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Faculty of Textile Engineering

Properties of Fibres

Part 1: *Introduction to Textile Fibres*

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Credit and Exam Conditions

Credit: Participation in all laboratory courses + elaboration of semestral works

Exam: Assignment – 20%
Written exam – 80%

Attendance: *Students with low attendance will not be allowed to appear for the final examination.*

Course content

1. Introduction, basic types of fibres
2. Molecular structure of fibres, measurements of viscosity
3. Supermolecular structure of fibres, models
4. Evaluation of supermolecular structure (orientation, crystallinity)
5. Geometric characteristics of fibres
6. Surface characteristics of fibres (roughness, friction)
7. Sorption characteristics of fibres I (sorption isotherms, sorption mechanisms, wicking)
8. Sorption characteristics of fibres II (wetting, dynamic processes)
9. Mechanical characteristics of fibres (fracture mechanisms)
10. Fibres viscoelasticity
11. Dynamic mechanical characteristics of fibres
12. Electrical characteristics of fibres
13. Thermal characteristics of fibres I (thermal conductivity, models)
14. Thermal characteristics of fibres II (thermal analysis)

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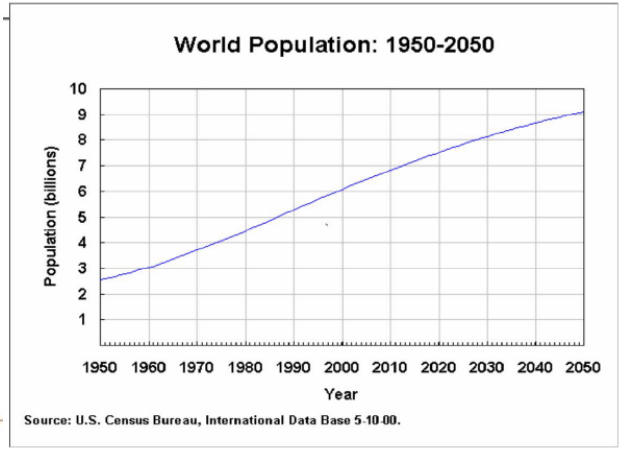
Background

- Textiles generic term (from Latin texere "to weave") originally applied to woven fabrics but now it is also applied to natural and synthetic filaments, yarns and threads and as well to woven, knitted, felted, tufted, braided, bonded, knotted and embroidered fabrics made from them and to nonwoven fabrics produced by mechanically and chemically bonding fibers.
- Textiles are accompanying humans from birth to death.
- In developed countries annual consumption of textiles is around 25-30 kg per person.
- Annual turnover is approximately 1620 trillion USD. At present textile is in the third place among all branches.

One person needs 30 kg of textile products per year.



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Textile fibers

HISTORY OF TEXTILE FIBERS

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History of Natural fibers

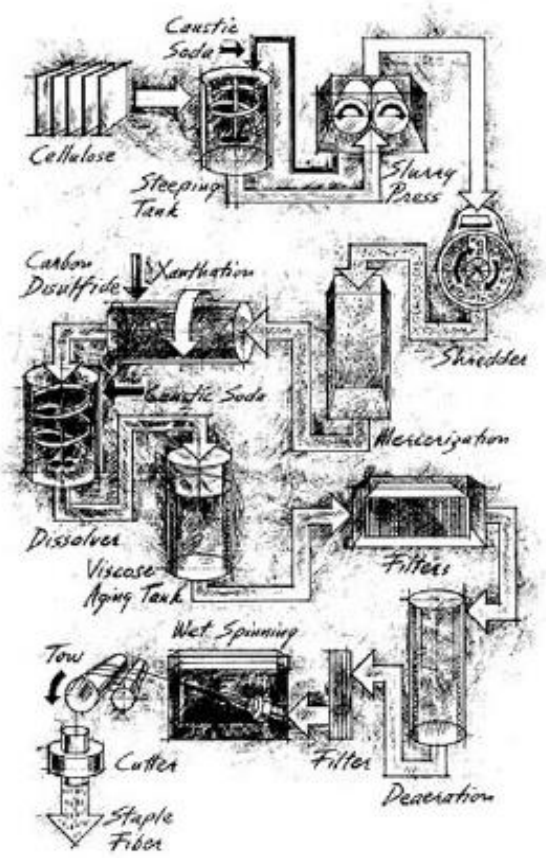
The use of natural fibers for textile materials began before recorded history.

- The oldest indication of fiber use is discovery of flax and wool fabrics at excavation sites of the Swiss lake dwellers (***7th and 6th centuries B.C***).
- Hemp, presumably the oldest cultivated fiber plant, originated in Southeast Asia, then spread to China, where reports of cultivation date to ***4500 B.C***.
- The art of weaving and spinning linen was already well developed in Egypt by ***3400 B.C***.
- Reports of the spinning of cotton in India date back to ***3000 B.C***.
- The manufacture of silk and silk products originated in China from ***2640 B.C***.
- In the ***18th and 19th centuries***, the Industrial Revolution encouraged the further invention of machines for use in processing various natural fibers, resulting in a tremendous upsurge in fiber production.

History of Artificial fibers

Many early scientists to attempt to develop fiber resembling the thread of silkworm;

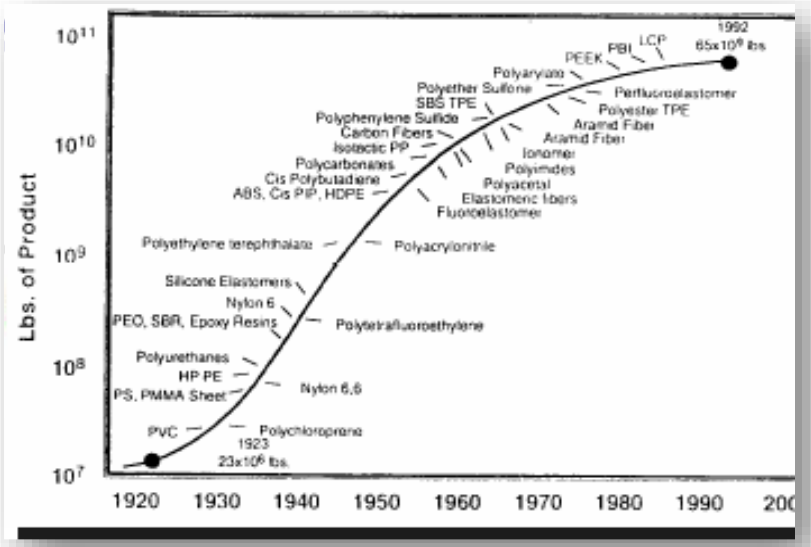
- In 1664, the English scientist Robert Hooke suggested the possibility of synthesizing a glutinous substance similar to the fluid secreted by the silkworm when it spins its cocoon.
- In 1890, the commercial production of manufactured fibers started, originally named as **artificial silk**, launched by the French scientist Count Hilaire de Chardonnet.
- In 1924, the term artificial silk was replaced by the more definitive name Rayon, which in 1937 was officially recognized in the USA by the Federal Trade Commission as the generic term for the new fiber.
- Subsequently, two major processes used in rayon production led to the classification of rayons into two distinct categories, viscose rayon and acetate rayon. Lyocell and Tencell fibers belong to this group of fibers as well.



Viscose Process

Discovery of synthetic fibers

Year	Selected Fibers
1910	Rayon
1924	Acetate
1930	Rubber
1936	Glass
1939	Nylon, Vinyon
1941	Saran
1946	Metallic
1949	Modacrylic, Olefin
1950	Acrylic
1953	Polyester
1959	Spandex
1961	Aramid
1983	Pbi
1992	Lyocell



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Textile fibers

INTRODUCTION

What is Textile fiber?

- The term textile fiber refers to fibers that can be spun into yarn or made into fabric.
- A textile is flexible material consisting of network of natural or artificial fiber often referred to as thread or yarn.
- fibers have been defined by the "Textile Institute" as units of matter characterized by;

✓ **flexibility**
✓ **fineness and**
✓ **high ratio of length to thickness**

Textile fibers (contd...)

- Other characteristics might be added, if the fiber is to be of any use for general textile purposes, a sufficiently high temperature stability and a certain minimum strength and moderate extensibility.

- The characteristic dimensions of fibers are the basis of their use and need to be stressed:

✓ **Individual fibers (or elements of a continuous filament) weigh only a few micrograms**
✓ **Their length/width ratio is at least 1000:1**

- It is the basic structural element of textile products.

- It is the smallest textile component which is microscopic hair like substance that may be manmade or natural.

