What are fibers?

- The basic unit of fabrics
- Woven together to form fabric
- Besides hair, one of the most common items left at a crime scene

Trace Evidence

- Pet hair on clothes or rugs
- Hair on brush
- Soil tracked inside on shoes
- Drop of blood on t shirt
- A used facial tissue
- Broken glass
- Fingerprints on glass
- Paint chips
- Fiber from clothing

Even though Trace Evidence is Tiny…Many a conviction depended on Trace!

Fibers and Forensics

- How are fibers used in Forensic Science?
  - To create a link between crime and suspect.
- Fibers are not specific to an individual, but…
  - often fall off and are picked up during activities and go unnoticed
  - may provide police with evidence even if a suspect wears gloves
- Fibers are a form of trace evidence
  - Where can fibers originate?
  - They generally come from clothing, drapery, wigs, carpeting, furniture, and blankets

Fibers are generally used to place evidence that has transferred from a victim or suspect's clothing

- Locard's Principle - When two people come in contact there is transfer of material both ways
  - Some clothing transfers better than others
  - Some clothing accepts transfer particles better than others
  - Particles can also transfer from rugs, bedding, or furniture

Other factors that may influence particle transfer:

- Length of time contact occurred
- Nature of contact, violent contact may yield more transfer
- Length of time that passed since the alleged contact occurred

Man-made or synthetic fibers make up 1/2 of all fibers found in textile mills

- You can determine a lot from how a fiber appears under the microscope
  - Type of Fiber
  - Manufacturer even
  - Unusual cross-sections of fiber increase the probative value

Fiber is often found:

- Caught in screens or on jagged surfaces
- Around broken glass
- On cars involved in a hit and run
- Transferred during a struggle

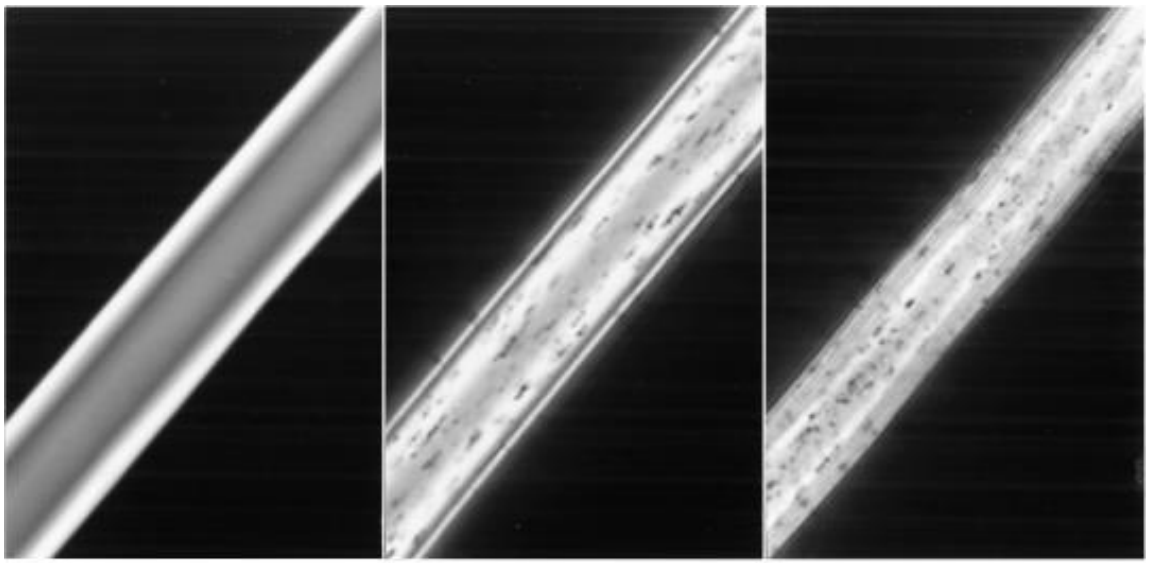
Fiber Evidence

- The problem with fiber evidence is that fibers are not unique.
- Unlike fingerprints or DNA, they cannot pinpoint an offender in any definitive manner.
- There must be other factors involved, such as evidence that the fibers can corroborate or something unique to the fibers that set them apart.

How Do Forensic Scientists Use Fibers?

Fiber evaluation can show

- Type of fiber
- Color
- Possibility of violence
- Location of suspects
- Point of origin



polypropylene nylon polyester

Fiber Collection

- It is collected in the same manner as hair
- Collection is time consuming and tedious
- Most analysis is done under the microscope
- Fiber has less parts than hair but is still as valuable

How Do Forensic Scientists Obtain Fibers?

Special vacuums

- Sticky tape
- Lint Rollers
- Forceps

Methods of Analyzing Fibers

- Without Damaging Fibers
  - Microscopes reveal characteristic shapes and markings (Infrared microscopy)
  - Infrared spectroscopy reveals chemical structures to differentiate similar fibers
- Destructive Testing Methods
  - Burning fibers
  - Dissolving fibers in various liquids

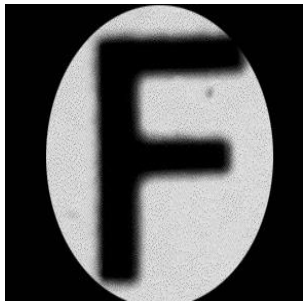
Methods of Analyzing Fibers: Stereoscopic Microscope

The most commonly used microscope in crime labs
Offers a large working surface for bulky items

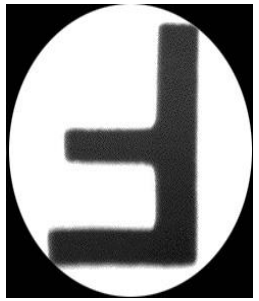
Although it will magnify only 125x, the stereomicroscope is the microscope most commonly used in forensics.

Figure 04.07

Courtesy of Leica Microsystems, Inc.



Stereo Microscope



Compound Microscope

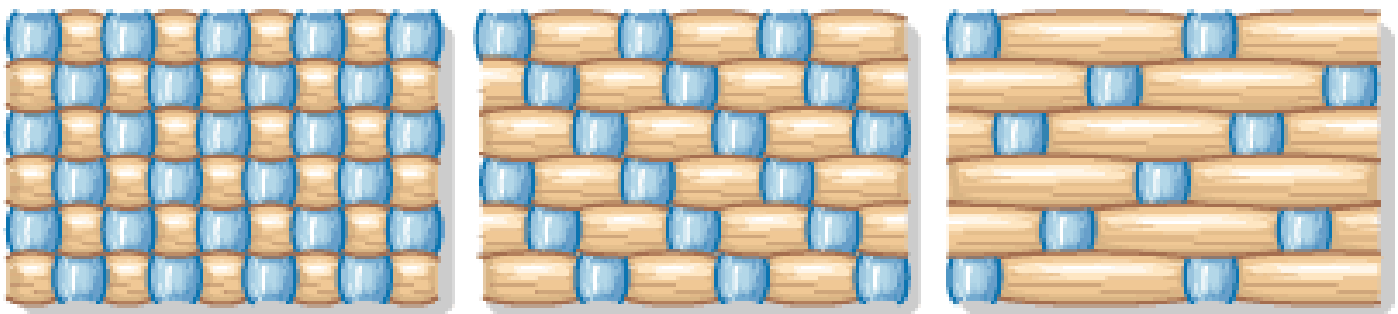
Development of fibers

- Till the beginning of 20th century all fibers in use were natural
- Around 1891-92 the first man-made ‘Artificial Silk’ (Viscose rayon) was discovered
- In 1938, Dupont developed the first synthetic polyamide fiber ‘Nylon’, followed by the development of polyester
- Thus a distinct class of man-made fibers/ synthetic fibers were developed
- 1950-60s –acrylic, PP, PVA, Teflon, Lycra were developed
- In the last fifty years of research a host of new improved man-made cellulosic, protein, aramid and functional fibers have been developed

How do fibers make up fabric?

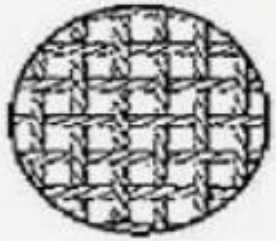
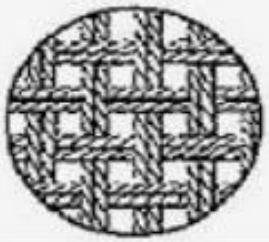
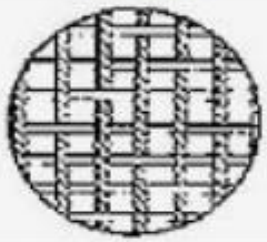
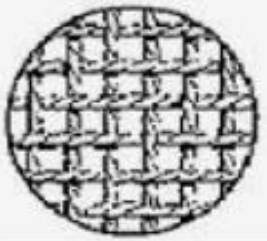
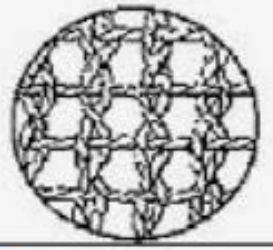
- Fibers aligned into a yarn (thread)
- Yarn is then woven, knitted, crocheted, knotted, braided etc. into a fabric

The three basic weaving patterns



PLAIN **TWILL** **SATIN**

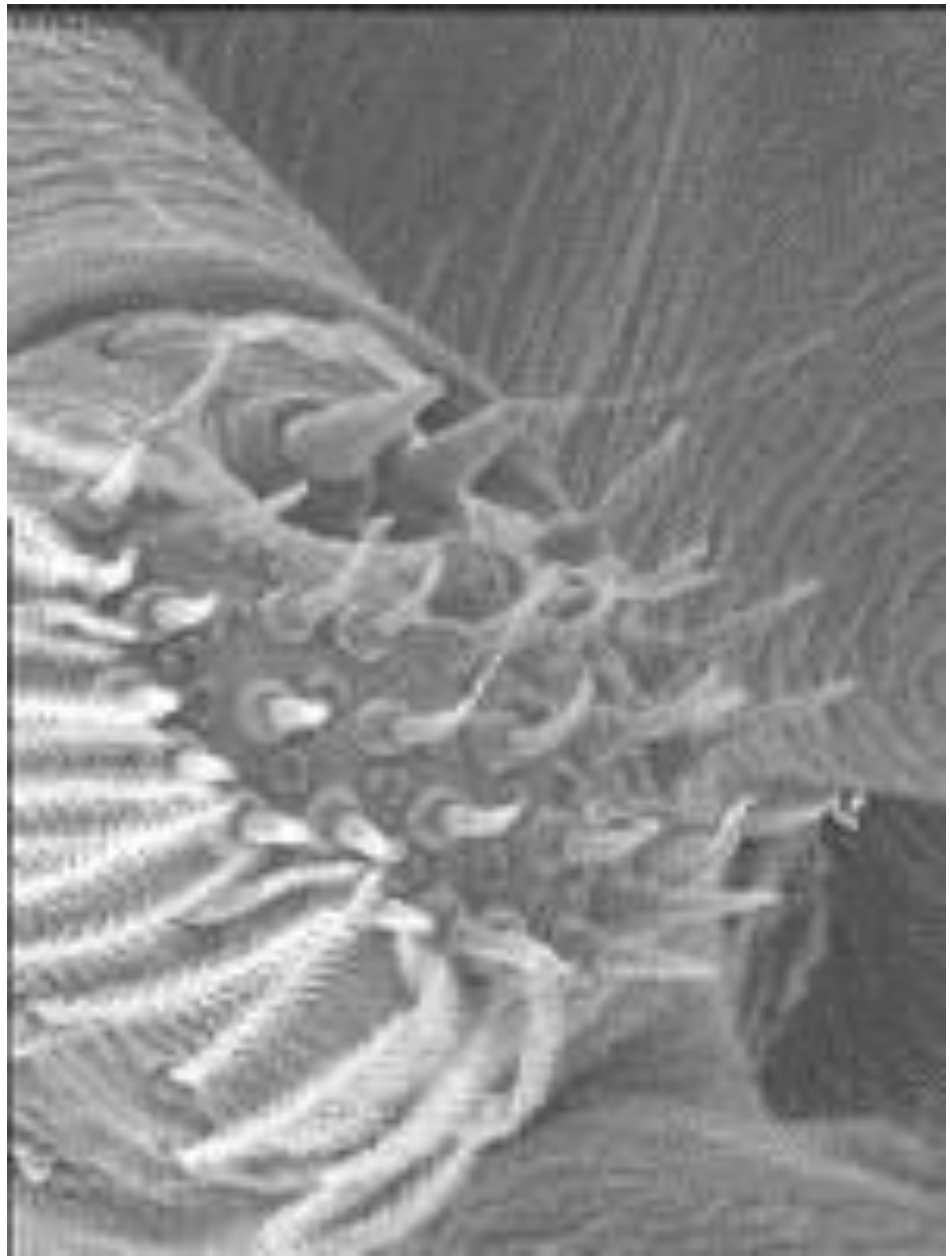
Weave Patterns

Plain / Tabby	Basket	Satin	Twill	Leno
				
◆ firm and wears well ◆ snag resistant ◆ low tear strength ◆ tends to wrinkle	◆ open or porous weave ◆ does not wrinkle ◆ not very durable ◆ tends to distort as yarns shift ◆ shrinks when washed	◆ not durable ◆ tends to snag and break during wear ◆ shiny surface ◆ high light reflectance ◆ little friction with other garments	◆ very strong ◆ dense and compact ◆ different faces ◆ diagonal design on surface ◆ soft and pliable	◆ open weave ◆ easily distorted with wear and washing ◆ stretches in one direction only

Why is the weaving pattern of interest to forensic scientists?

- Each type of fabric has its own characteristics which can be discovered by performing different tests
- Can tell what material may have been used during a crime

I just thought this was cool
SPIDER SPINNERETS – Master Weavers!



Weaving Yarn into a blanket

Man-made fibers like Nylon and Rayon – made from Petroleum products!

