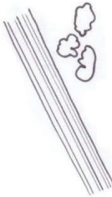




Ph. 6-26











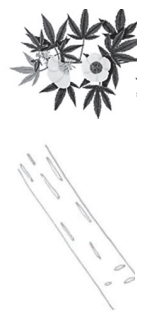

Ph. 6-27

<b>Ph. 6-15</b>	man-made fibres; round cross-section, $\varnothing$ 20 $\mu\text{m}$ ; black pigments; deformed; thermoplastic fibre; ID > POL CP, if polarization colours obscured: IR/R.
<b>Ph. 6-16</b>	man-made fibres; crenate cross-section, $\varnothing$ 12,5-20 $\mu\text{m}$ ; bright; dyed greenish grey; probably acetate; ID > SOL.
<b>Ph. 6-17</b>	man-made fibre; round cross-section, $\varnothing$ ca. 17,5 $\mu\text{m}$ ; ring dyeing, core green and periphery blue; medium, regularly distributed delustrants; ID > POL CP.
<b>Ph. 6-18</b>	natural, animal origin: leather tuft; micro-fibrillated bundle structure; dyed brown.
<b>Ph. 6-19</b>	natural; animal hair; uniserial ladder medulla; $\varnothing$ ca. 15 $\mu\text{m}$ ; dyed black; angora.
<b>Ph. 6-20</b>	man-made fibres; round cross-section, $\varnothing$ ca. 5 $\mu\text{m}$ ; dyed brown, no delustrants; microfibre bundle; tentative: polyester or polyamide; ID > IR/R.
<b>Ph. 6-21</b>	natural fibre, animal origin; slight twist; cross marks; irregularly dyed blue; probably silk, confirm with POL CP or IR.
<b>Ph. 6-22</b>	natural, animal hair; $\varnothing$ ca. 50 $\mu\text{m}$ ; dyed lilac; scales not protruding; large medulla cells (high medullar index); probably cashmere, see also [Ph. 2-57]; ID > REF.
<b>Ph. 6-23</b>	man-made fibre; regular trilobal cross-section; $\varnothing$ ca. 15 $\mu\text{m}$ ; dyed blue; thermoplastic fibre, probably polyester or polyamide; ID > POL CP.
<b>Ph. 6-24</b>	natural, animal hair; few fusi; dyed irregularly grey (no levelling of dye); medium thickness; straight; tentative: wool, confirm with scale casts.
<b>Ph. 6-25</b>	natural fibre, animal origin: down barbules; straight fibres, $\varnothing$ ca. 5 $\mu\text{m}$ ; dyed green; ring-shaped nodes.
<b>Ph. 6-26</b>	man-made fibres; irregular cross-section (many longitudinal striations); $\varnothing$ ca. 35 $\mu\text{m}$ ; blue pigments; probably viscose, confirm with POL CP.
<b>Ph. 6-27</b>	man-made fibre; round cross-section; $\varnothing$ 12,5 $\mu\text{m}$ ; fine delustrants, slightly streaked; dyed blue; mushroom end; thermoplastic fibre; ID: POL CP.
<b>Ph. 6-28</b>	man-made fibre; round cross-section; $\varnothing$ 22,5 $\mu\text{m}$ ; fine delustrants; coated with resin; probably abrasive fibres from a scouring sponge; ID: POL CP.
<b>Ph. 6-29</b>	man-made fibres; round cross-section; $\varnothing$ 7,5 $\mu\text{m}$ ; very straight, opaque rods; carbon, confirm with POL CP.

Tab. 6-4 Identification table of man-made fibres.

Generic fibre class	BF microscopy Physical properties	Crossed polars (CP)	Polarization colours CP + lambda plate parallel	CP + lambda plate perpendicular	Birefringence Elongation Relative RI	Dichroism
<b>Acrylics (PAN)</b> 	longitudinal surface marks XS bean, round or dogbone does not melt, chars above 300 °C	 1° order grey	 1° order red	 1° order blue	very low biref. negative elongation $n_{//} < n_M ; n_L < n_M$	none
<b>Modacrylics (MAC)</b> 	XS dogbone, flattened, round does not melt, flame retardant	 1° order grey	blue or red	red or blue	very low biref. positive or negative elongation $n_{//} < n_M ; n_L < n_M$	none
<b>Diacetate</b> 	XS crenate, cloud-like very lustrous dissolves in aq. formic acid (50%), in aq. conc. acetic acid (50%) or in acetone (70% v/v) Melting range 240-260 °C	 1° order grey	 1° order blue	 1° order red	$\sim 0.003$ positive elongation $n_{//} < n_M ; n_L < n_M$	none or weak, regular
<b>Triacetate</b> 	XS crenate, cloud-like very lustrous dissolves in dichloromethane or in chloroform (diacetates may swell) Melting range 290-300 °C	no	faintly blue	faintly red	$\sim 0$ almost isotropic $n_{//} < n_M ; n_L < n_M$	weak, regular or none

Tab. 6-5 Identification table of vegetable fibres (continued).