Classification of fibers

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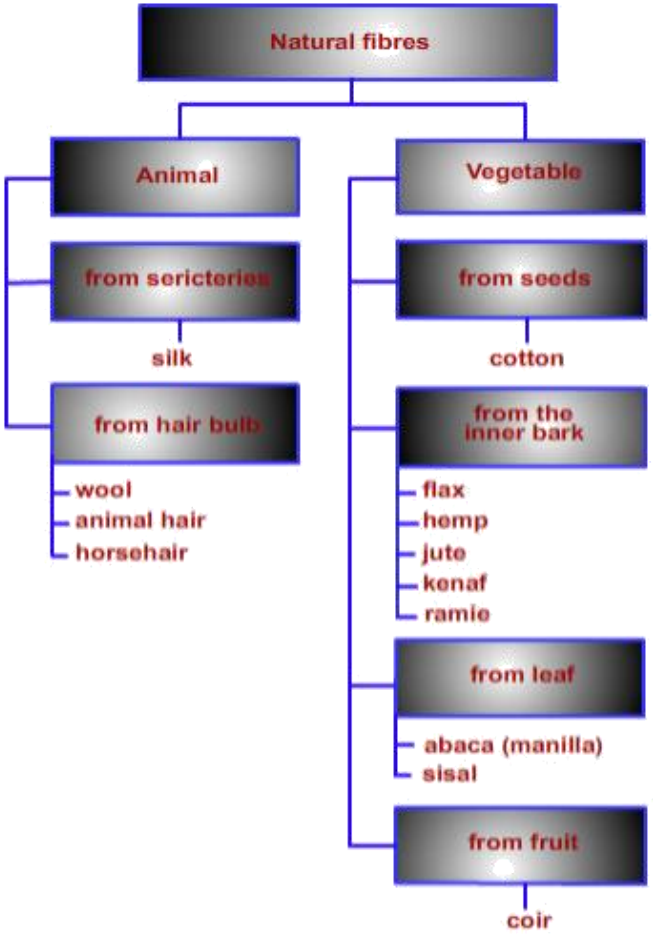
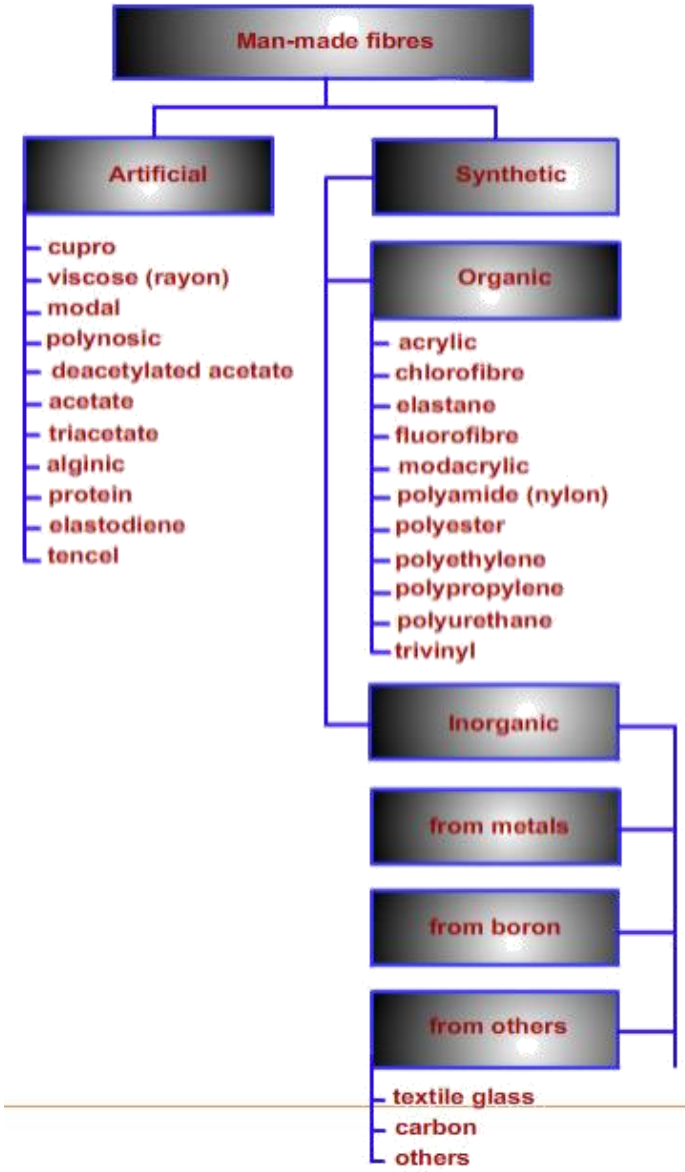




- ✓ Type(Natural and manufactured)
- ✓ Length(Short staple, long staple, continuous filament)
- ✓ Size(Ultra fine, fine, regular, course)

Fiber Production types

- A **staple** fiber is a fiber of relatively short length
  - Range from a few millimetres (e.g. the shortest cotton fibers, known as linters) to around a metre (e.g. fibers from bast plants).
  - Typically between 3 and 20 cm in length. Given the differences in average fiber length, cotton fibers (2–3 cm) and wool fibers (5 cm or more) are, for example, sometimes referred to as 'short staple' and 'long staple' fibers, respectively.
- A **filament** is a fiber of indefinite length.
  - The various silks are the only natural filament fibers.
  - Can be used in single or multifilament form.
- A **tow** can mean two different things:
  - In the synthetic fiber industry, a tow is a large assembly of filaments that is destined to be cut into shorter (staple) fibers.
  - In the processing of natural fibers (flax), tow is the shorter fiber produced when the stalks are processed to extract the fibers (the long fibers are called line flax).

Natural fiber

- Any hair like raw material directly obtainable from an animal, vegetable or mineral source that can be convertible after spinning into yarns and then into fabric.
- Under them there are various categories:

  ✓Plant
  ✓Animal
  ✓minerals

BAST (Stem)

- **Flax** (*Linum Usitatissimum*)
- **Hemp** (*Cannabis Sativa*)
- **Kenaf** (*Hibiscus Cannabinus*)
- **Jute** (*Corchorus Capsularis*)
- **Ramie** (*Boechmeria Nivea*)
- **Isora** (*Helicteres Isora*)
- **Nettle** (*Helicteres Isora*)

LEAF

- **Ananas** (*Ananas Bracteatus*)
- **Sisal** (*Agave Sisalana*)
- **Abaca** (*Musa Textilis Nee*)
- **Curua** (*Ananas Erectifolius*)
- **Cabuya** (*Furcraea Andina*)
- **Palm**
  - **African Palm**
  - **Chambira** (*Astrocaryum Chambira*)
- **Opuntia** (*Opuntia Galapagos*)
- **Jipijapa** (*Carludovica Palmata*)
- **Yucca** (*Yucca* L)

SEEDS

- **Cotton** (*Gossypium*)
- **Coir** (*Cocos Nucifera*)
- **Kapok** (*Ceiba Pentandra*)
- **Soya** (*Glycine*)
- **Poplar** (*Populus Tremula*)
- **Calotropis** (*Calotropis Procera*)

FRUIT

- **Coir** (*Cocos Nucifera*)
- **Luffa** (*Luffa Aegyptiaca*)

GRASS

- **Bamboo** (*Bambusa* Shreb.)
- **Totora** (*Scirpus Californicus*)

WOOD

- hardwood
- softwood

Industrial Hemp

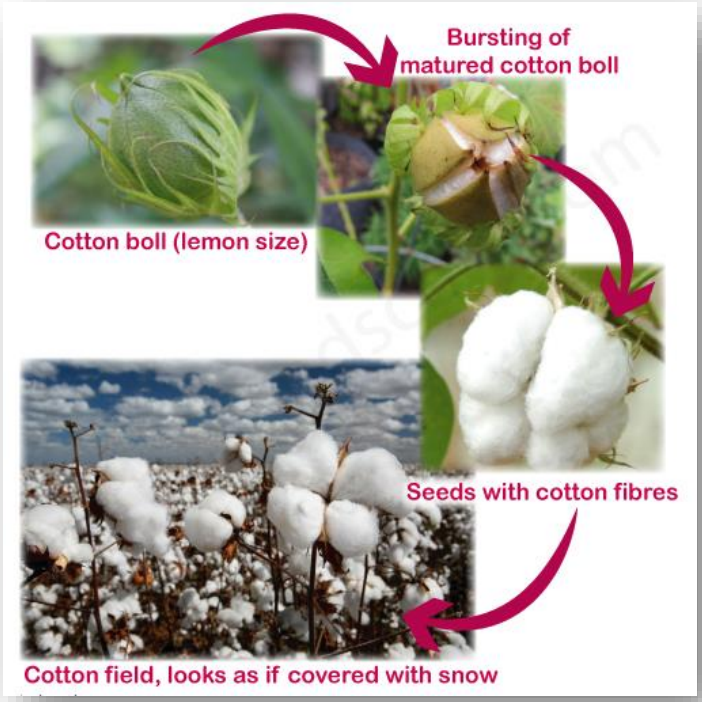
Fiber Flax

Cotton

- Cotton is a soft fiber that grows around the seeds of the cotton plant.
- Cotton fiber grows in the seed pod or boll of the cotton plant. Each fiber is a single elongated cell that is flat twisted and ribbon like with a wide inner hollow (lumen).