Fibres

spun into yarns

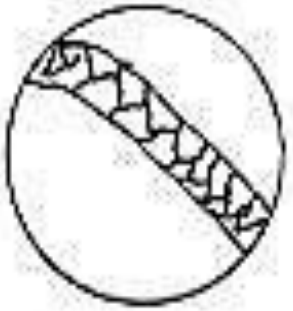
woven or knitted into fabric

made into products

Fibers can be natural, mineral, or synthetic

Fiber Forensics

Cashmere



Wool - diagonal lines that intersect

Acrylic - no horizontal lines, vertical extrusion lines, nubs outside fiber

Camel Hair - some parallel horizontal lines, and some diagonal intersecting

Cotton - almost rope-like

Hemp - wider and flatter with many vertical lines

To make the case, you need to know what kind of fiber it is

Basic Visual Comparisons

Fiber

- Uniform and irregular types
- Variety of shapes
- Absence of cuticle and medulla

Hair

- Irregular only
- Always circular
- Visible structural features: cuticle and medulla

Available Forensic Information

Fiber

- Natural or synthetic
- Can determine if a source is consistent with questioned fiber (class evidence)

Hair

- Human vs. non-human
- Species ID
- Ancestry, body area of origin, length, artificial treatment, root type, DNA

Fibers

Natural

- Animal
  - Hair
  - Silk
- Vegetable
  - Bast (flax)
  - Leaf (sisal)
  - Seed (cotton)
- Mineral
  - Asbestos

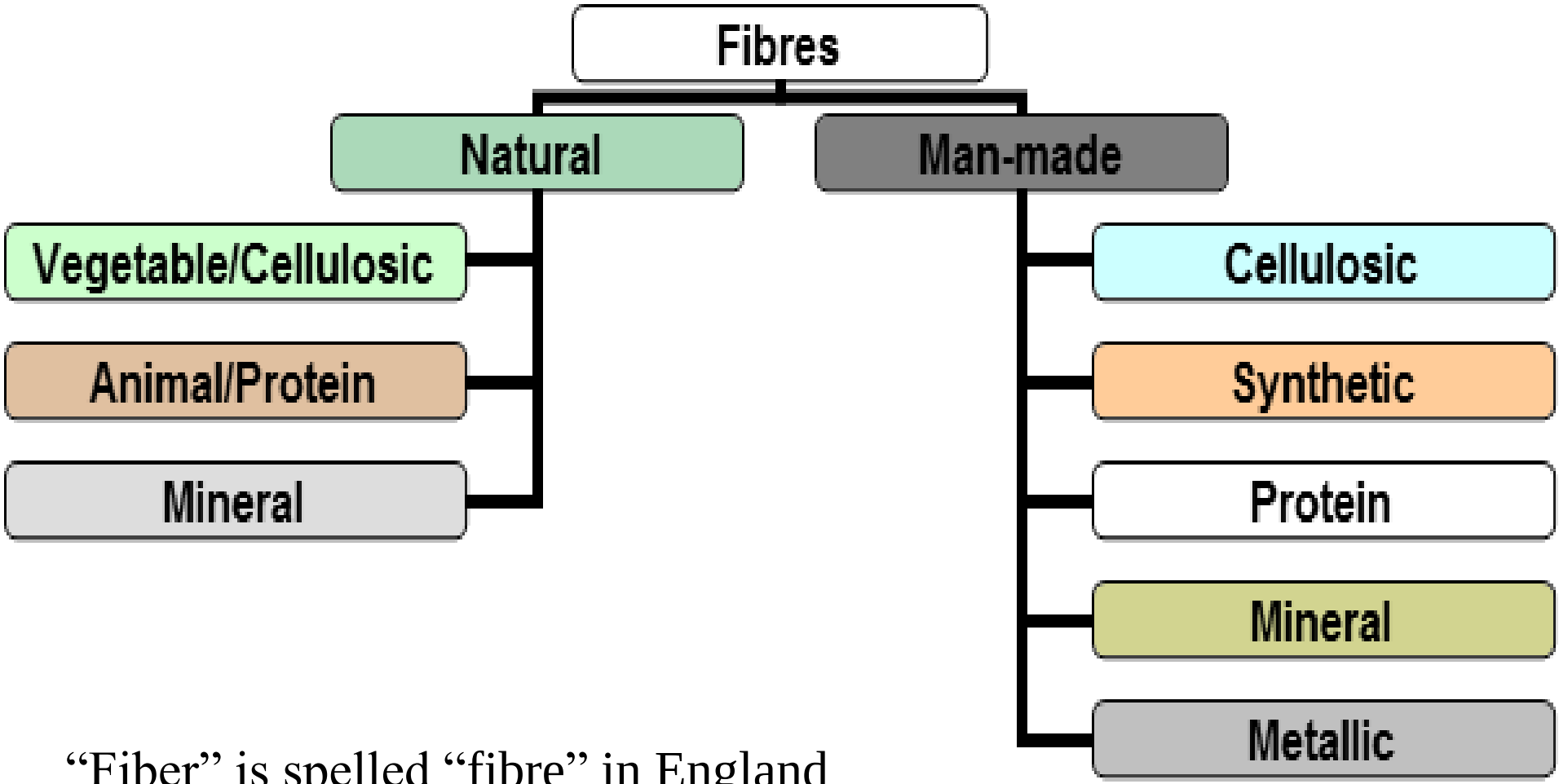
Synthetic

- Organic
  - Synthetic Polymers
    - Polyester
  - Natural Polymers
    - Rubber
    - Rayon
- Inorganic
  - Carbon
  - Glass

Comparison of natural and synthetic fibers

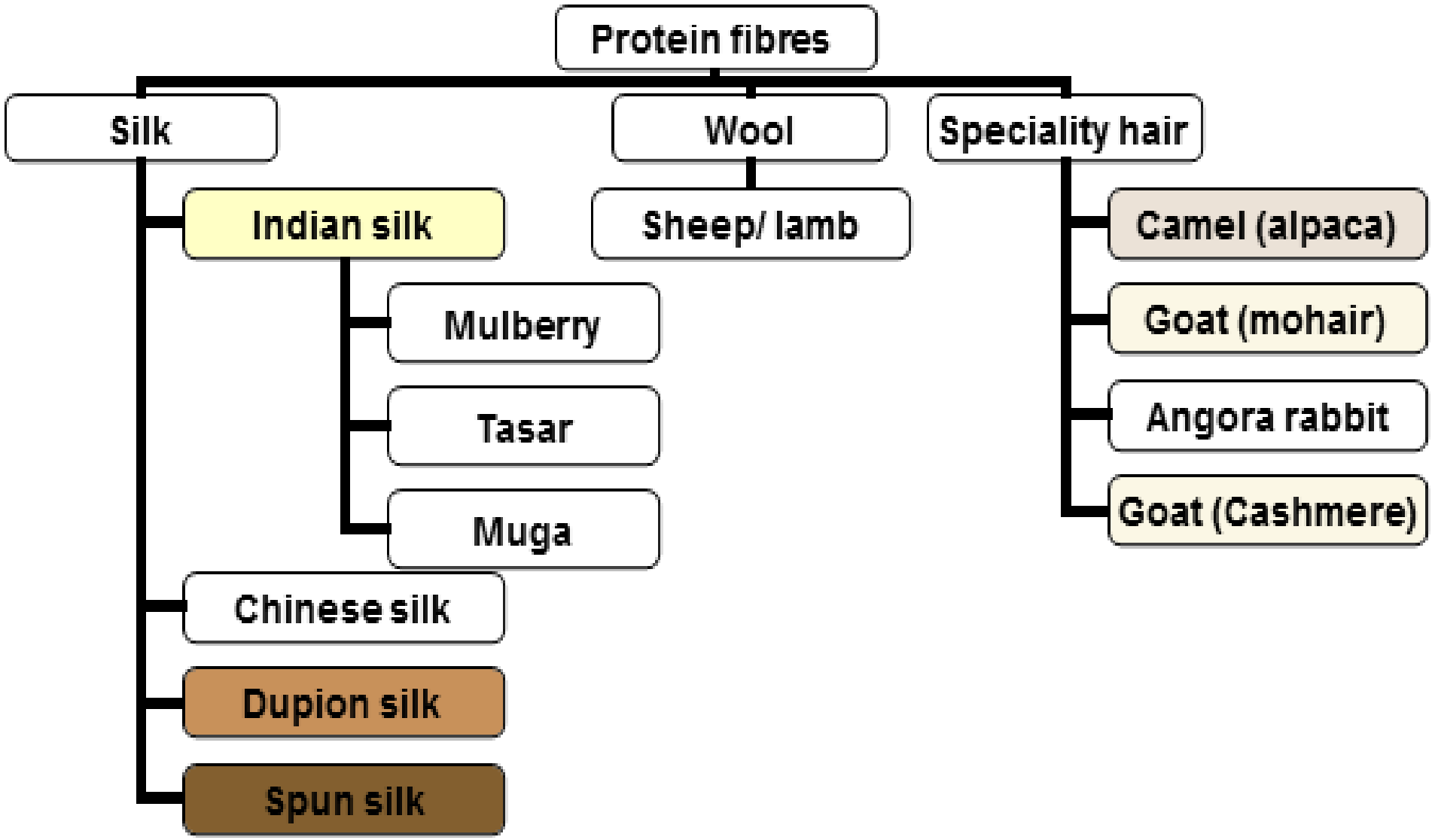
- Synthetic fibers are much stronger than natural fibers.
- Unlike natural fibers, synthetic fibers are not damaged by microorganisms.
- Synthetic fibers can deteriorate in bright sun and melt at a lower temperature than natural fibers.
- Under magnification, all synthetic fibers have very regular diameters.
- Hairs have a cuticle.

Two Types of Fibers



"Fiber" is spelled "fibre" in England

Natural fibers from animals are made of protein



Wool is another commonly found fiber used in clothing, blankets, rugs

- Wool originates from sheep
- Wool has a particularly knotted, twisted appearance up close under a microscope

Wool can come from multiple sources

- Sheep
- Cashmere goats
- Alpaca
- Camel

Angora

Angora rabbits

Polarized microscopy image of angora fiber

Angora wool

- The hair of the Angora rabbit is allowed to grow 3 or more inches long before it is clipped, sheared, or plucked. This process causes no harm to the animals and are carried out four times each year.
- The total annual yield for a single Angora rabbit ranges from 7 to 14 ounces, is enough to construct one small garment, such as a short-sleeved sweater.
- Clothing of Angora rabbit wool are usually have a very nice feel against the skin. Many people who find garments made of sheep’s wool scratchy and uncomfortable find Angora wool comfortable.

Cashmere

Cashmere / Pashmina goats

Polarized light microscopy image of cashmere

- **Properties**

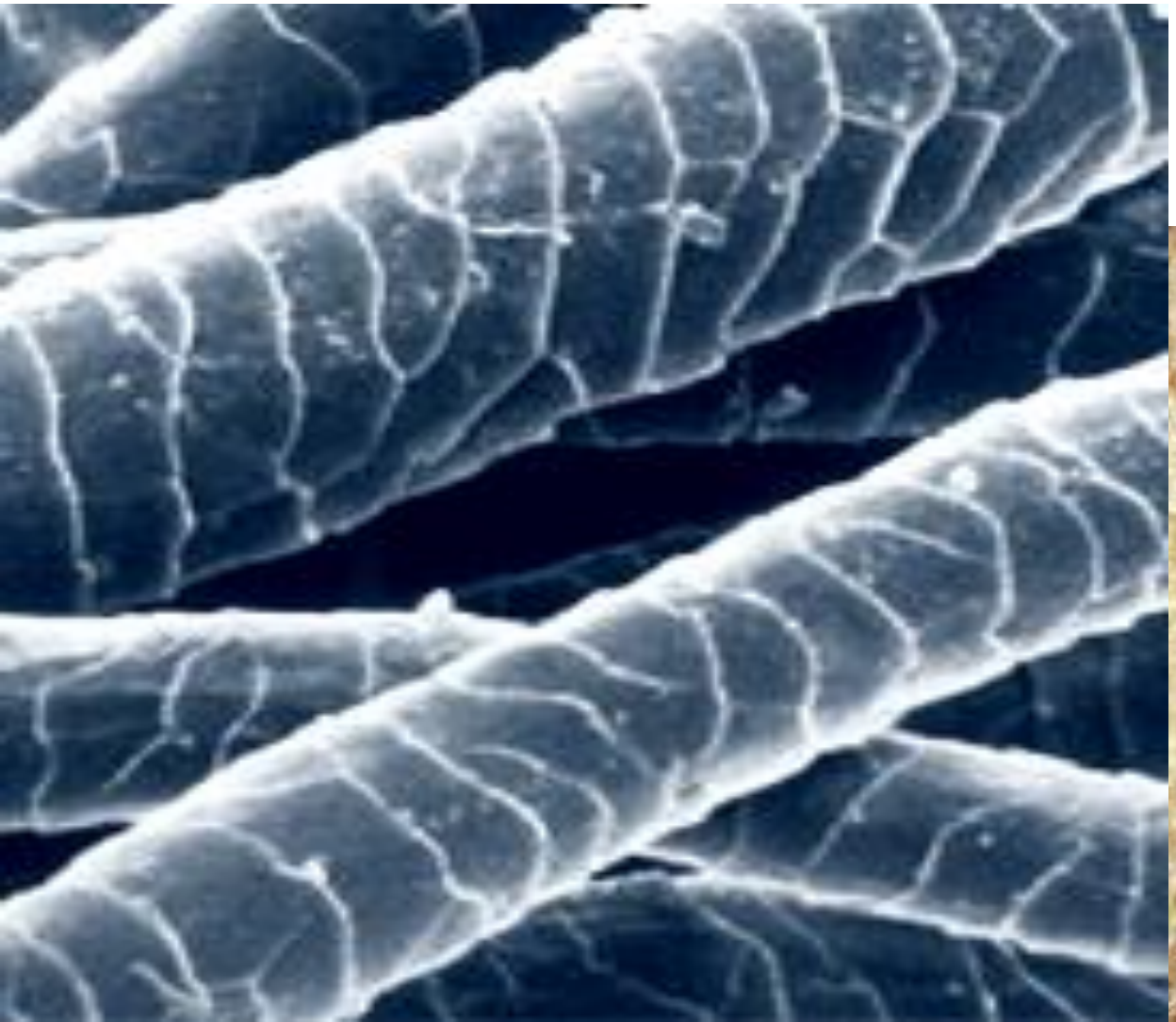
- fiber is cylindrical, soft and silky, light weight
- In order to avoid pilling by local friction, the lining must be slippery
- Cashmere/ Pashmina can be dyed in different colours

- **Care factors**

- Preferably dry cleaned, should be dried in shade, not direct sunlight
- Cashmere garments should be folded and kept and should not be hanged to prevent deformation.