Generic fibre class Origin of fibre	BF microscopy General characteristics	Crossed polars (CP) 45°	Polarization microscopy CP extinction position	Modified Herzog *
<b>Flax</b> stem of <i>Linum usitatissimum</i> 	bamboo knots (transverse nodes) cross marks straight, slight directional changes at nodes ulimates: $\varnothing$ 10 - 15 $\mu$ m dyed in garments	bright 1° en 2° order colours, till <i>greenish-blue</i> (7,5 $\mu$ m) or <i>greenish-yellow</i> (10 $\mu$ m) birefringence $\sim$ 0.050	complete extinction, except in nodes and cross marks	
<b>Hemp</b> stem of <i>Cannabis sativa</i> 	nodes cross marks ulimates : $\varnothing$ 25 $\mu$ m (15-50 $\mu$ m), length 0,5 - 5 cm; blunt and irregular ends bundle length 1-2 m dyed in garments	blue and brown colour	complete extinction, except in nodes blurry spots, with cross marks	
<b>Jute</b> stem of <i>Corchorus</i> spp. 	smooth borders, no nodes few cross marks ulimates: $\varnothing$ 15-25 $\mu$ m, length 1-6 mm; spindle-shaped XS polygonal large lumen, thick cell walls	bright colours	complete extinction, except in nodes spotty	
<b>Ramie</b> stem of <i>Boehmeria</i> spp. 	nodes cross marks star-shaped crystals dyed in garments	bright colours	complete extinction, except in nodes irregular cross marks	
<b>Kenaf</b> (Guinea hennepe or mesta) stem of <i>Hibiscus cannabinus</i> 	transverse and longitudinal elements		almost complete extinction	

## 6.6 INDEX OF FIBRE CHARACTERISTICS

In [Tab. 6-7], the fibre characteristics discussed in the previous chapters are listed per category. After the name and alternate name(s) of the characteristic, the number between round brackets refers to the drawings in [Fig. 6-5]. References to fibre pictures, figures, or text pages are also indicated.

Tab. 6-7 Index of fibre characteristics.

General features	Figures [Fig.]	Photomicrographs [Ph.]	Text pages
• fibre colour	2-21	1-1	26, 80
- even dyeing		2-5, 2-6, 4-1	81, 287
- ring dyeing		2-7	82
- zone dyeing		2-8, 5-4	83, 315
- tiger tail acrylics		2-9	83
- pigmentary print		2-15, 2-41, 5-8	91, 120
- non-pigmentary print / surface dyeing		2-15, 3-64, 4-6	91, 273, 291
- dip-dyeing		5-6	317
• length			
- staple fibres	2-12		
- fibre filaments	2-12, 2-13		
• diameter or thickness	1-5, 1-17,	2-16	28, 91
- minimum and maximum	2-21		
• flow			
- smooth		1-15, 1-18	44
- crimped	2-20	1-11, 1-12, 1-13, 1-14	40
- undulated (18)		1-4	31
- buckling in wool (25)		1-13	42
• cross-section (XS)	2-14, 2-21	2-49, 2-72, 3-20, 4-12	28, 93, 108, 165, 298
- round or circular XS		1-1, 2-18	93
- bean or kidney XS		1-2, 2-18, 2-19, 3-1	94
- dogbone, peanut or dumbbell XS		2-20, 2-36, 3-2, 3-3	96
- irregular XS		2-21, 3-6, 5-5	97
- crenate XS		2-22, 3-4, 3-5	97
- flattened or oblate XS		1-3, 2-27	102
- trilobal XS		2-24, 2-25, 3-16, 3-17	101, 225
- multilobal XS		2-26	102
- polygonal XS		2-23, 2-83, 3-15, 5-7	98, 187, 225, 318
- special or designer XS	2-14	3-18	107
- hollow fibre		2-32	107
- bicomponent fibres		2-28 → 2-31	103
Internal features	[Fig.]	[Ph.]	Text pages
• delustrants or dulling agents (1)	2-21	2-1	76
- homogeneous distribution		2-2	
- streaked (2)		2-3, 2-4	
• pigments (3)	2-21	2-10, 4-4	85, 290
- pigment colour			
- pigment size			
- pigment distribution		2-11	
- melanin pigments (27)	2-18	2-58, 2-59	133
• fish eyes (4)	2-21	2-12 → 2-14	88
• medulla in animal hair (23)	2-18	5-14 → 5-16	328 - 330
- flow	2-19		
- type	2-19		
- medullary index	2-19		
- uniserial and multiserial ladder	2-22	1-15, 1-16, 2-54, 2-55, 3-60	44, 140
• cortical fusi in animal hair (24)	2-18	2-50	134
• inclusions		4-7	292
• microvacuoles		2-77	173
• spiral elements in sisal	2-22	2-47	126