- Composition - **90% cellulose, 6% moisture and the remaining are fats and impurities.**
- Outer surface is covered with a protective wax like coating which gives fiber an adhesive quality.

- Cotton fibers can be made into a wide variety of fabrics ranging from lightweight voiles and laces to heavy sailcloths and thick-piled velveteens, suitable for a great variety of **wearing apparel, home furnishings, and industrial uses.**

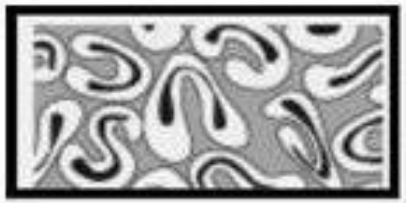


Longitudinal View

Mature flat and ribbon-like with convolutions, thick wall and small lumen
- Immature very thin wall and a large lumen with few convolutions
- Dead very thin and almost transparent
- Mercerized smooth and cylindrical, fewer convolutions and lumen or sometimes may be absent

Cross-Sectional View

Kidney Shaped
- Elliptical
- Very thin like a strip
- Nearly round or circular



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Macro-structure of Cotton

Length is one of the most important properties of cotton fibers. Under a microscope, a cotton fiber appears as very fine and regular. **Length of fiber is about 10 mm to 65 mm, depending upon the quality of the fiber.** Fibers are attached to the seeds inside the boll of the cotton plant. **There are six or seven seeds in a boll and with each seed up to 20,000 fibers are attached.** The length of these fibers (also called staples) is divided into short, medium, and long:

Short staple cotton is between 3/8" to 15/16" (0.95cm to 2.4cm) in length
Medium staple cotton is between 1" to 1-1/8" (2.54cm to 2.86cm) in length
Long staple cotton is between 1-3/16" to 2-1/2" (3cm to 6.35cm) in length

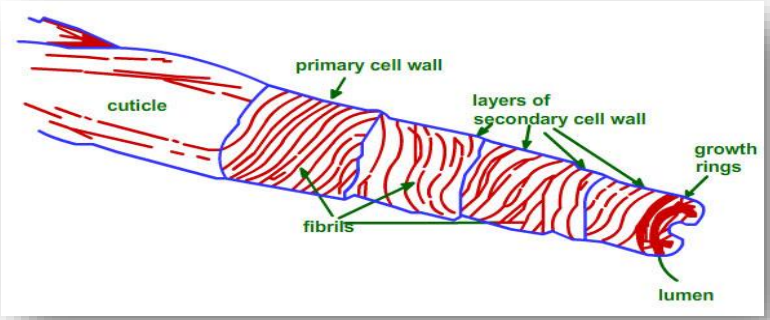
Diameter of fiber ranges from about 11 µm to 22 µm makes it finest fiber in common use.

Normally the color of cotton is creamy white . Cotton fibers vary in color from near white to light tan.

The color of cotton fibers depends on its;

- ✓ **type**
- ✓ **environment**
- ✓ **soil**
- ✓ **climatic conditions**

These factors influences the amount of protein and minerals within the fiber.

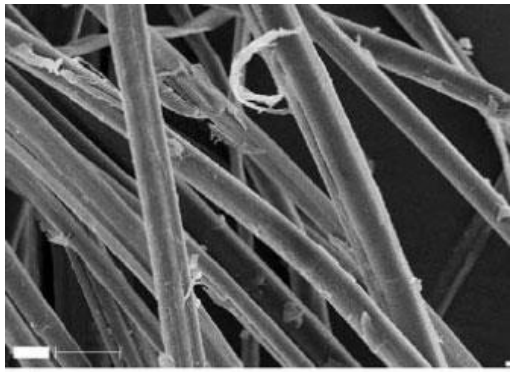


The **"cuticle"** is the outer waxy layer. Cuticle consists of pectins and proteinaceous materials. It serves as a smooth, water-resistant coating, which protects the fiber from chemical and other degrading agents.
The **"primary wall"** is the original thin cell wall, which is immediately present underneath the cuticle . It is 200nm thick. It mainly consists of cellulose or network of small strands of cellulose, called fibrils. The fibrils spiral at about 70° to the fiber axis. This spiraling imparts strength to the primary cell.
The **"secondary wall"** layers of cellulose consist of concentric layers present beneath the primary cell wall , which constitutes the main portion of the cotton fiber. Its fibrils are about 10 nm thick, but of undefined length. Near the primary cell wall, the fibrils of the secondary wall spiral at about 20° to 30° to the fiber axis.
The **"lumen"** is the hollow canal that runs the length of the fiber. It is filled with cell sap during the growth period.

Hemp

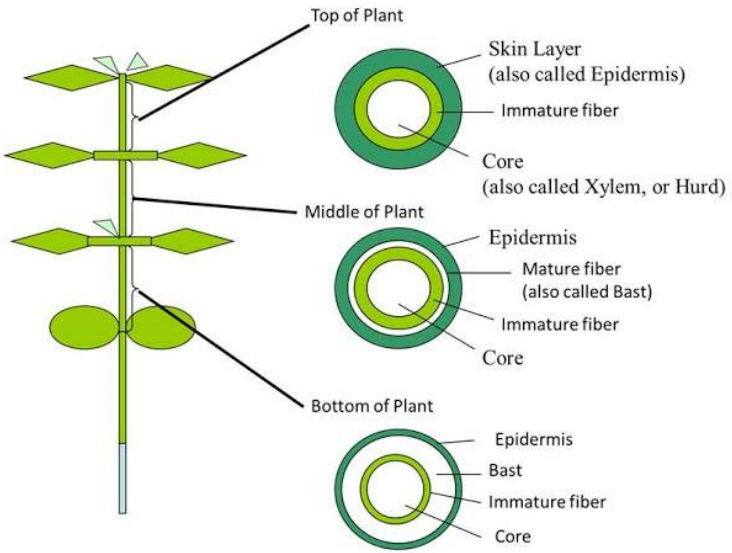
- Hemp is called a fiber of hundred uses.
- Hemp was so important in England in the sixteenth century that King Henry VIII passed an act on parliament which fined farmers who failed to grow the crop. Besides fabrics, Hemp is also used in the production of paper.
- The oldest piece of paper – over 2000 years old – was discovered in China and is made from Hemp.
- Until 1883, between 75% and 90% of all paper in the world was made with Hemp fiber. Hemp paper can also be recycled more times than wood-based paper.
- **Hemp is a bast fiber plant similar to Flax, Kenaf, Jute, and Ramie.**
- Hemp fiber is longer, stronger, more absorbent, more mildew resistant and more insulative than Cotton fiber. There are thirty varieties of Hemp fiber.

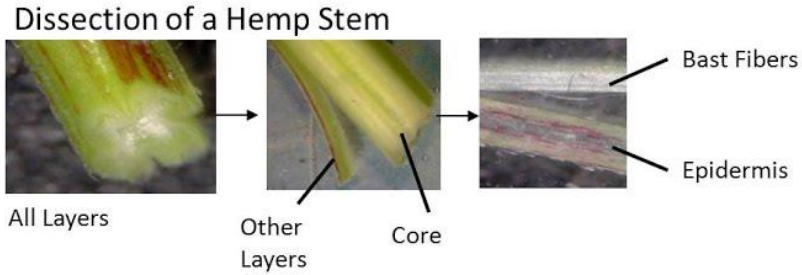
  - ✓ **Coarse Hemp fibers** and yarns are woven into cordage, rope, sacking and heavy –duty tarpaulins.
  - ✓ In Italy, fine Hemp fibers are used for interior design and apparel fabrics. Hemp is used in tapestry, hats, shawls, rugs, posters, and towel.
  - ✓ **Dyed hemp yarn** from Hungary is suitable for rug weaving, placemats, crochet and other craft items.
  - ✓ Central American Hemp is chiefly used for cordage.
  - ✓ Manila “Hemp” is a fiber from the leaves of the Abaca plant; it is very strong, fine, white, lustrous and, though brittle, it is adaptable for the weaving of coarse fabrics.