Alpaca

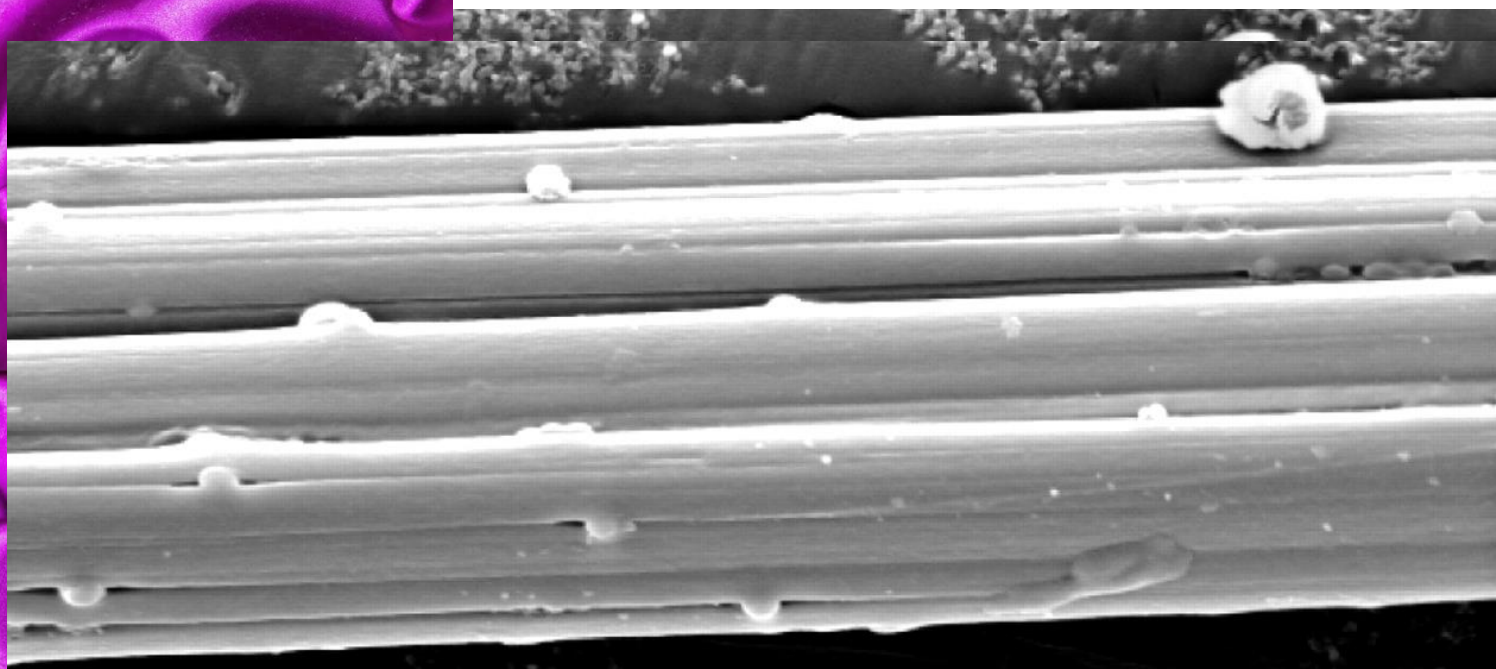
What you see in the microscope – Wool



Silk

Silk under the microscope

Under the microscope the silk fiber looks like a smooth glass rod. Occasionally markings show that are caused by the coating of the silk fiber, called gum or sericin which has not all been removed



Natural fibers from plants are made of Cellulose

Kenaf fiber

Kenaf Products

Sisal

Hemp

Coir (coconut) mat

Towels from bamboo fiber

Hemp filament bag

Costume from pina fiber

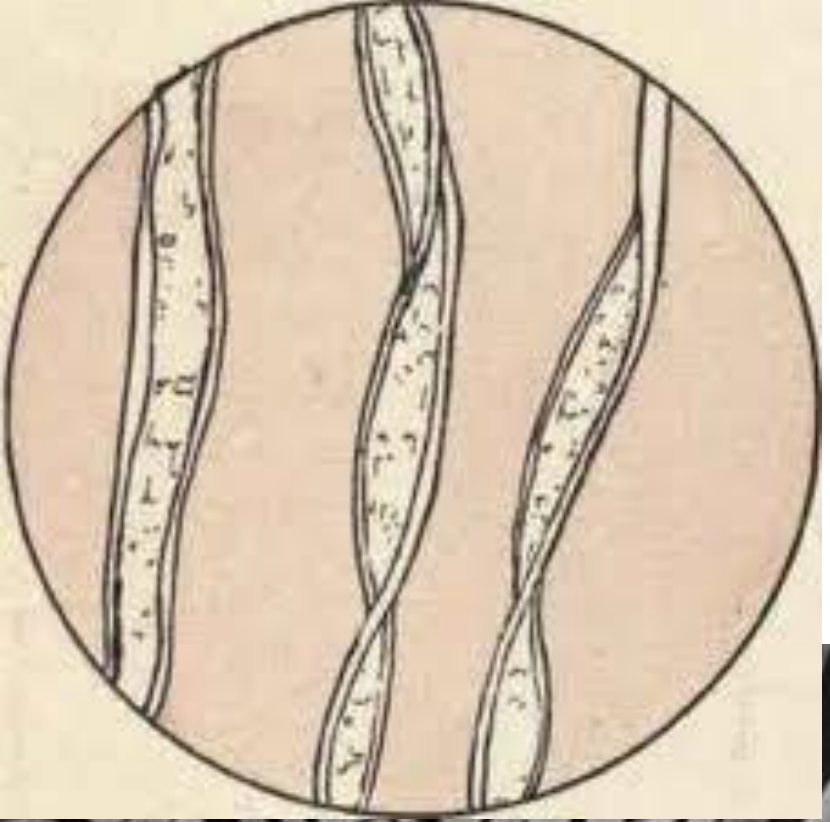
Cotton fiber

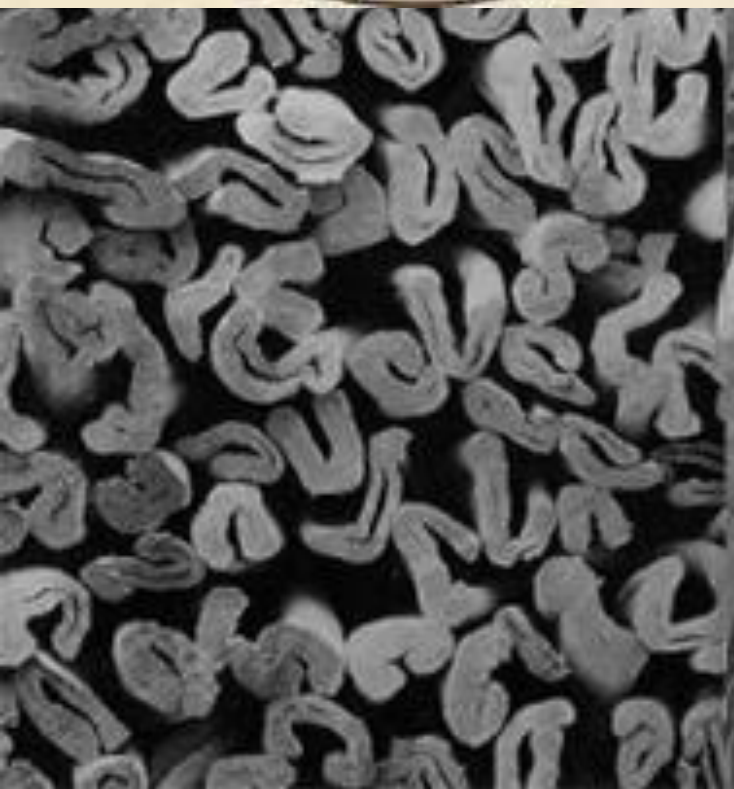
Jute

Extraction of Banana fiber

Cotton under the microscope

Cotton has a distinct ribbon like shape with twists at irregular intervals





Linen

- Linen is known to be the world’s strongest natural fiber. It is so durable it’s even used in paper money to increase strength
- Linen is not as soft as cotton
- Oinen is very cool and comfortable in hot weather

What you see in the microscope

– Flax (Linen)

- The linen fiber, like cotton, comes from a plant. However, it comes from a different part of the plant, the stem itself
- Under the microscope the linen fiber looks like a jointed bamboo rod. These joints are called nodes and the ends of the fibers are pointed

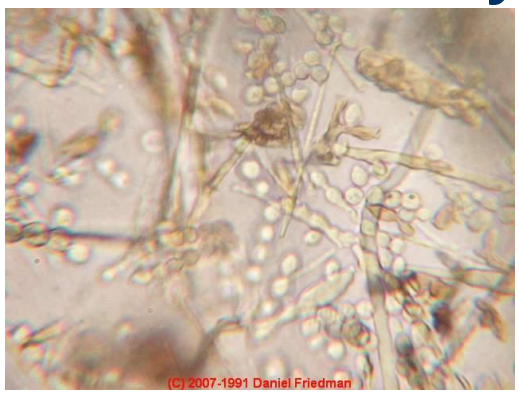
Fiber Classification –*Natural Fibers*

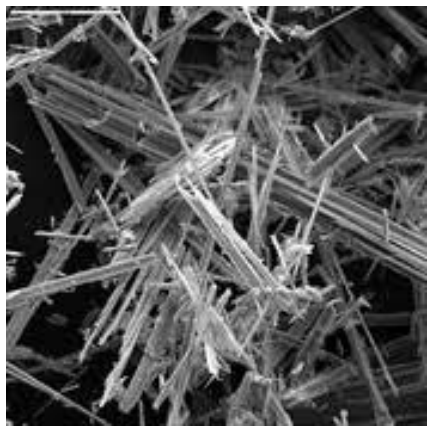
- Seed fibers
  - Cotton is found in the seedpod of the cotton plant. Because of the ease with which cotton can be woven and dyed, it has been used extensively for clothing and household textiles.
- Fruit fibers
  - **Coir** is a coarse fiber obtained from the covering surrounding coconuts. When woven together, they are stronger than flax or cotton. Coir fiber is relatively waterproof which makes it ideal for such things as doormats and baskets.
- Stem fibers
  - Hemp, jute, and flax are all produced from the thick region of plant stems. They do not grow as single, unconnected fibers like cotton, but in bundles. These bundles may be six feet in length and extend the entire length of a plant.

Fiber Classification —*Natural Fibers*

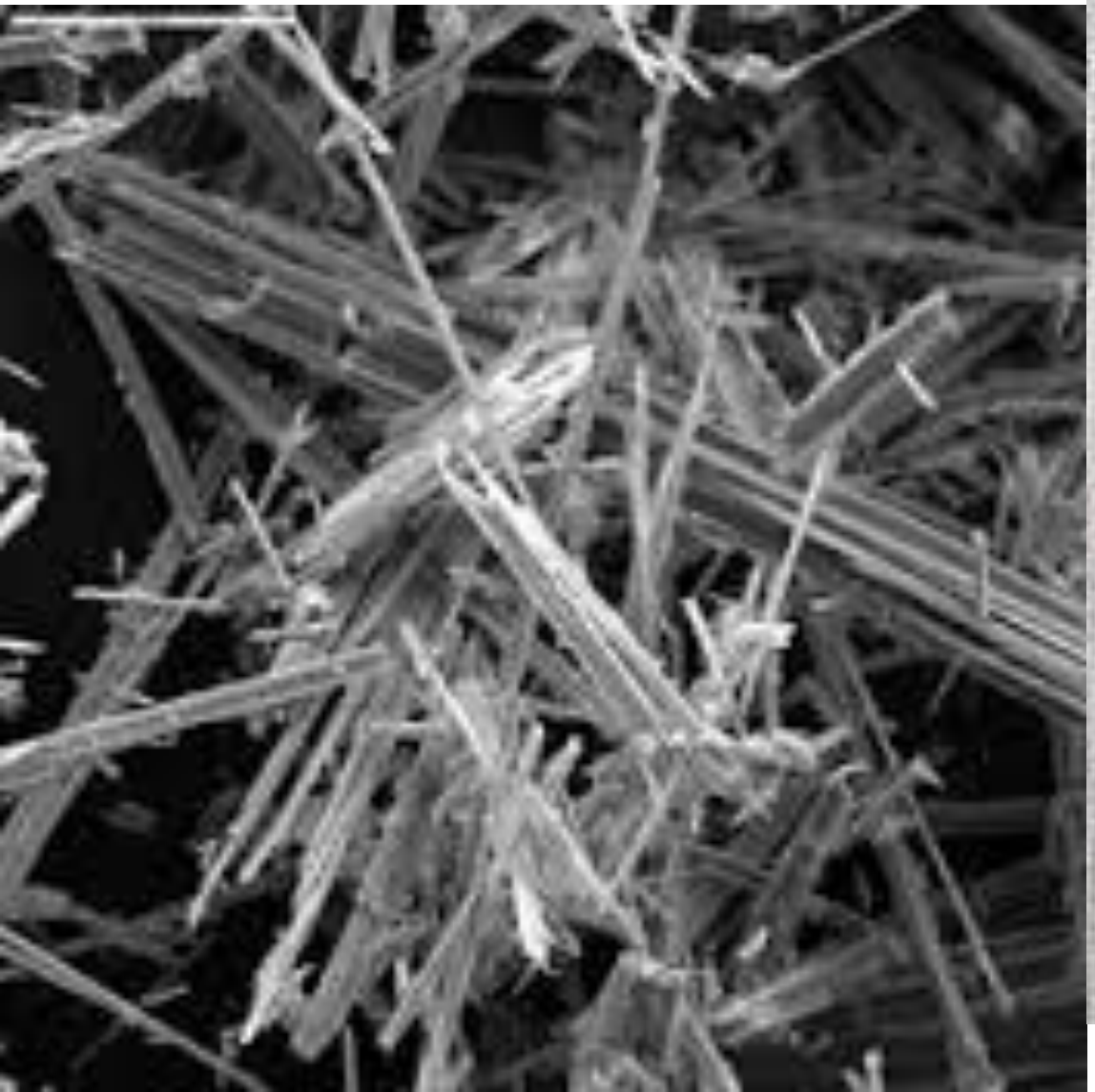
Mineral Fibers:

- Fiberglass—a fibrous form of glass
- Asbestos—a crystalline structure





What you see in the microscope – Mineral fiber (Asbestos)



Synthetic Fibers

- Petroleum is the basis for these fibers, and they have very different characteristics from other fibers.
- Monomers in large vats are joined together to form polymers. The fibers produced are spun together into yarns.
- They have no internal structures, and under magnification they show regular diameters

More than half of all fibers used in the production of textile materials are man-made.