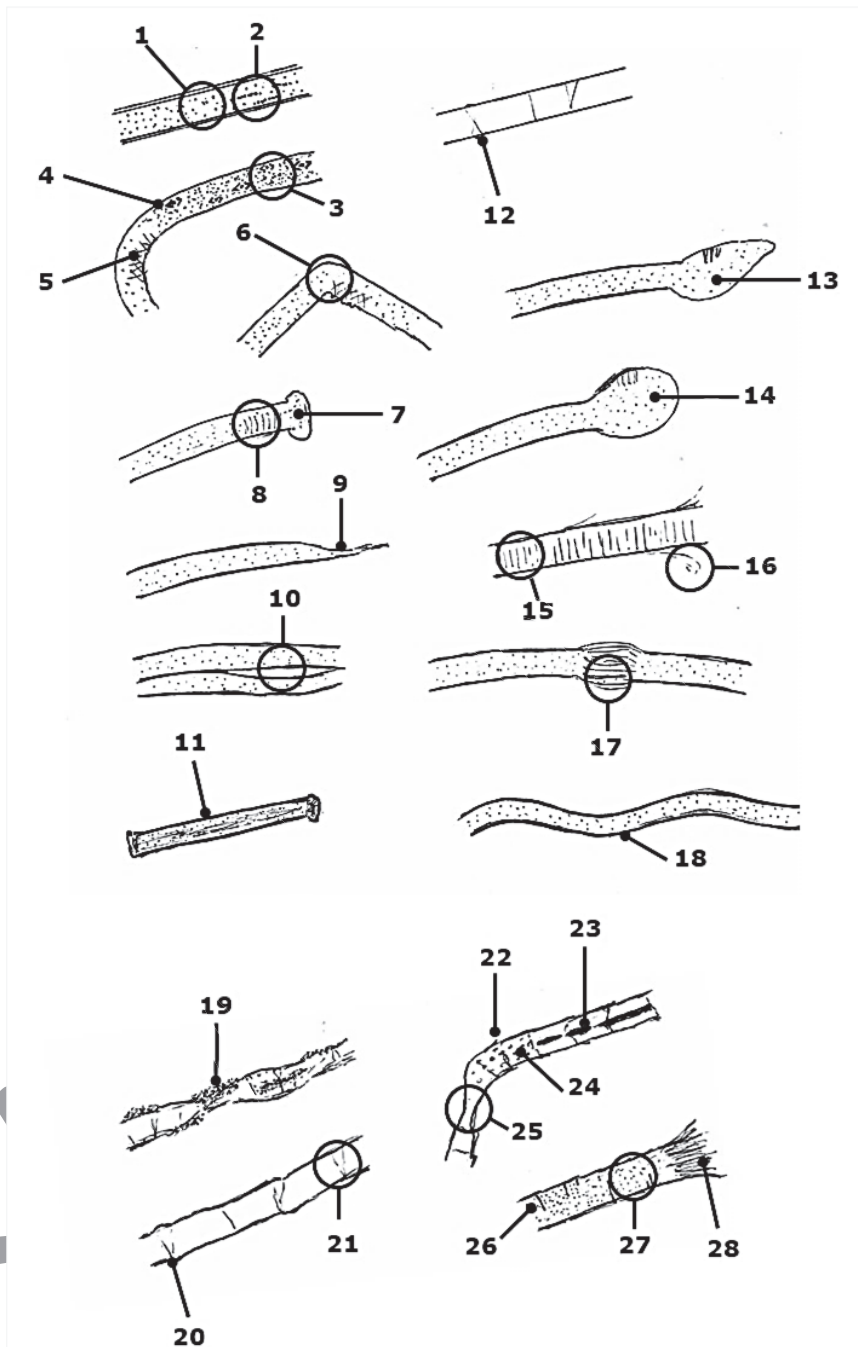


Fig. 6-5 Some characteristics of man-made and natural fibres.