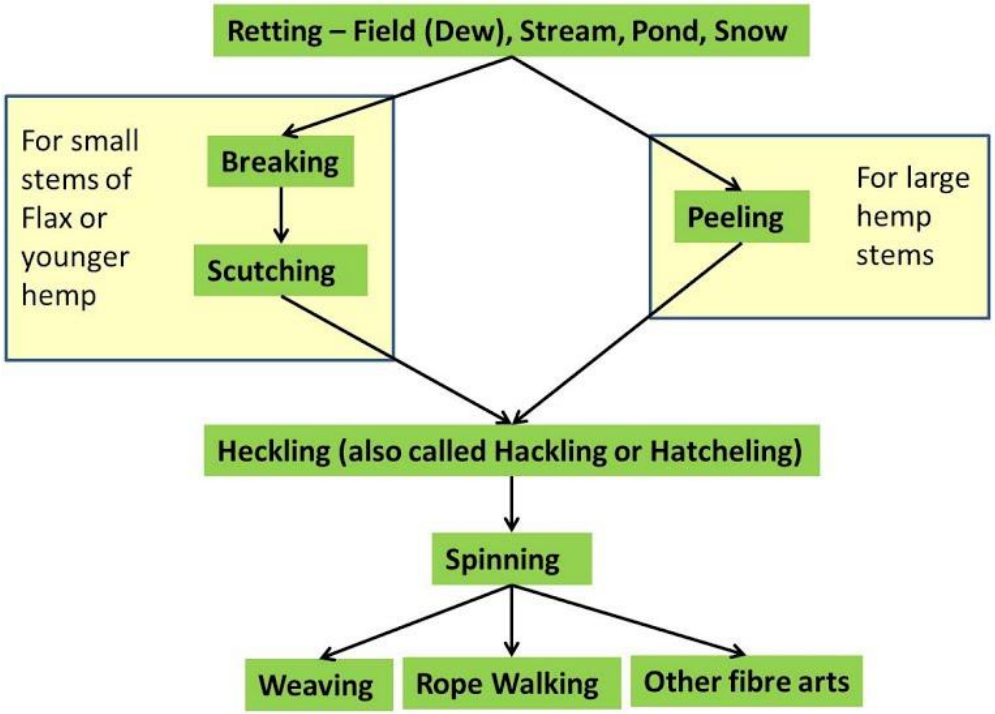


(a) hemp stalks
(b) longitudinal section of hemp stalks.

Hemp (contd…)

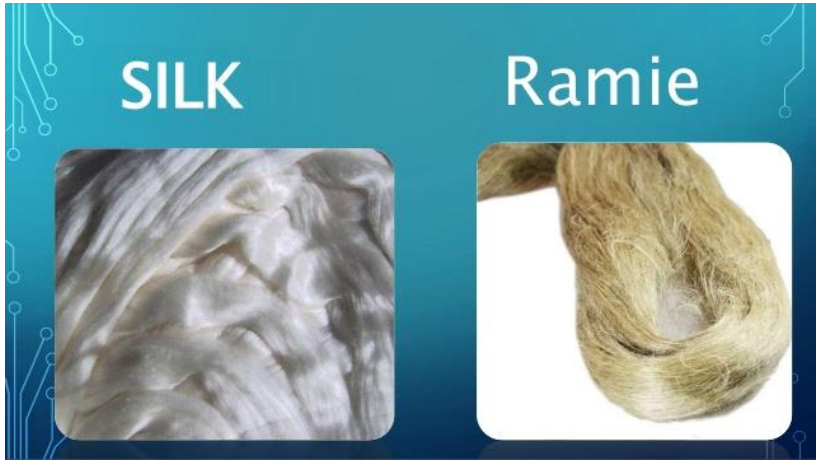

Top of Plant
Skin Layer
(also called Epidermis)
Immature fiber
Core
(also called Xylem, or Hurd)
Middle of Plant
Epidermis
Mature fiber
(also called Bast)
Immature fiber
Core
Bottom of Plant
Epidermis
Bast
Immature fiber
Core


Dissection of a Hemp Stem
Bast Fibers
Epidermis
All Layers
Other Layers
Core

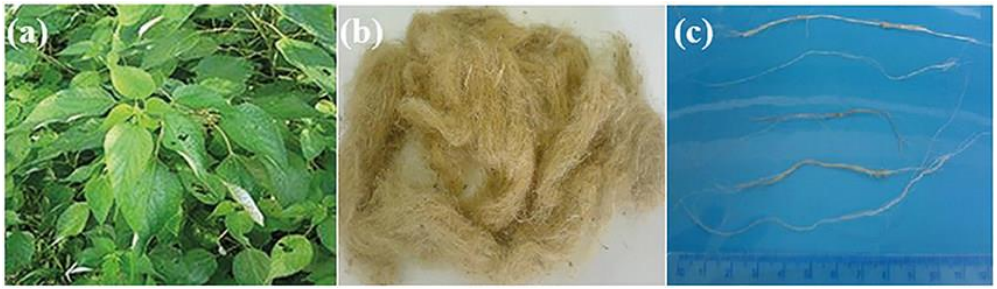

Retting – Field (Dew), Stream, Pond, Snow
For small stems of Flax or younger hemp
Breaking
Scutching
Peeling
For large hemp stems
Heckling (also called Hackling or Hatcheling)
Spinning
Weaving
Rope Walking
Other fibre arts

Ramie

- Ramie is one of the oldest fiber crops.
- Ramie requires chemical processing to de-gum the fiber.
- It is a fine absorbent, quick drying fiber, slightly stiff and possess high natural lustre.
- Ramie fiber is located in the bark of Boehmeria nivea, a member of the nettle family (Urticaceae). The plant is a native of China (hence, its name China grass), where it has been used for fabrics and fishing nets for hundreds of years. It is also grown in the Philippines, Japan, Brazil, and Europe.



- The ramie plant grows 1–2.5 m high with stems 8–16 mm thick.
- Traditional uses for ramie have been for heavy industrial-type fabrics such as canvas, packaging material, and upholstery.



The typical ramie plant (a), bunch of ramie fibers (b) and separated ramie fibers (c).

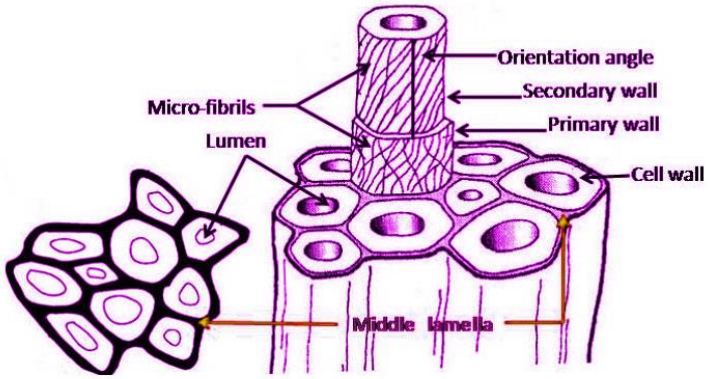
Jute

- Jute fiber is obtained from two herbaceous annual plants, Corchorus capsularis (linden family, Tiliaceae) originating from Asia, and C. olitorius originating from Africa. The former has a round seed pod, and the latter a long pod.
- Jute is grown mainly in India, Bangladesh, Thailand, and Nepal.
- The plants are harvested by hand, dried in the field for defoliation, and water (pool) retted for periods up to a month.
- **Uses of Jute fiber:**

✓ The strands are also used for twine, while kraft pulping of jute gives ultimate fibers for cigarette papers.

✓ New uses of jute in finer yarns and textiles, composites and boards, and paper products.

✓ A particularly promising an outlet for jute is in molded composites with thermoplastic materials for interior automobile head, door and trunk liners.



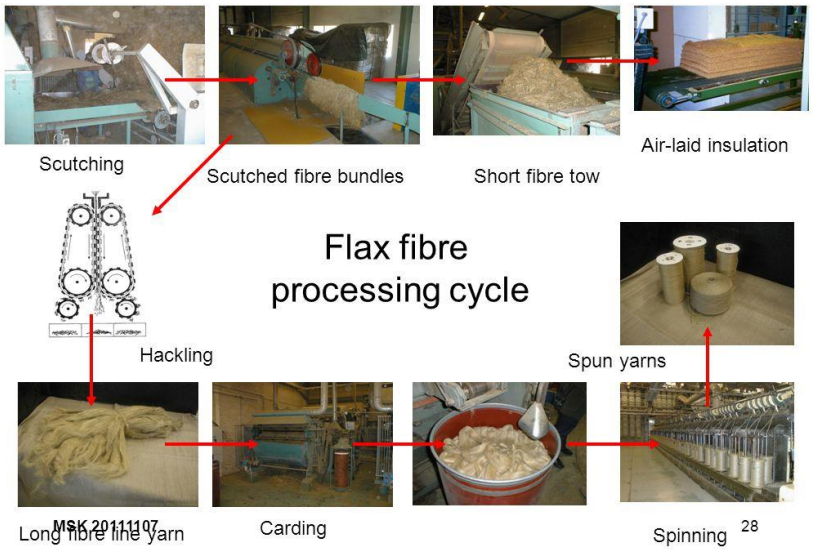
Cross-sectional view and micro-structure of jute fiber

Micro-fibrils are composed of celluloses. The cell wall of each ultimate cell is found to have two divisions – a thin primary wall and a thick secondary wall. Both these walls are composed of ultra-fine micro-fibrils. The fibrils are lying in criss-cross manner in the primary wall whereas the fibrils are arranged in ordered manner (orientation angle 7 to 8^0) in the secondary wall. The cross-sections of the ultimate cells are found to be more or less polygonal with rounded corners. The layer of natural cement (lignin) present between the ultimate cells is known as middle lamella. The round or oval shaped central canal of each ultimate cell is known as lumen.