Polyester and nylon fibers are the most commonly encountered man-made fibers, followed by acrylics, rayons, and acetates.

The shape of a man-made fiber can determine the value placed on that fiber.

The cross section of a man-made fiber can be manufacturer-specific

Synthetic Fibers

Cellulose esters-- These are derived from cellulose and produced by chemically **modifying** the natural polymers to create an entirely new compound **not** found in nature. Examples:

-Rayon- most common. first man-made fiber; soft, versatile.

-Acetate- less expensive, less polluting than rayon.

Synthetic polymer fibers

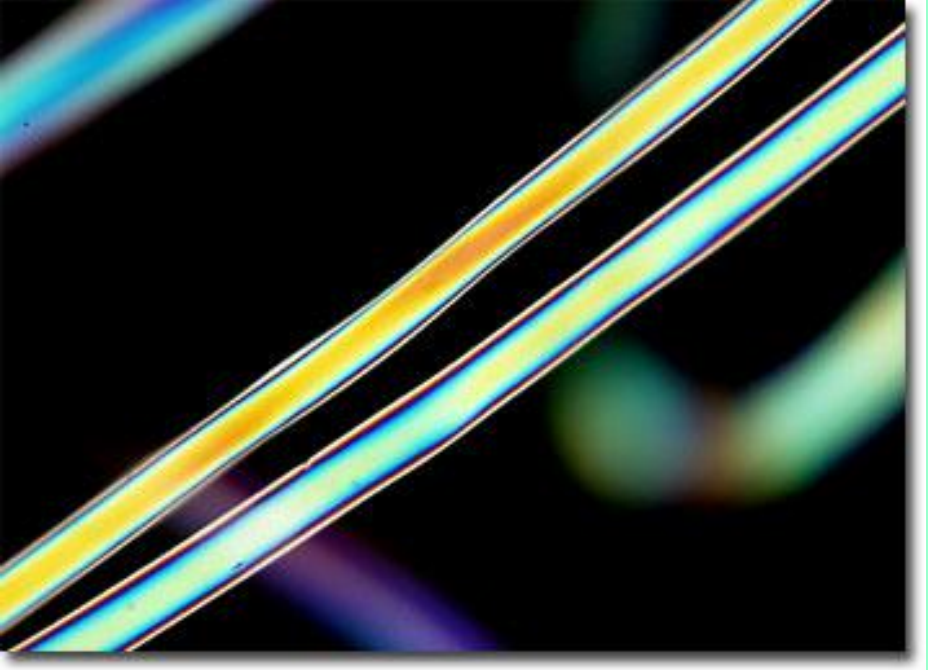
Petroleum Plastics- these originate from derivatives of petroleum, coal and natural gas. They are **totally** man-made. Example:

- **Nylon**- most durable man-made fabric; extremely light weight. First introduced as artificial silk for pantyhose.

Acrylic- most widely used man-made fiber. Inexpensive and tends to ball easily.

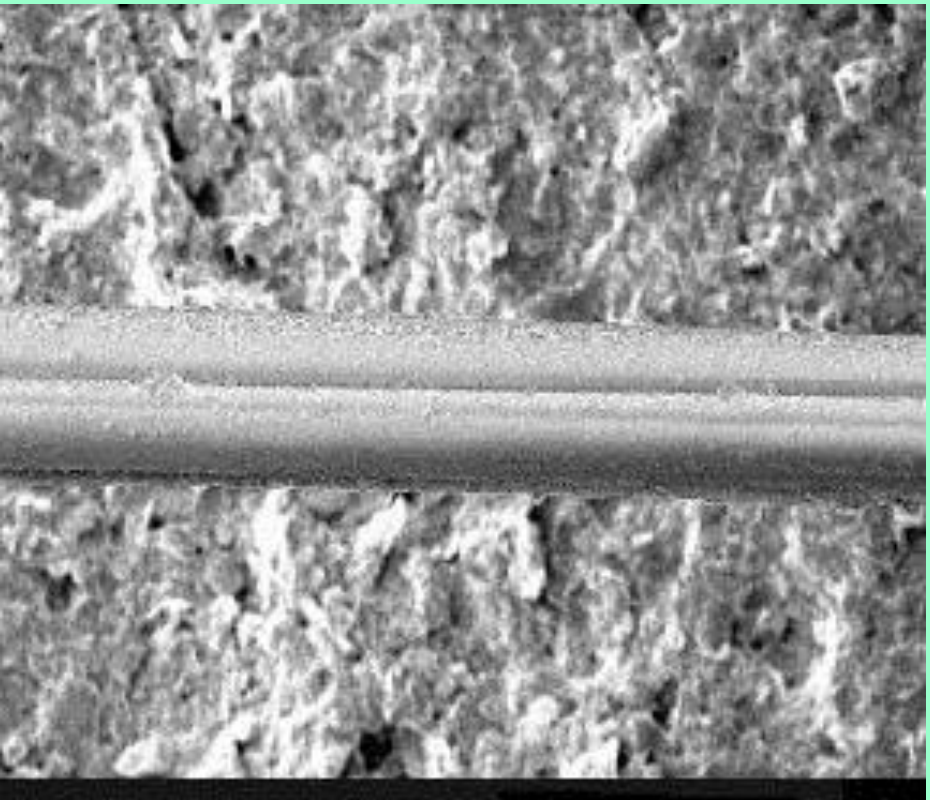
Polyester- -provides warmth from a lightweight, soft and resilient fabric. Common in polar fleece and many wrinkle resistant pants.

Spandex- extreme elastic properties.