Flax

- The flax fiber from the annual plant Linum usitatissimum (flax family, Linaceae) has been used since ancient times as the fiber for linen.
- The plant grows in temperate, moderately moist climates, for example, in Belgium, France, Ireland, Italy, and Russia. The plant is also cultivated for its seed, from which linseed oil is produced. A by-product of the seed plant is the tow fiber used in papermaking.
- The flax fiber is the strongest of the vegetable fibers, even stronger than cotton.
- The fiber is highly absorbent, an important property for clothing, but is particularly inextensible.

Flax Plant and Fibre



The most important application is in;

- ✓ Linen for clothing, fabrics, lace, and sheeting.
- ✓ Canvas, threads and twines, and certain industrial applications such as fire hoses.
- ✓ Chemical pulping of flax provides the raw material for the production of high-quality currency and writing paper.
- ✓ Flax fiber is also commonly used in cigarette papers.

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Kapok

- Kapok fiber is a silky cotton-like substance that surrounds the seeds in the pods of the ceiba tree.
- It is eight times lighter than cotton.
- It is used as a thermal-insulator.
- It is lightweight, non-allergic, non-toxic, resistant to rot and odourless.
- Due to it's inelasticity and fragile nature, it cannot be spun
- Kapok fiber contains wax layer on its surface, which affords this fiber to show excellent hydrophobic–oleophilic characteristics, and accordingly, this fiber has received much attention in recent years as the oil-absorbing material.
- **Featured with natural microtubes structure, kapok fiber can also be used as;**
  - ✓ Desirable template material or supported candidate such as for catalyst carriers.
  - ✓ Kapok fiber can blend with other fibers to achieve the required apparel textiles.




other seed fibers—kapok

kapok is obtained from the seed of the Java kapok (silk cotton) tree or the Indian kapok tree

fiber is lightweight, soft, hollow, very buoyant; breaks down quickly

difficult to spin into yarns—used mainly as fiberfill

researchers are studying ways to blend kapok with cotton for apparel uses

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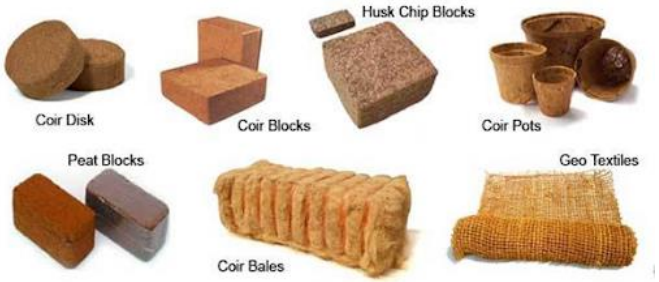
Coir

- fiber mechanically extracted from dry mature coconut husk after soaking.
- It is long, hard and strong fiber but with with lower softness, lower water absorption capacity and shorter life than retted fiber.



Uses of coir fiber:

- ✓ Mattress filling
- ✓ Mattress fiber
- ✓ automobile upholstery
- ✓ Twisted fiber
- ✓ Shipping industry and fishing
- ✓ Coir rope
- ✓ Woven geotextiles
- ✓ Sound barrier applications

Animal fiber

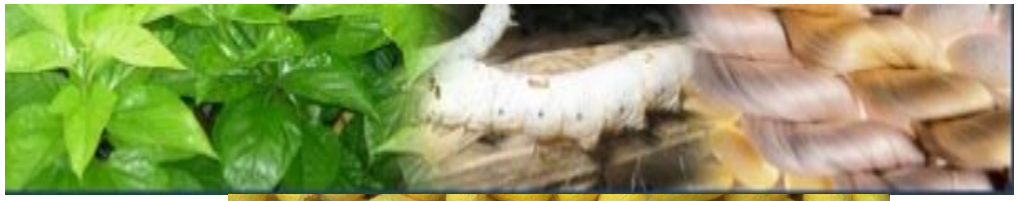
- Animal fibers are natural fibers that consist largely of proteins such as silk, hair/fur, wool and feathers.

- The most commonly used animal fibers are;

✓ Hair fibers (staple) – Wool, Specialty hair fibers
✓ Secretion fibers (Filament) – Silk, Spider silk (Insect fiber)

SILK

- Silk is one of the oldest fibers known by humankind.
- It is a natural protein fiber, which has been used in textile manufacture for at least 5,000 years.
- About 90% of commercial silk fibers employed in the textile industry come from Lepidopteran silkworms from the Bombycidae family. In the textile industry, it is commonly referred to “mulberry silk”.
- Silk is considered a premier textile material in the world due to its high tensile strength, its shine and ability to bind chemical dyes.
- Since silk is expensive, it is used in luxury apparels and high-quality specialized goods.



Types of silk:

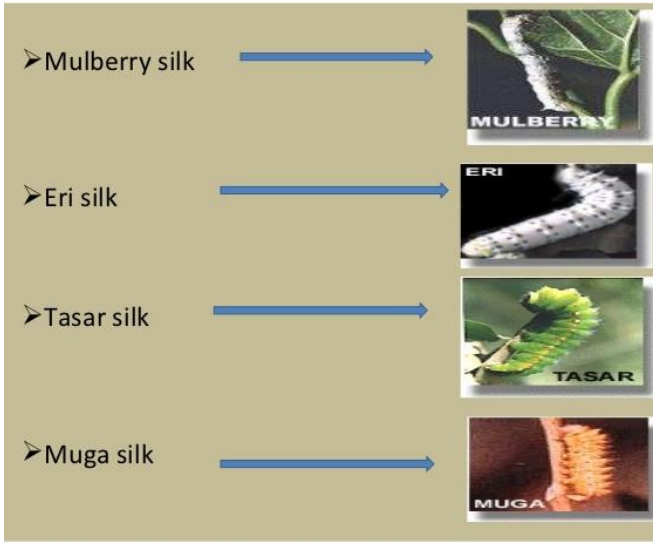
Domestic silk - Mulberry silk: This is a white to yellow colored silk. It is fine and is used mainly for apparel.

Wild silk –

Muga silk: This a golden yellow colored. It is made from the semi-cultivated silkworm, which feeds on the aromatic leaves of somand soalu plants.

Eri silk: This is from the domesticated silkworm. It feeds mainly on castor leaves.

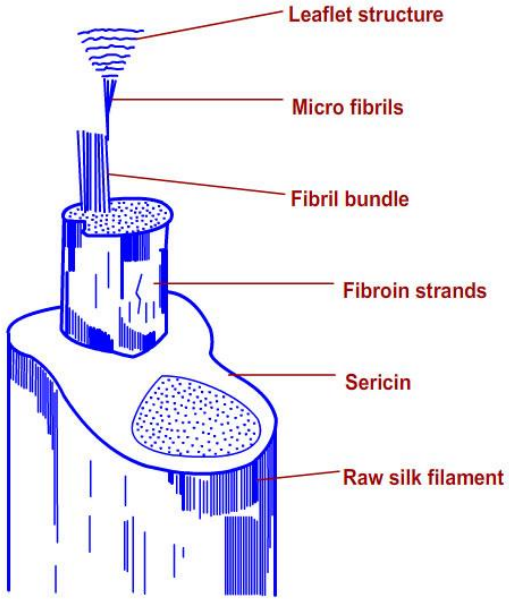
Tussar silk: It is known as Kosa silk, valued for its purity and texture. Kosa silk drawn from coccons of wild silk worm.



SILK

Life Cycle

- Silk is made of proteins secreted in the fluid state by a caterpillar, popularly know as “Silkworm”.
- Silkworms feed on the selected food plants and spin cocoons as a “protective shell” to perpetuate the life.
- It has four stages in its life cycle – Egg, caterpillar, pupa and moth.



Longitudinal View

Smooth surface, Structureless, triangular shaped transparent rod(Wild silk/Tussah silk – broader fiber with fine, longitudinal lines passing across filament)

Cross-Sectional View

Triangular shape with rounded corners(Tussah silk flat wedge or spindle-shaped

- ✓ **Fibroin** has high proportions of alanine, glycine and serine. A small amount of cystein is also present.
- ✓ There are a low proportion of amino acid residues with large side chains in silk.
- ✓ This is one of the reasons why silk absorbs relatively lower amount of acid and alkali as compared to wool.

WOOL

- Wool is the fibrous covering from sheep and is by far the most important animal fiber used in textiles.
- It is the earliest fiber to be spun and woven into cloth.
- Sheep wool comes in the form of a corrugated fiber having a diameter of 16 to 40 µm and a total length of 35–350 mm.

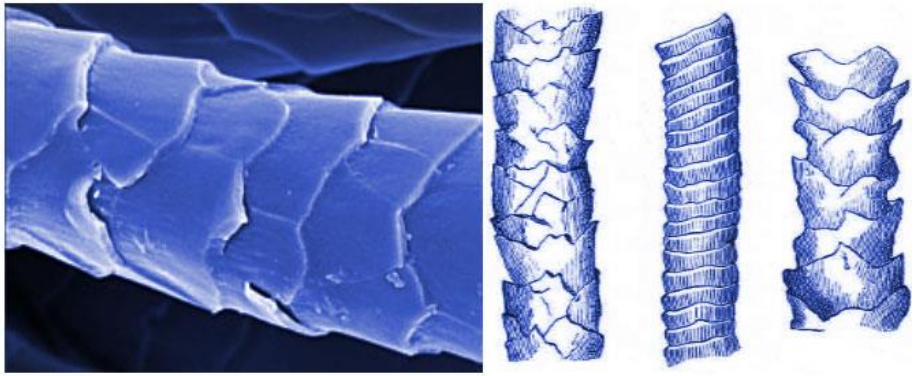
- There are two types of wool namely **clipped or fleece wool taken from live sheep** and **pulled wool removed from already dead sheep.**
- Merino wool is the best grade wool. It is 50–125 mm long. They have irregular crimp with the finer fiber generally showing lower growth rates and higher crimp.
- In addition to clothing, wool is used as carpeting, felt, insulation.

Longitudinal View

Cylindrical, irregular, rough surface, scale-like structure, dark medulla may appear on coarse wool fibers

Cross-Sectional View

Nearly round or circular, medulla may appear



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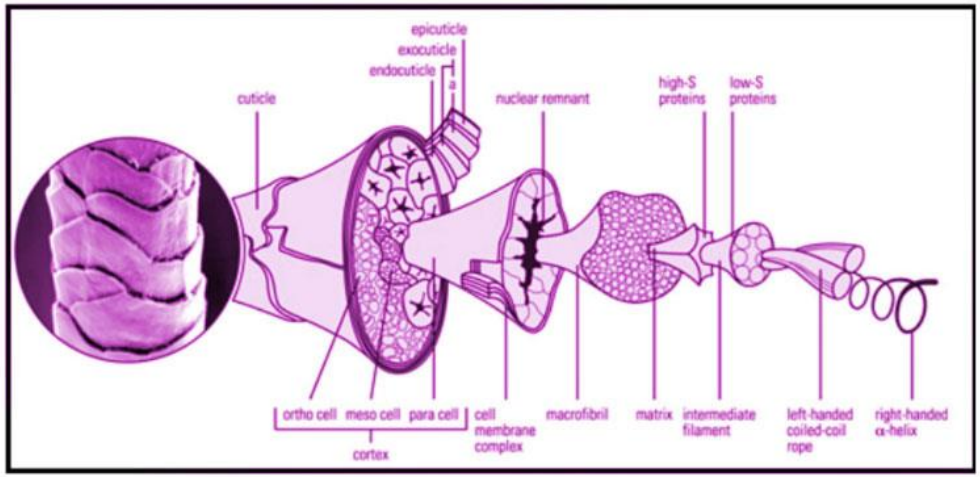
Micro-structure of Wool



The micro structure of wool fiber consists of three main components, the cuticle, cortex and medulla.

Cuticle : The cuticle is the layer of overlapping epithelial cell's surrounding the wool fiber. There are three cuticle.

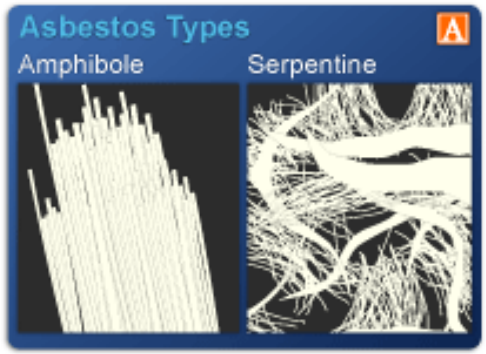
Epi Cuticle: The epicuticle is the outermost layer covers of the wool fiber.
Exocuticle : The overlapping epithelial cell forms the exocuticle.
Endocuticle: The endocuticle is the intermediate connecting layer bonding the epithelial cell of the cortex of the wool fiber.

The Cortex: The cortex or core, of the fiber forms about 90% of the fiber volume. It consists of countless, long, spindle shaped cells or cortical cells. It is composed of two regions known as ortho and para cortex. The ortho cortex absorbing more dye than para cortex. The ortho and para cortex spiral around one another. Fine wool fibers have about 20 such cells, whereas coarse wool fibers have about 50 cortical cells across diameter of their cross-section.

Medulla: Coarser fibers have a hollow space running lengthwise through the center. This is medulla.

Mineral

- Asbestos is the only natural mineral fiber obtained from varieties of rocks.
- It is fibrous form of silicate of magnesium and calcium containing iron and aluminium and other minerals.
- It is acid proof, flame proof and rust proof.
- It's particles are carcinogenic and hence it's use is restricted.



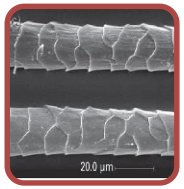
Discontinued Asbestos Products;

- ✓ Vinyl asbestos tiles
- ✓ Asbestos cement
- ✓ Asbestos roofing felt
- ✓ Asbestos reinforced plastics
- ✓ Asbestos adhesives, sealants and coatings

Microscopic images of fibers

(a) longitudinal view of cotton fibers showing their characteristic twist

(b) view of cross-sections of cotton fibers showing their characteristic dog-bone shape



(c) wool fibers showing scales on the fiber surface

(d) silk fibers showing a trilobal cross-section

(e) nylon fiber with round cross-section

(f) nylon fibers with hollow cross-sections in a woven fabric

(g) viscose rayon fiber with a multilobal cross-section

(h) acrylic fiber showing a dog-bone shaped cross-section.

Man-made fibers

- Known as Manufactured fiber.
  - ✓ Synthetic or man-made fibers generally come from synthetic materials such as petrochemicals.
  - ✓ Some types of synthetic fibers are manufactured from natural cellulose;
    - including rayon, modal, and the more recently developed Lyocell.

- A class name for various genera of fibers (including filaments) produced from fiber-forming substances which may be:
  - ✓ Polymers synthesized from chemical compounds, e.g., acrylic fiber, nylon fiber, polyester fiber, polyethylene fiber, polyurethane fiber, and polyvinyl fibers;
  - ✓ Modified or transformed natural polymers, e.g., alginic and cellulose-based fibers such as acetates fiber and rayons fiber; and
  - ✓ Minerals, e.g., glasses. The term manufactured usually refers to all chemically produced fibers to distinguish them from the truly natural fibers such as cotton, wool, silk, flax, etc. e.g: Glass fiber.

Man-made cellulosic fibers

- Rayon is manufactured regenerated cellulosic fibre.
- It has serrated round shape with smooth surface.
- It loses 30-50% of it's strength when it is wet.
- Rayon is produced from naturally occurring polymers.
- The fiber is sold as artificial silk.
- There are two principal varieties of rayon namely viscose and cupra ammonium rayon (Bemberg silk).

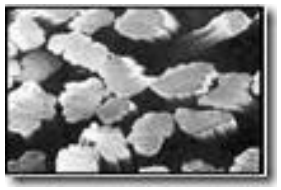
✓ **In apparel, rayon is used alone or in blends with other fibres in applications where cotton is normally used.**
✓ **High-strength rayon, produced by drawing (stretching) the filaments during manufacture to induce crystallization of the cellulose polymers, is made into tire cord for use in automobile tires.**
✓ **Rayon is also blended with wood pulp in papermaking.**

Longitudinal View
- Normal type fairly dense longitudinal striations or fine lines
- Special type-may be smooth and Structure less

Cross-Sectional View
- Irregular with a serrated outline
- Oval or round


- Acetate is a manufactured fiber in which the fiber forming substance is cellulose acetate.
- Acetate is derived from cellulose by reacting purified cellulose from wood pulp with acetic acid and acetic anhydride in the presence of sulfuric acid.