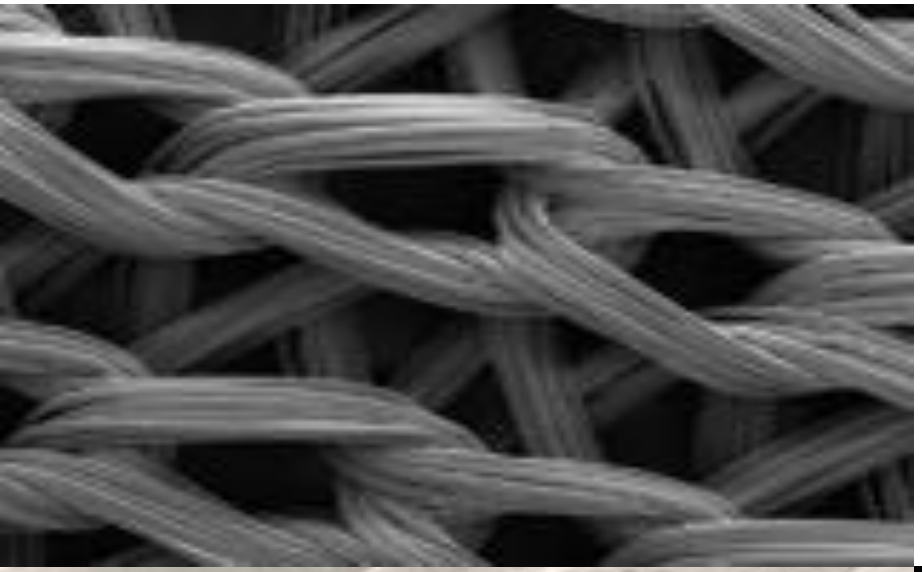


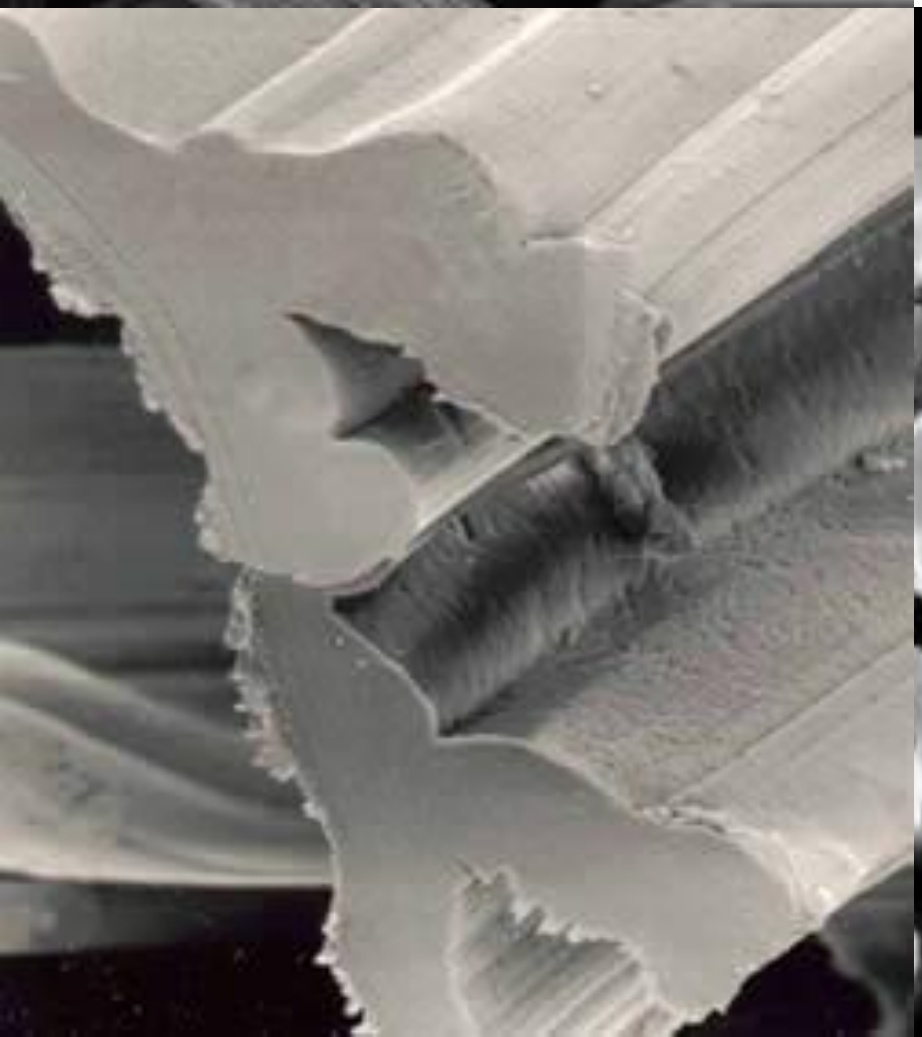
Rayon

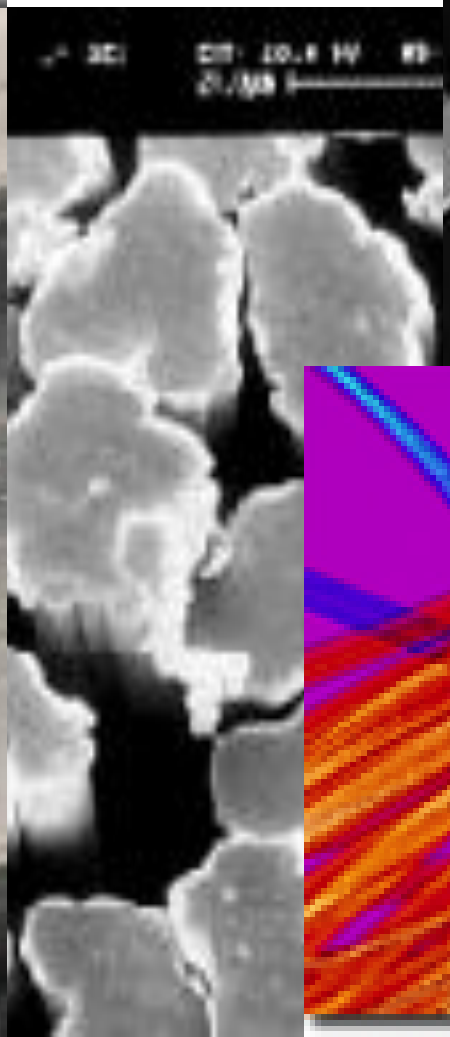
First manufactured in 1911

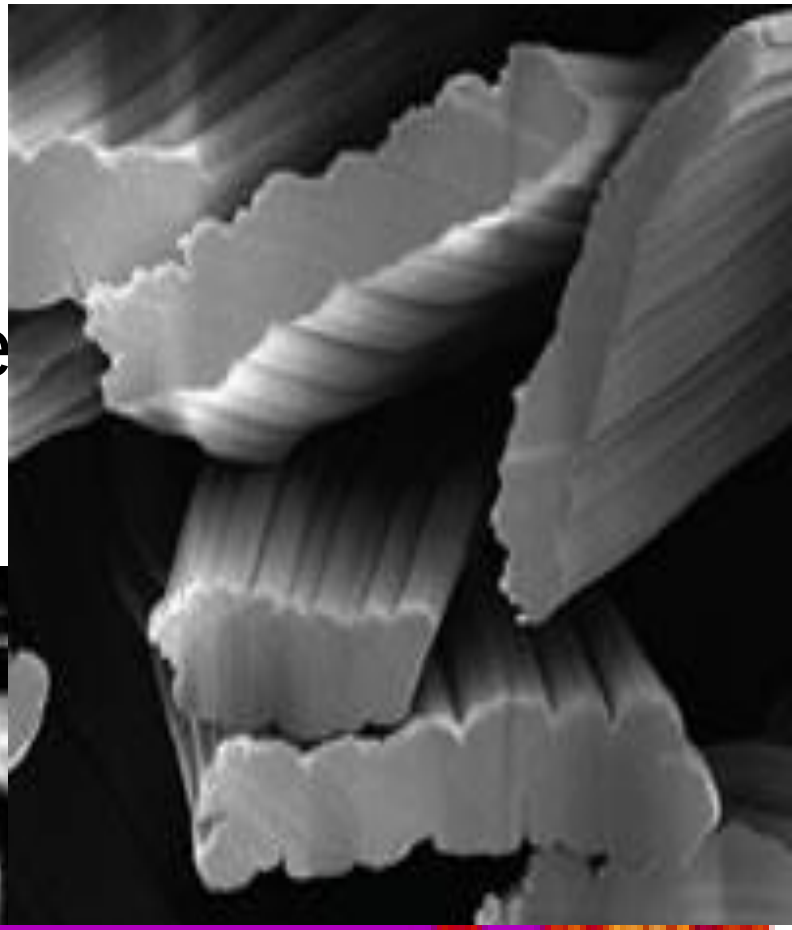


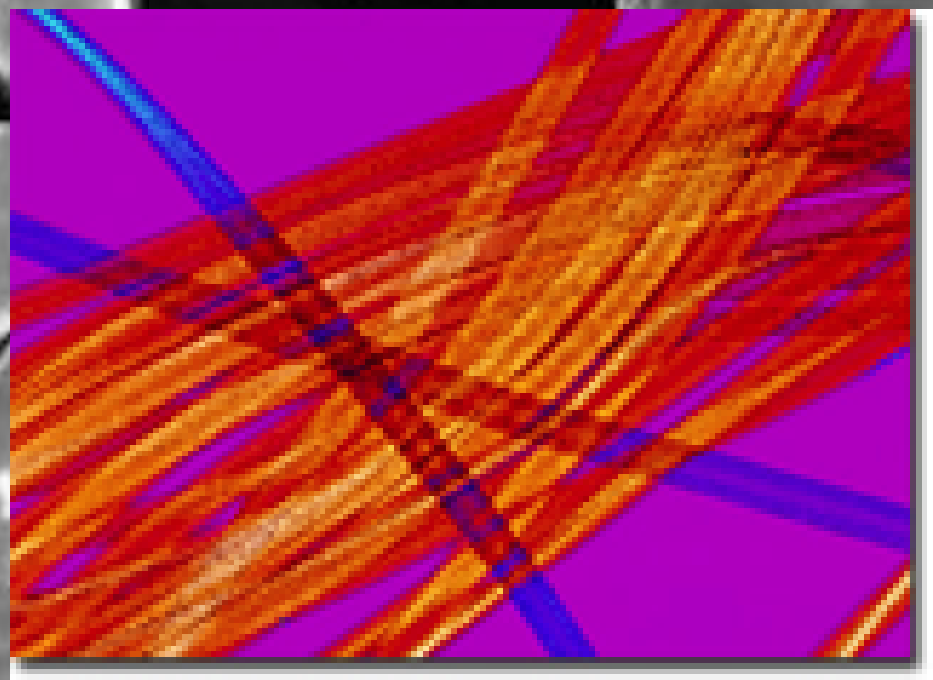
Rayon in the microscope











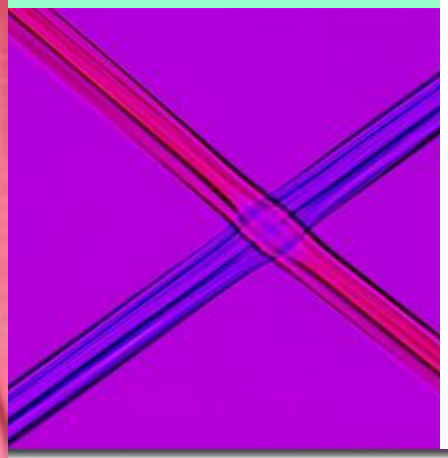
Acetate

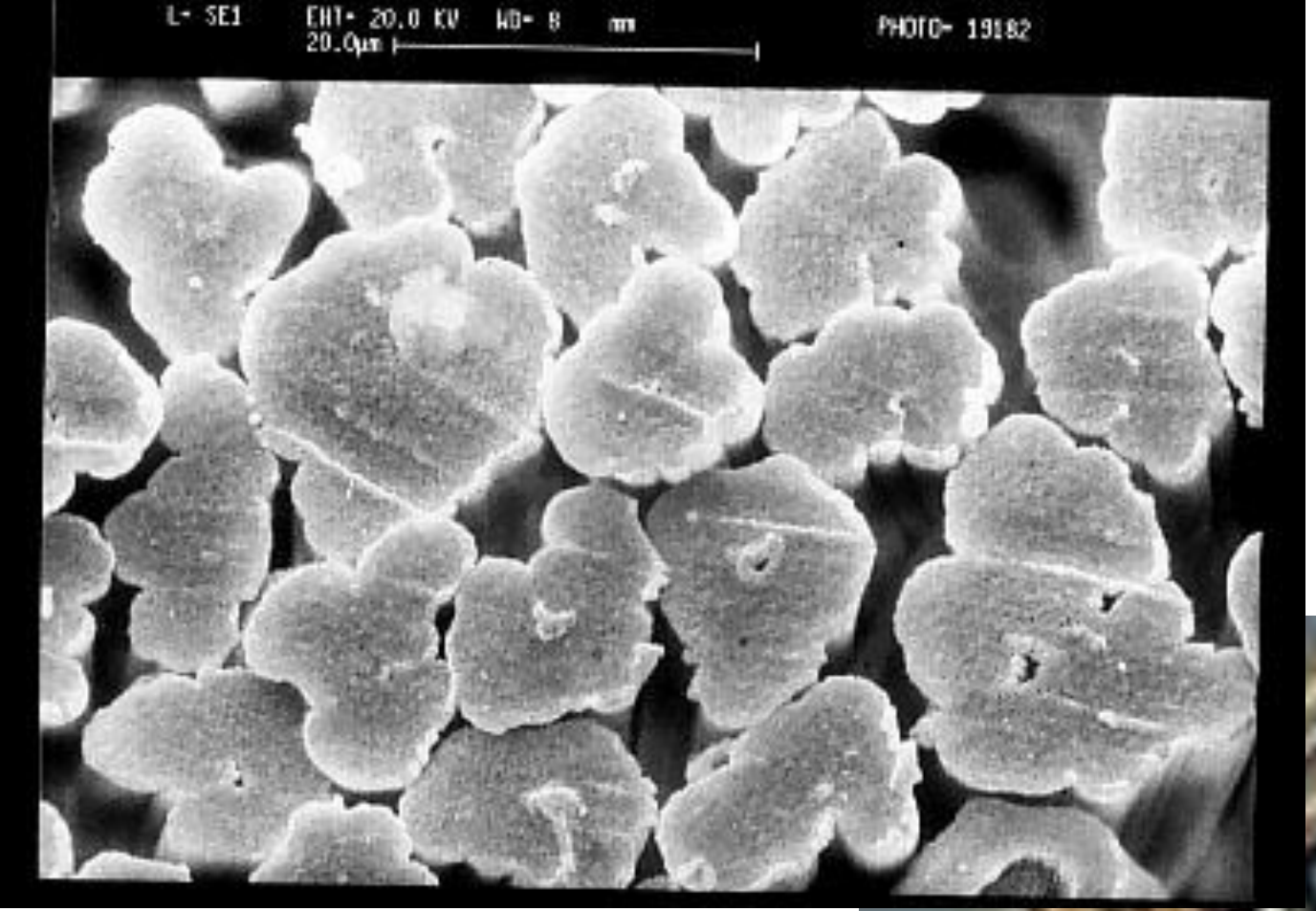
Breathable fabric

Luxurious feel, appearance

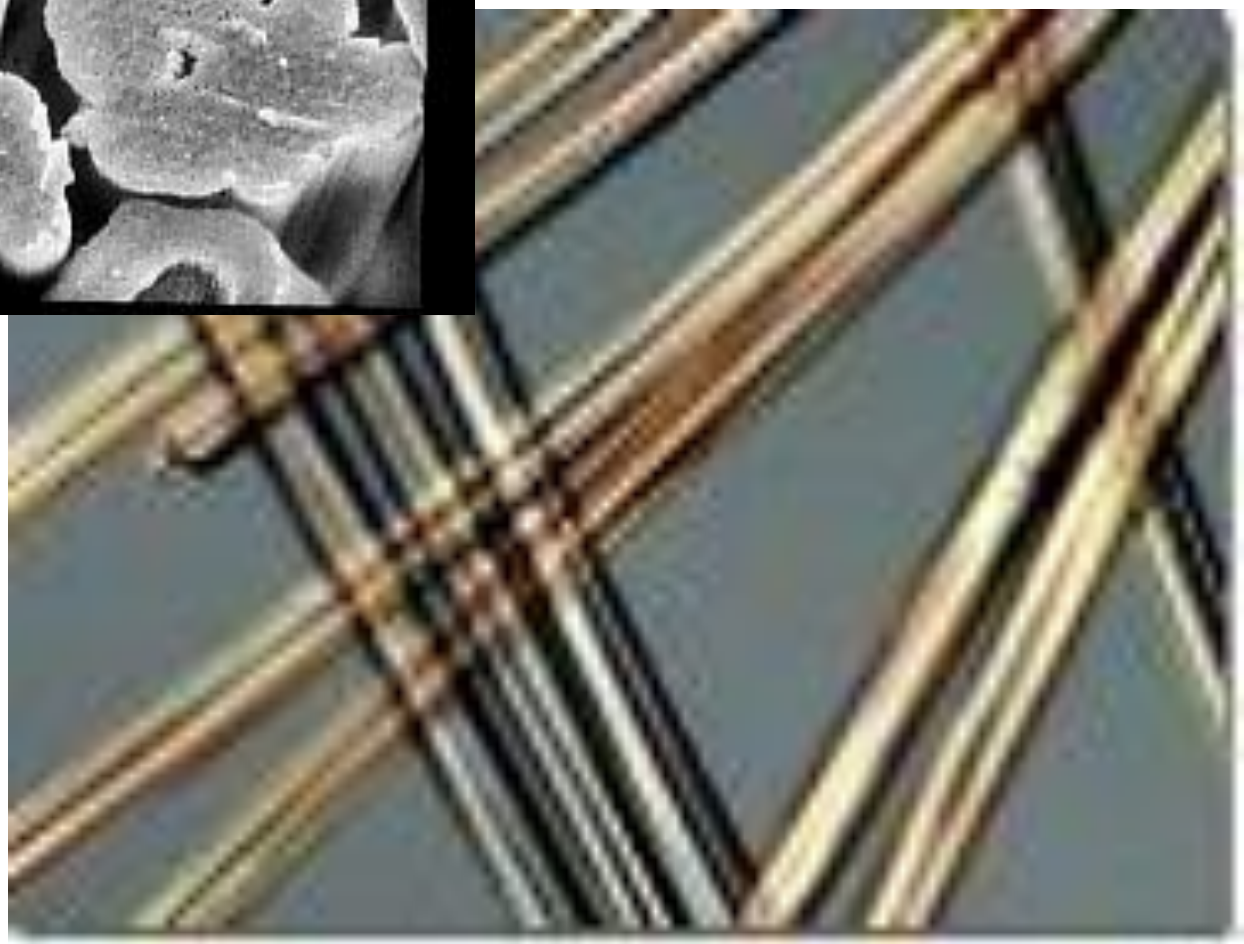
Wide range of colors

Shrink, moth & mildew resistant





What you see in the microscope – Acetate



Fiber Classification —*Synthetic Polymer Fibers*

<u>Synthetic Polymer Fibers</u>

- Petroleum base
- Very different from other fibers
- Monomers join to form polymers
- Fibers are spun together into yarns
- No internal structures
- Uniform diameters

Fiber Classification —*Synthetic Cellulose Fibers*

Regenerated Fibers (derived from cellulose):

- Rayon
  - Most common in this group
  - Imitates natural fibers, but stronger
- Celenese®
  - Cellulose chemically combined with acetate
  - Found in many carpets
- Polyamide nylon
  - Cellulose combined with three acetate units
  - Breathable and lightweight
  - Used in performance clothing

Fiber Classification —*Synthetic Polymer Fibers*

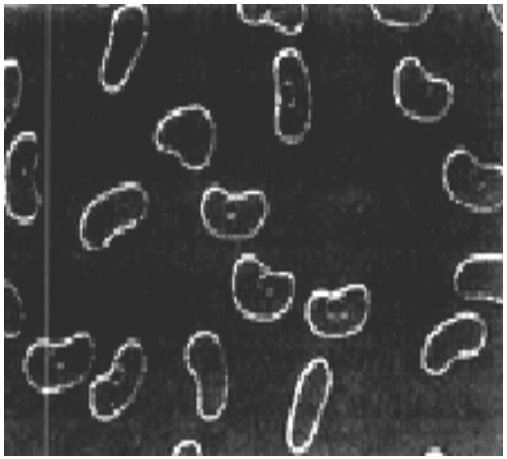
spandex nylon

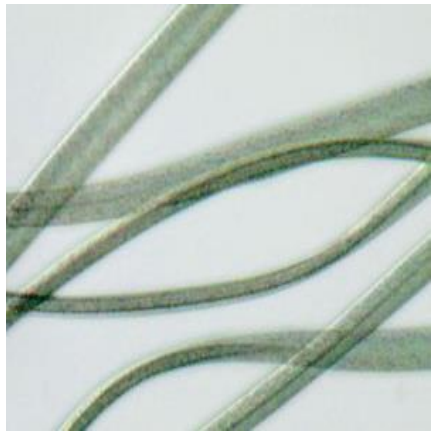
- Polyester
  - “Polar fleece”
  - Wrinkle-resistant
  - Not easily broken down by light or concentrated acid
  - Added to natural fibers for strength
- Nylon
  - Easily broken down by light and concentrated acid
  - Otherwise similar to polyester

Acrylic

Soft, warm
Wool-like
Fiber retains shape
Resilient
Quick-drying
Shrink, moth, fade resistant

Acrylic





General cross-section and surface view of acrylic fiber

- **Comfort factors**
- Acrylics have a soft handle
- The slight waviness of the acrylic fibers provides slight bulkiness to the yarns and warmth

- **Care factors**
- Easily laundered, machine washable, dries fast

Modacrylic winterwear

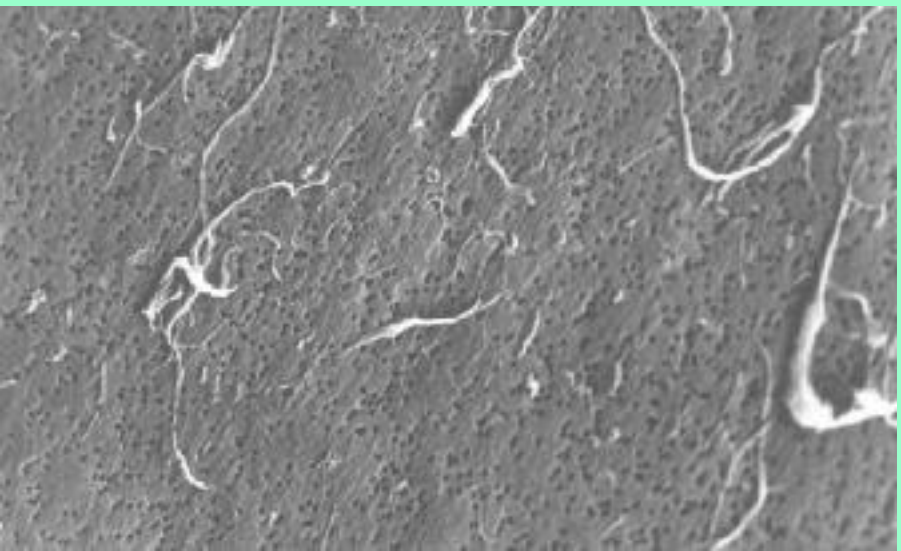
Blankets

Police vests

Inflight products

Aramid

Great strength
Stretch resistant
Does not melt
Highly flame-resistant
Fibers maintain shape and structure even at very high temperatures



High strength, high modulus organic fibers

- **Para-aramids**

e.g. Kevlar (Dupont)

Twaron (Acordis)

- **Ultra high molecular weight polyethylene** (UHMWPE)

e.g. Dyneema

Spectra (Allied signal)

Applications

Bullet proof helmet

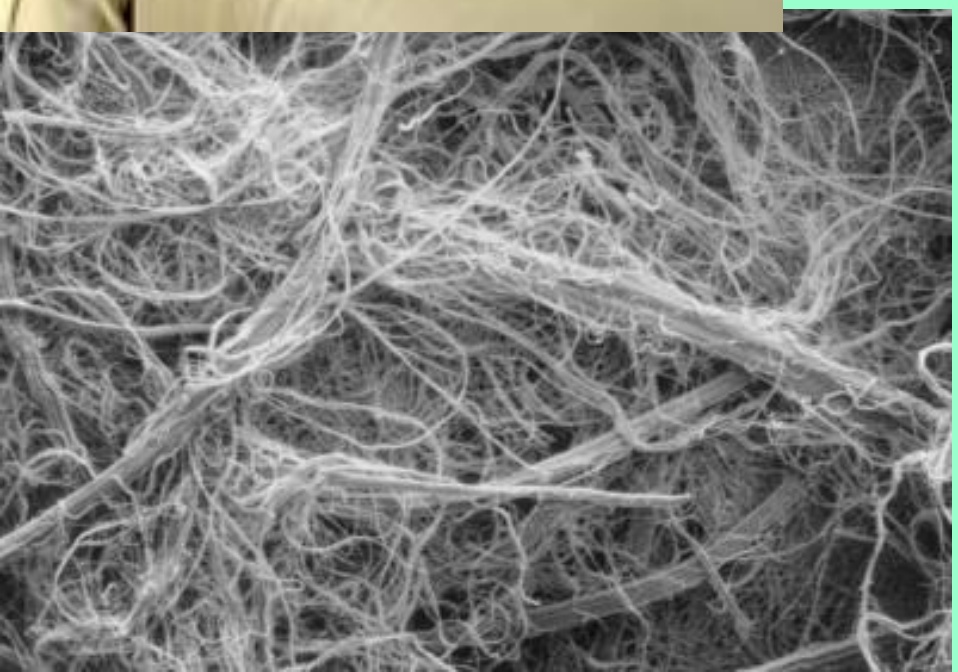
Bullet proof vest

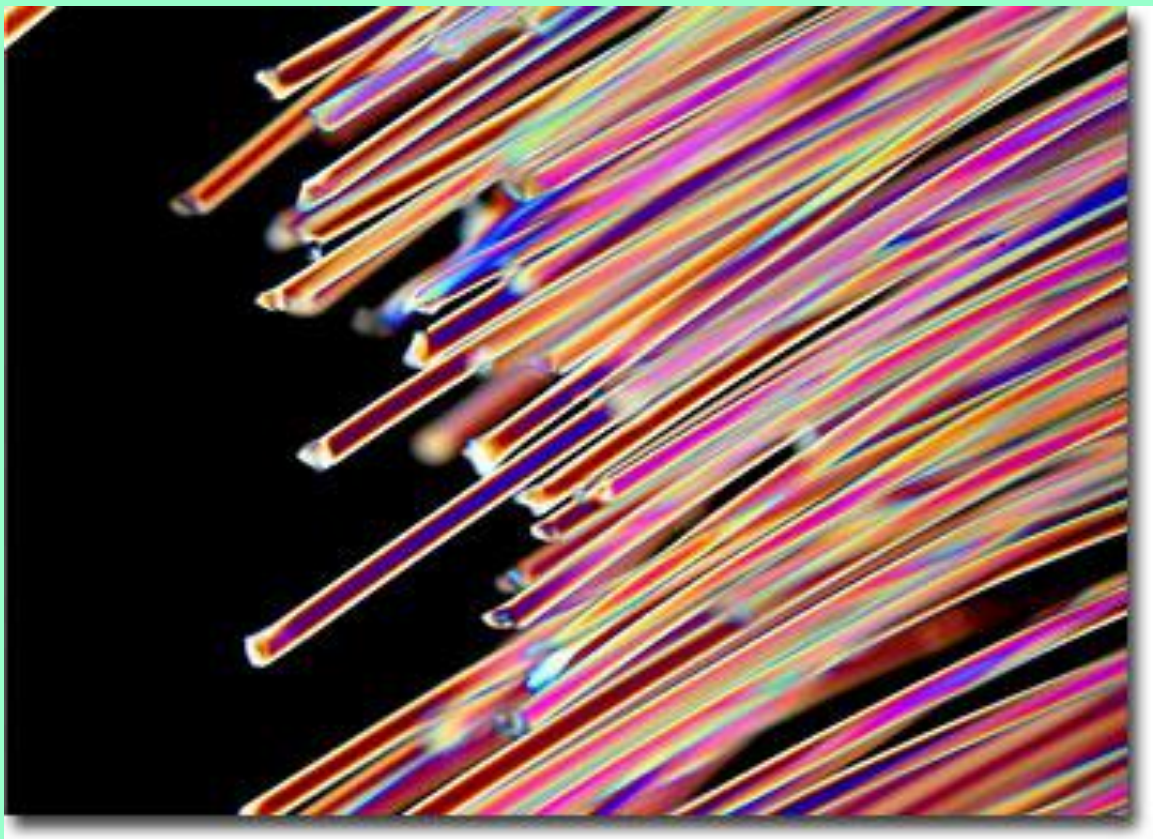
Cut resistant gloves using yarn made of kevlar sheath and spandex core

Kevlar and PTFE rope

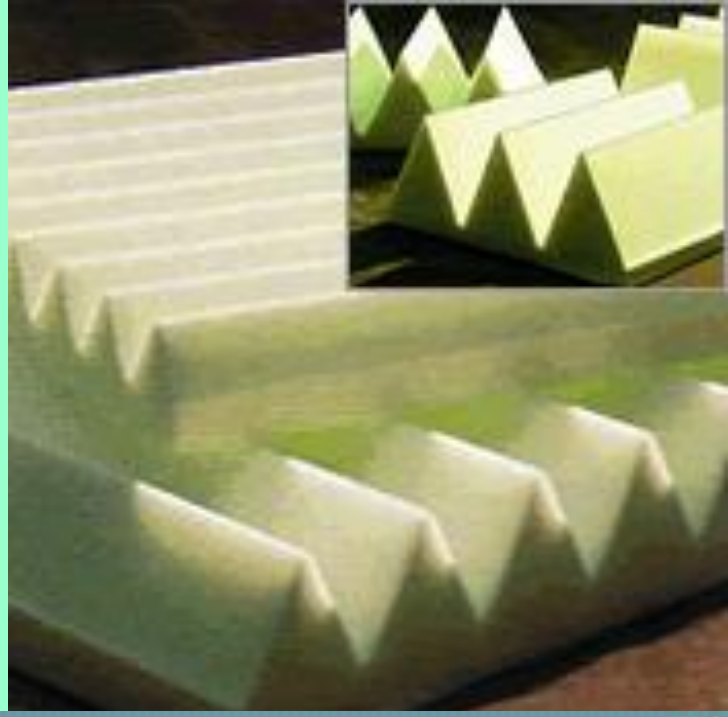
Lyocell

Soft, strong absorbent
Easily dyed
Fiber can be made into many textures





Melamine

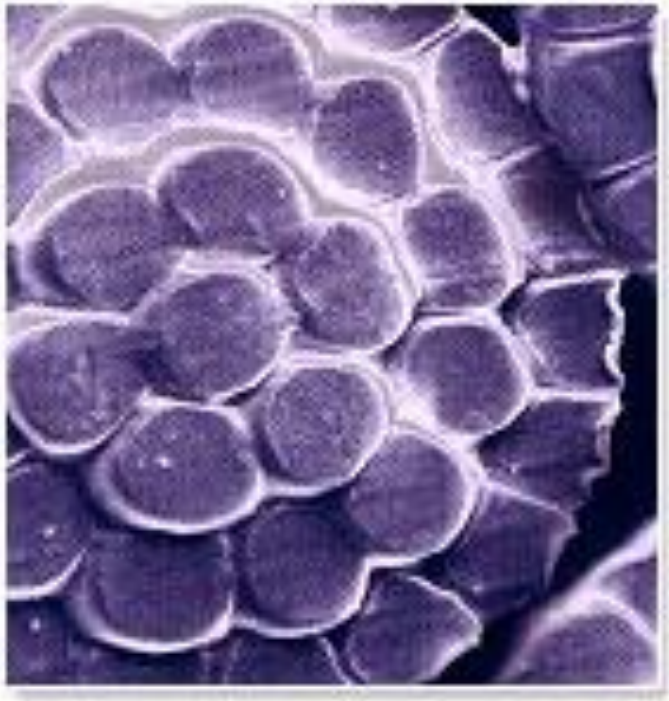


White fiber, easily dyed
Flame resistant
Does not conduct heat
Plastic used to make “unbreakable”
Dishes
Used to make airplane seats
Firefighter’s protective wear

Fiber Classification —Synthetic Polymer Fibers

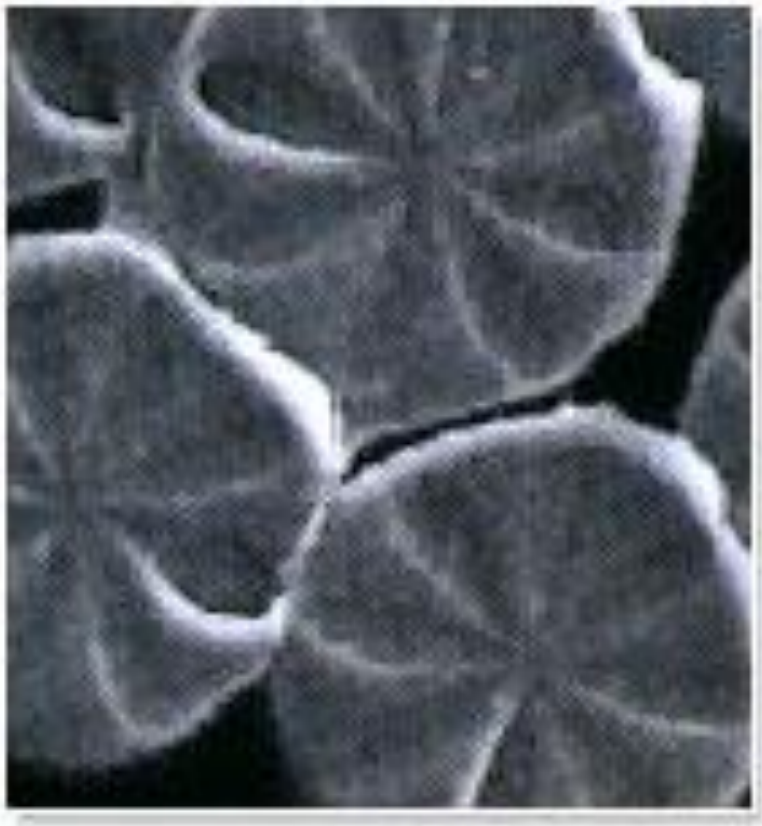
- Acrylic
  - Inexpensive
  - Tends to “ball” easily
  - Substitute for artificial wool or fur
- Olefins
  - High performance
  - Quick drying
  - Resistant to wear

Microfilaments



Sea island type microfiber manufactured by Toray Japan

- **Linear density of approximately 1.0 dtex or less**
- **Usually made from polyester/nylon**
- **Brand names: Mitrelle, Setila, Micrell, Tactel**



Splittable microfiber

(Kanebo Japan,Elaston)

- **Used for production of fashionable clothing and also bacteria barrier fabric for medical applications**
- **Split technique of production produces microfilaments that can be used for wiping cloth for optical and microelectronic industries**

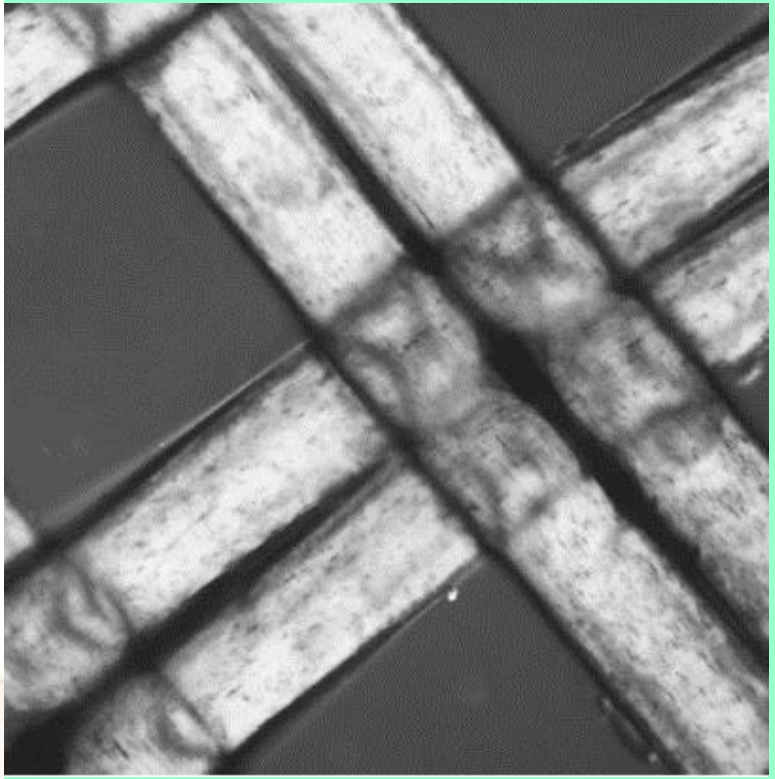
Microfilament products

Microfilament fabric can be constructed to be impermeable to water droplets while allowing air and moisture vapour circulation, with good wicking properties.