✓ **It is used in apparel blouses, dresses, linings, wedding and party attire, home furnishings, draperies, upholstery and slip covers etc.**
✓ **It is also used in high absorbency products like diapers, feminine hygiene products, cigarette filters, surgical products, and other filters.**



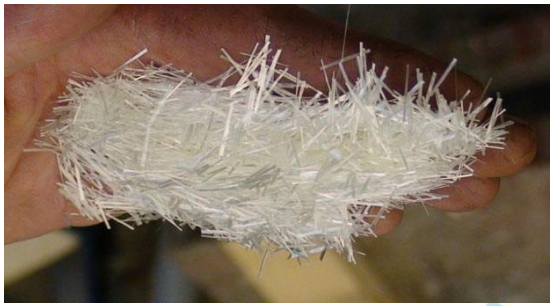
Longitudinal View
Uniform in width with a few distinct longitudinal striations

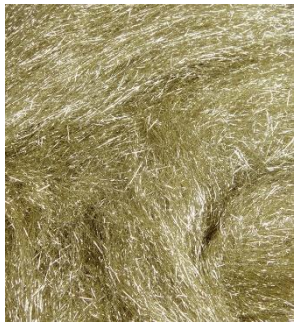
Cross-Sectional View
Irregular with a serrated outline

Synthetic fibers

❑ Inorganic fibers

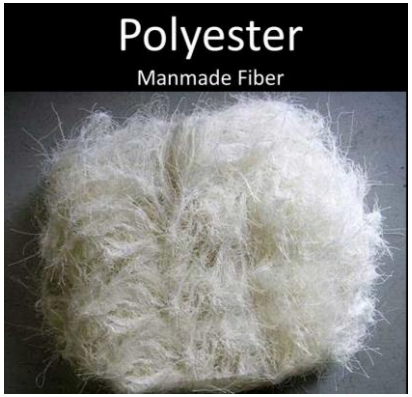
- ❖ Glass – Silica sand, limestone and other minerals
- ❖ Ceramic – Alumina, Silica and Graphite fibers – carbon
- ❖ Metallic fibers – Aliminum, Silver, Gold and Stainless Steel





❑ Man-made synthetic fibers

- ✓ Polyamides – Nylon 6, 6.6, 6.10 etc.,
- ✓ Polyester – Terylene, Terene, Dacron etc.,
- ✓ Polyvinyl derivates
- ✓ Polyvinylchloride
- ✓ Polyvinylchloride acetate
- ✓ Polyvinylchloride – Acrylonitrile
- ✓ Polyacrylonitrile
- ✓ Polyvinyl alcohol
- ✓ Polystyrene and copolymers
- ✓ Polyvinylide chloride and copolymers
- ✓ Polyolefins
- ✓ Polyethylene
- ✓ Polypropylene



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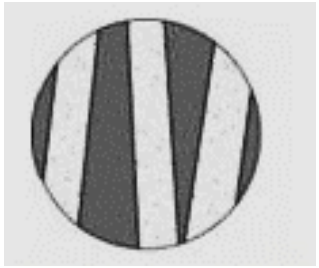
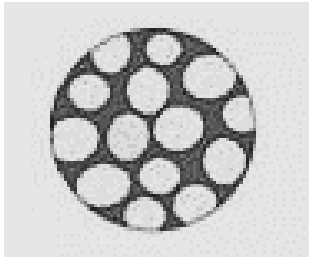
Polyester

- Polyester (polyethylene terephthalate) is derived from a chemical reaction involving petroleum, air, and water. This artificial fiber is comprised of purified terephthalic acid (PTA) and monoethylene glycol (MEG).
- Fiber strength can range from 2.5 grams/denier to 9.5 grams/denier.
- Polyester is the most used synthetic fiber.
- The fiber can be manufactured in different shapes and sizes for specific purposes.
- It has Good elasticity, wrinkle resistance, shape retention, excellent wash-and-wear performance and durability.



Longitudinal View
Structureless, uniform diameter, rod-like appearance



Cross-Sectional View
Circular

Uses of polyester fiber;

- ✓ **Apparel:** Every form of clothing
- ✓ **Home Furnishings:** Carpets, curtains, draperies, sheets and pillow cases, wall coverings, and upholstery
- ✓ **Other Uses:** Hoses, power belting, ropes and nets, thread, tire cord, auto upholstery, sails, floppy disk liners, and fiberfill for various products including pillows and furniture

Nylon

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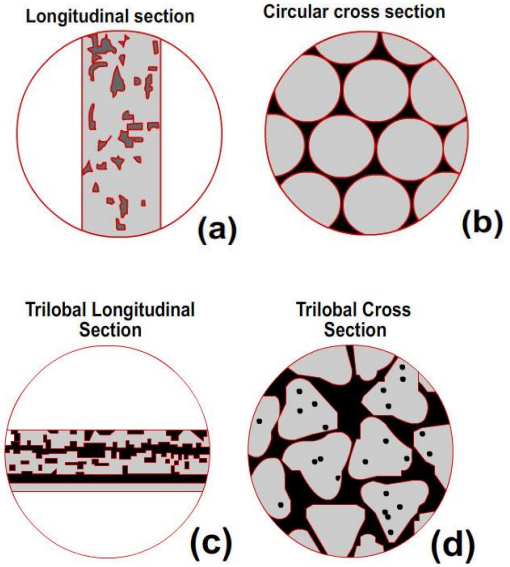
- Nylon is one of the most common polymers used as a fiber.
- There are several forms of nylon depending upon chemical synthesis such as **nylon 4, 6, 6.6, 6.10, 6.12, 8, 10, 11.**
- Nylons are also called as **polyamides** because of the characteristic amide groups in their backbone chain. These amide groups are polar and are linked with each other with hydrogen bonds.
- Nylon is a **regular and symmetrical fiber with crystalline regions.**



Longitudinal View

Structureless, uniform diameter, rod-like appearance

Cross-Sectional View

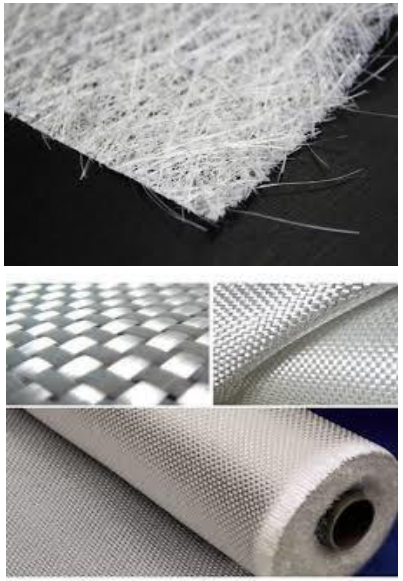
Circular

Some Major Nylon Fiber Uses;

- ✓ **Apparel:** Blouses, dresses, foundation garments, hosiery, lingerie, underwear, raincoats, ski apparel, windbreakers, swimwear, and cycle wear .
- ✓ **Home Furnishings:** Bedspreads, carpets, curtains, upholstery
- ✓ **Industrial and Other Uses:** Tire cord, hoses, conveyer and seat belts, parachutes, racket strings, ropes and nets, sleeping bags, tarpaulins, tents, thread, mono filament fishing line, dental floss.

Glass

- Glass fiber also called **fiberglass**. It is material made from extremely fine fibers of glass Fiberglass is a lightweight, extremely strong, and robust material.
- Glass is the oldest, and most familiar, performance fiber. Fibers have been manufactured from glass since the 1930s.
- Generally, glass consists of quartz sand, soda, sodium sulphate, potash, feldspar and a number of refining and dying additives.



Types of Glass Fiber

As to the raw material glass used to make glass fibers or nonwovens of glass fibers, the following classification is known:

1. **A-glass**: With regard to its composition, it is close to window glass. In the Federal Republic of Germany it is mainly used in the manufacture of process equipment.
2. **C-glass**: This kind of glass shows better resistance to chemical impact.
3. **E-glass**: This kind of glass combines the characteristics of C-glass with very good insulation to electricity.
4. **AE-glass**: Alkali resistant glass.

Glass fibers are used for various purpose (Uses are based on types of glass fiber);

- ✓ For making home furnishing fabrics;
- ✓ For making apparels and garments; and
- ✓ For the purpose tires and reinforced plastics.
- ✓ Composites

Metallic

- Metallic fibers, known generically as metallic, including manufactured fibers composed of metal, metal-coated plastic,or of a core covered by metal (usually aluminum).