Microfilament spunlace nonwoven : Soft, drapable and much lighter than traditional textiles. Highly dense and compact fiber structure, very good barrier properties, thermal insulation, wind resistance and UV protection and highly breathable with very good moisture management.

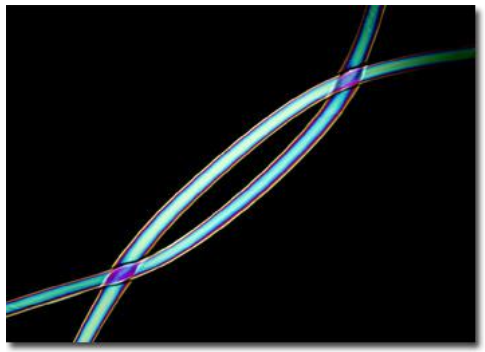
Nylon

Early man-made fiber (1930’s)
Very strong fiber
Supple fabric
Resilient, holds its shape
Abrasion-resistant
Lustrous fabric
Water-resistant
Oil and chemical resistant
Used to make seatbelts, clothing, carpets, bedding, drapes, parachutes, tents



What you see in the microscope – Nylon

Polypropylene (Olefin fibers)



Polarized microscope image of PP filament

Carpets

Medical products

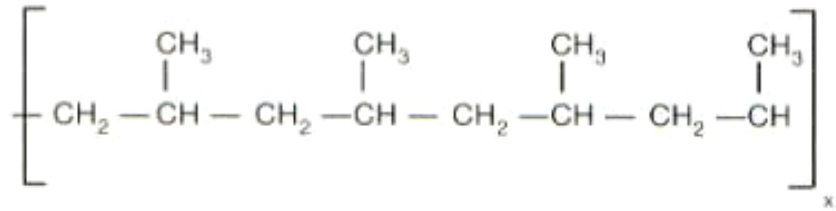
Grass mats

PP products

Crop covers

Bags

Antiweed fabric

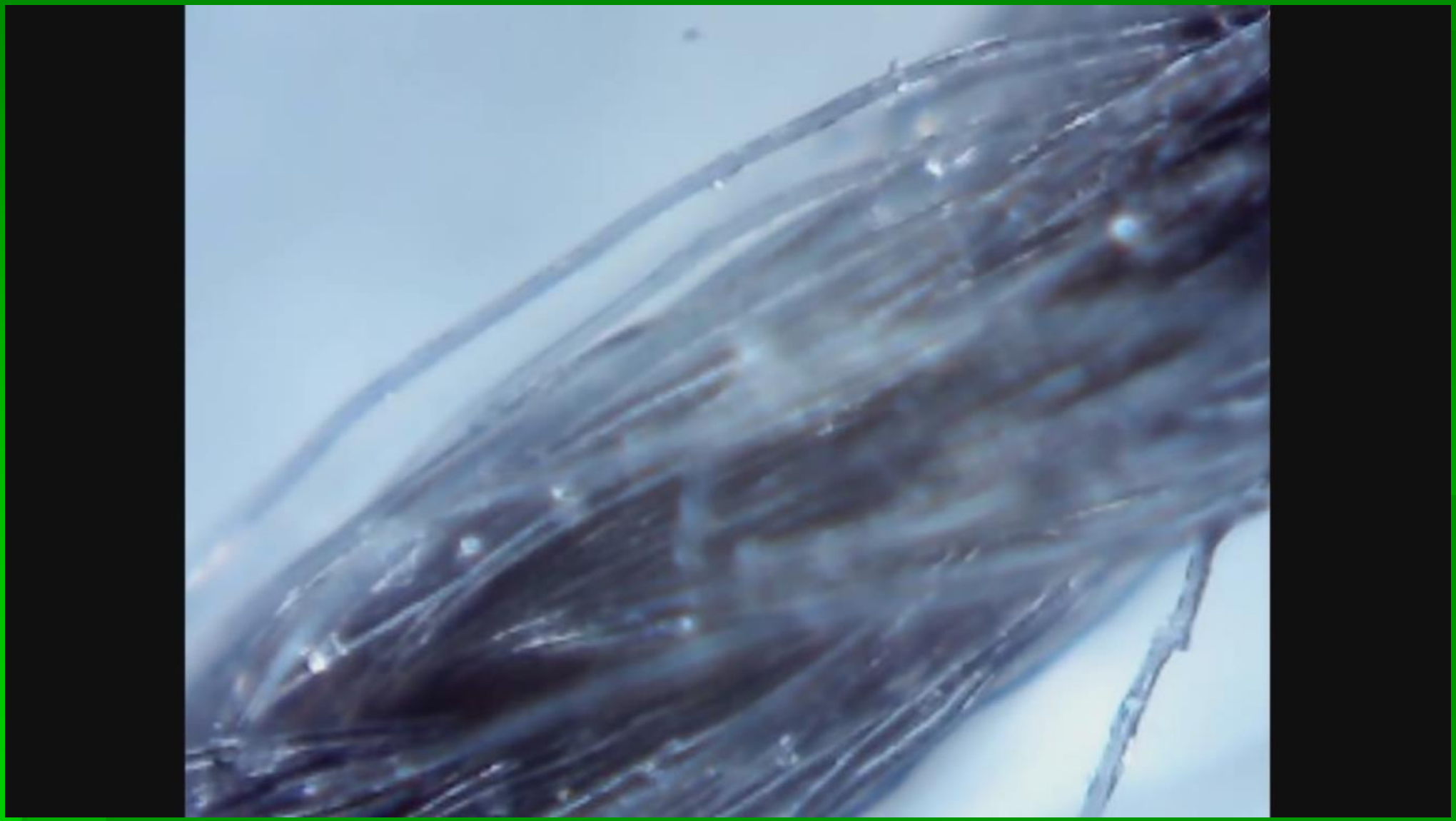


- Different types of yarn, tapes, sheets and nonwoven products can be made
- Used widely in the production of disposable medical protective apparels, carpets and industrial textiles

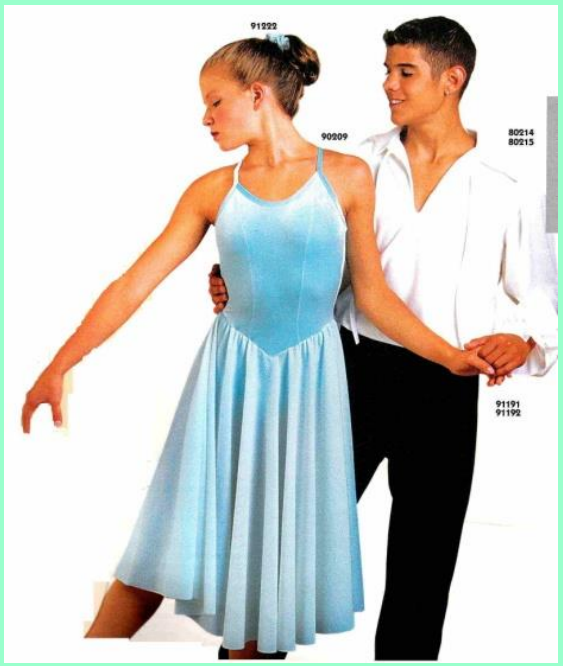
Polyester

Polyester fabrics and fibers are extremely strong.
Polyester is very durable: resistant to most chemicals, stretching and shrinking, wrinkle resistant, mildew and abrasion resistant.
Polyester is hydrophobic in nature and quick drying. It can be used for insulation by manufacturing hollow fibers.
Polyester retains its shape and hence is good for making outdoor clothing for harsh climates.
It is easily washed and dried

Polyester



Spandex



Sampling and Testing: An Example

Fiber Burn Analysis Key

When fiber is removed from flame,

1a. It ceases to burn ..... Go to 2

1b. Fiber continues to burn ..... Go to 3

2a. Fibers have the odor of burning hair ..... Go to 4

2b. Fibers do not smell like hair ..... polyester

3a. Fibers produce a small amount of light ash residue ..... rayon

3b. Fibers produce a gray fluffy ash ..... cotton

4a. A hard black bead results from burning ..... wool

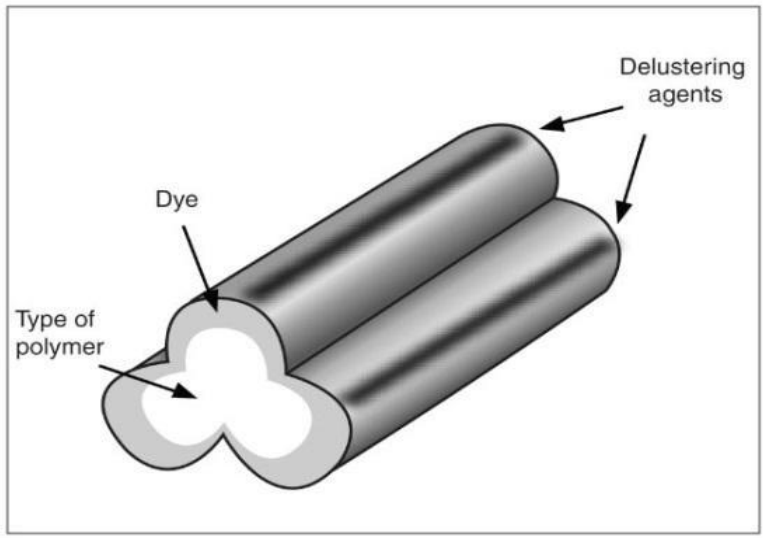
4b. A brittle, black residue results ..... silk

HOW CAN WE TELL THE DIFFERENCE BETWEEN SYTHETIC AND NATURAL FIBERS?

- **Step 1: Natural vs synthetic, use a comparison microscope**
- **Examine the color, diameter, cross-section shape, pitting or striations, etc.**
- **Synthetic fibers have smooth surfaces, uniform size & shape**

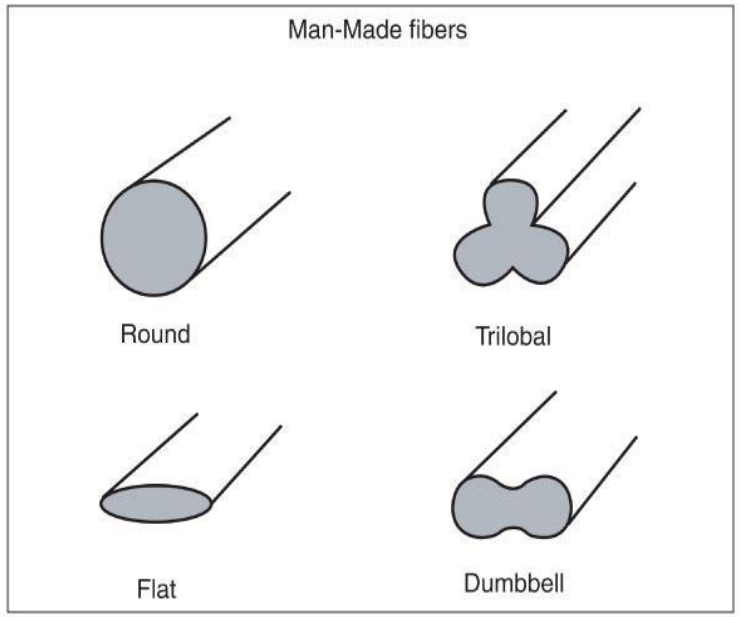
Color, texture, shape, and surface features are all used to compare fibers.

Figure 04.26



The spinneret can be replaced with different shaped holes to make fibers with different cross sections.

Figure 04.25



HOW CAN WE TELL THE DIFFERENCE BETWEEN SYTHETIC AND NATURAL FIBERS?

- **Step 2: chemical composition of synthetics**
- **Use Infrared spectroscopy, refractive index or polarized light to identify types of synthetic fiber**
- **Dye can be extracted and the colors separated by thin layer chromatography (TLC)**

TLC is a screening test for drug samples.

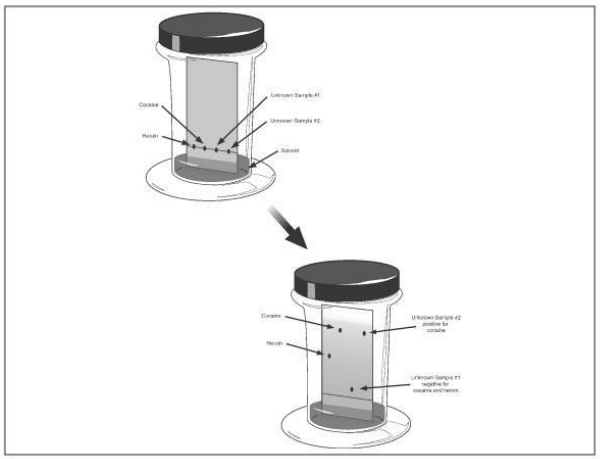
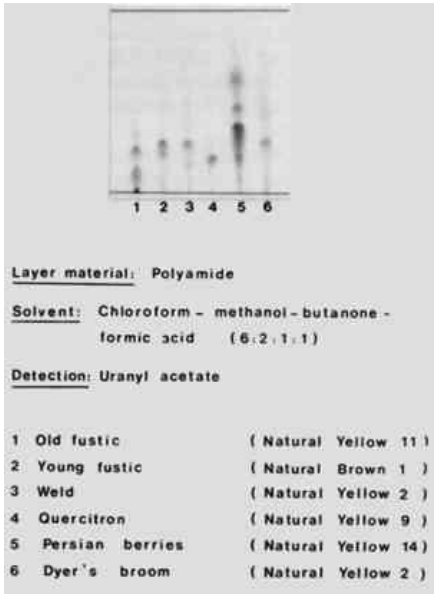


Figure 11.20



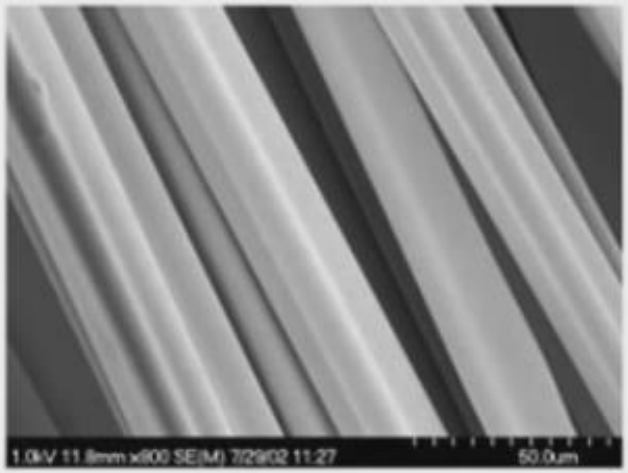
Fiber Shape

Synthetic fibers

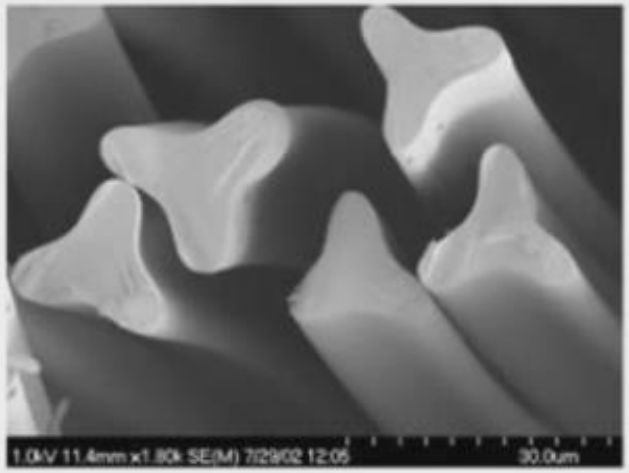
- Variety of shapes
- Most common:
  - Trilobal
  - Hollow
  - Circular

  - All very uniform in shape!

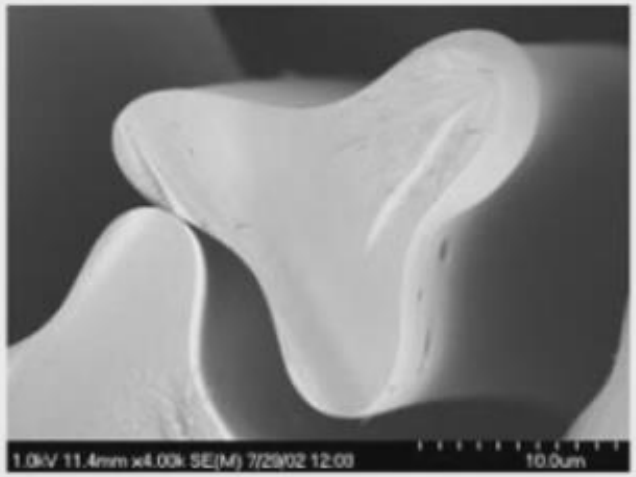
Trilobal



(a)



(b)

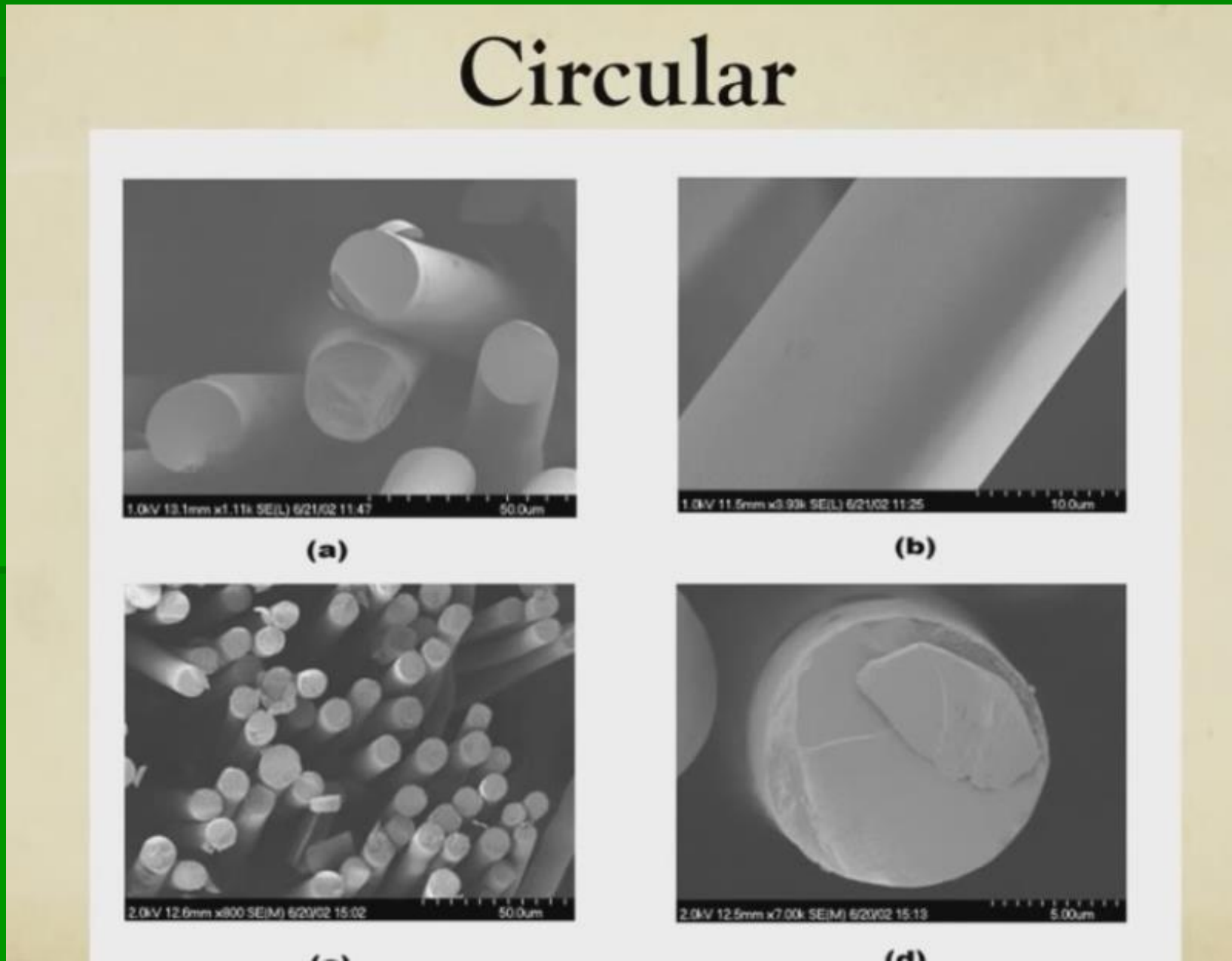


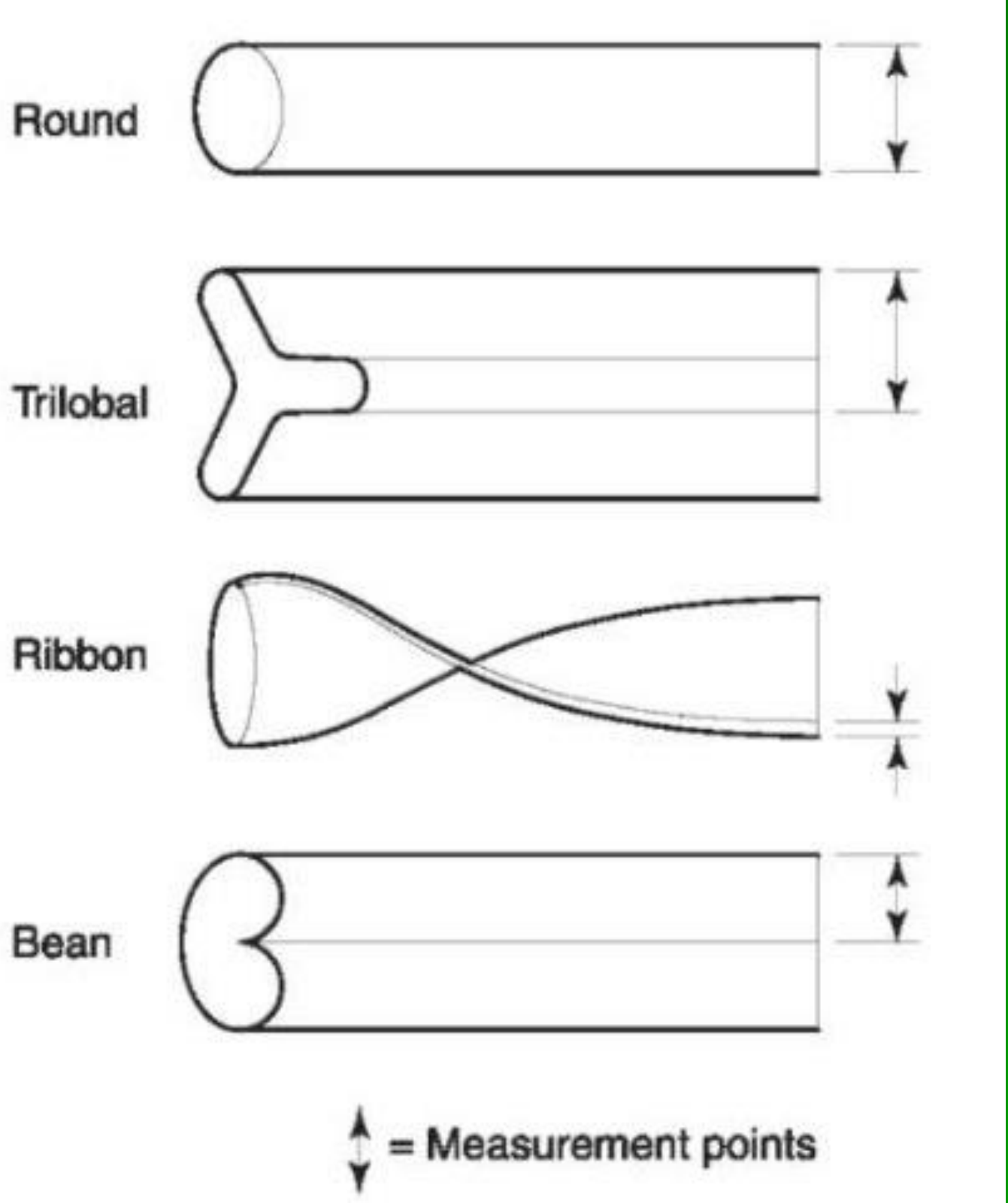
(c)

(d)

Hollow

Some man-made fibers are circular like hairs, but the is no medulla or cuticle




Round
Trilobal
Ribbon
Bean
= Measurement points

Summary

- Fibers are analyzed using burn tests, tests for solubility in different solutions, polarized light microscopy, or infrared spectroscopy.
- Fibers are classified as natural or synthetic.
- Natural fiber sources include:
  - Animal hair
  - Plant seeds, fruit, stems, or leaves
  - Minerals.

READ the slides. Then answer the questions (on paper)

1) Synthetic fibers are made of large molecules called polymers which are made of smaller repeating units called monomers. These fibers are mass produced. Why is that a problem for forensic scientists?

2) Fibers collected as trace evidence are often considered to be class evidence and not individual evidence. For example, the presence of a white cotton fiber found on a suspect and found on a victim at a crime scene is not enough evidence to convict the suspect. Justify this statement.

3) Give 4 examples of natural fibers.

4) What is the most common one?

READ the slides. Then answer the questions (on paper)

5) List 2 natural animal fibers. What are they made of? What would they look like under the microscope?
6) List 2 natural plant fibers. What are they made of? What would they look like under the microscope?
7) What is an example of a mineral fiber and what does it look like under the microscope?
8) List 2 Petrochemical fibers. What does each one look like under the microscope?
9) The 2 non-destructive tools used to identify fibers are…
10) The 2 destructive tests (one we did in lab) are…
11) Prior to the 19th century, all fibers were:
12) Give a short description of the timeline for man-made fibers.

READ the slides. Then answer the questions (on paper)

13) Why are more than half the fibers in the world today man-made?

14) What is the strongest fiber?

15) What are 2 ways that synthetic fibers are superior to natural fibers?

16) What are 2 ways that natural fibers are superior to synthetic fibers?

17) Name 3 different fibers that are produced by animals.

18) Name 3 different fibers that are produced from petroleum, such as coal, oil, or natural gas

READ the slides. Then answer the questions (on paper)

19) Name 3 different fibers that are produced by plants.

20) A crime-scene investigator views two small, red fibers. One fiber was obtained from the crime scene off the victim's body, and the other red fiber was removed from the cuff of the suspect's pants. Although the two fibers appear to be from the same fabric, the crime-scene investigator determines that the two fibers are indeed very different. List five other characteristics of the fibers that can be detected under a compound microscope that could be used to distinguish the two red fibers.

READ the slides. Then answer the questions (on paper)

21. A fiber is collected at a crime scene. When viewed under a compound microscope, what two traits would indicate that the fiber was a human hair and not a piece of fiber obtained from an article of clothing?
22. Why are fibers are an excellent source of trace evidence?
23. Natural fibers can be harvested from ..
24. Why was asbestos, a mineral fiber, used so extensively in the 20th century?
25. What are some common shapes for man-made fibers?
26. What if a woman's roommate borrowed her coat and was then involved in a crime that left textile evidence behind? How could investigators distinguish between the woman involved in the crime and the owner of the coat?
27. Would you ever be 100% sure of the conclusion you made? Explain