- Metallic fibers are;
  - ✓ usually washable
  - ✓ requires low temperatures when ironed
  - ✓ dry-cleaned with most of the common cleaning solvents.
  - ✓ resistant to attack by insects and microorganisms.

- Metallic fibers are usually combined with others for decorative effect.
- Such combinations are used for knitting yarns, trimmings, and ribbons; in such apparel as knitwear, evening gowns, swimsuits, and neckties; and in such home furnishings as curtains, upholstery, and tablecloths. Industrial applications include automotive upholstery, theatre curtains, and grilles for radio and television sets.

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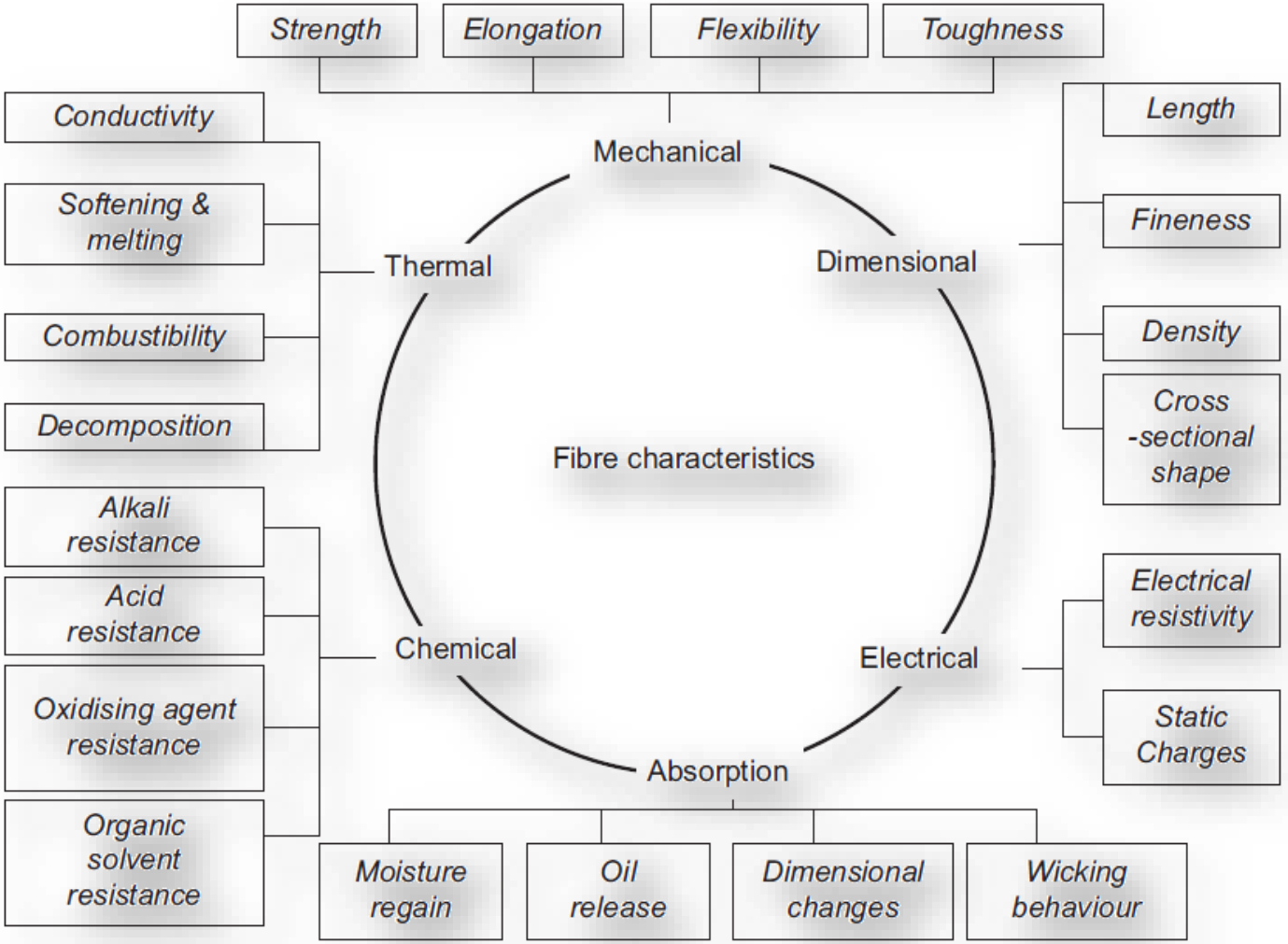
Textile fibers

PROPERTIES

Properties of fibers



Physical and Mechanical Properties

1. Length, shape and diameter (fineness)
2. Colour and lustre
3. Strength and flexibility
4. Abrasion resistance
5. Handle (or feel)
   - e.g. soft (cashmere); harsh (coir); crisp (linen); elastic (Lycra)
6. Moisture absorbency
7. Electrical properties

Cross-sectional shapes of fibers

Flat, oval, lumen, convolutions

Cotton

Oval to round, overlapping scales

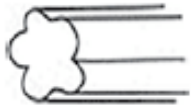
Wool

Triangular, rounded edges

Silk

Polygonal, lumen

Flax



Lobular, length wise striations

Acetate

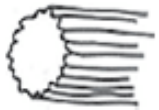
Circular, uniform in diameter

Nylon, polyester, lyocell

Lima bean, smooth

Trilobal

Antron (TM) nylon



Circular, serrated, lengthwise striations

Rayon

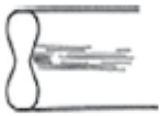
Lima bean, serrated

Avril (TM) rayon

Flat, broad

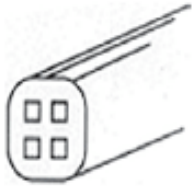
Acetate

Collapsed tube, hollow center



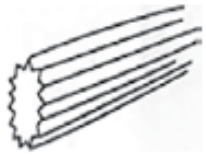
Dog-bone

Acrylic, Spandex



Square with voids

Anso IV (TM) nylon



Star or concertina

Fiber fineness

- Two ways of measuring the fineness of textile fibers.
  - Measure the diameters of a sample of the fibers and express the result as the average of these diameters.
    - ✓ Usually used for wool and animal hairs
    - ✓ The most usual unit is the micron (µm), which is one millionth of a metre.
      - ❖ As an example, fine Merino wool would have a diameter of between 18 and 20 µm.
  - Weight per unit length, such as denier or tex.
    - ✓ Applies particularly to filaments such as silk and certain synthetic fibers such as polyester and nylon
    - ✓ A denier is the weight in grams of 9000 m of filament or fiber.
      - ❖ An example is ladies 15 denier nylon stockings, which vary from about 1.3 denier to 2.5 denier.
    - ✓ The tex system, expressed in grams per 1000 m
      - ❖ Applied to fibers, especially in scientific and technical circles. Since fibers are usually very fine, millitex is more often used (1000 millitex = 1 tex).

fiber Density

Textile Fibers	Fiber Densities (g/cm^3)
Cotton	1.54
Flax	1.50
Jute	1.50
Wool	1.30
Silk	1.60
Polyester	1.22
Viscose	1.53
Cuprammonium	1.53
Polyurethane	1.15
Polypropylene	0.90
Polyethylene	0.92
Nylon 6	1.13
Nylon 66	1.14
Acrylic	1.14-1.17
Polyvinyl Alcohol	1.30

Tensile Strength & Extension

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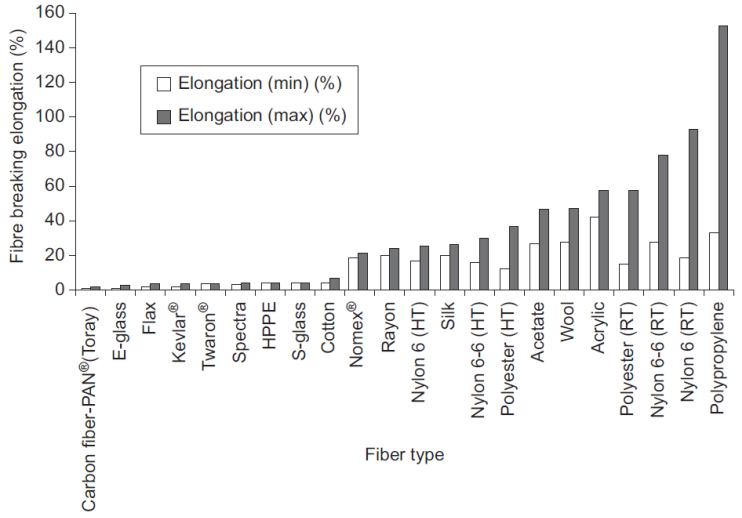
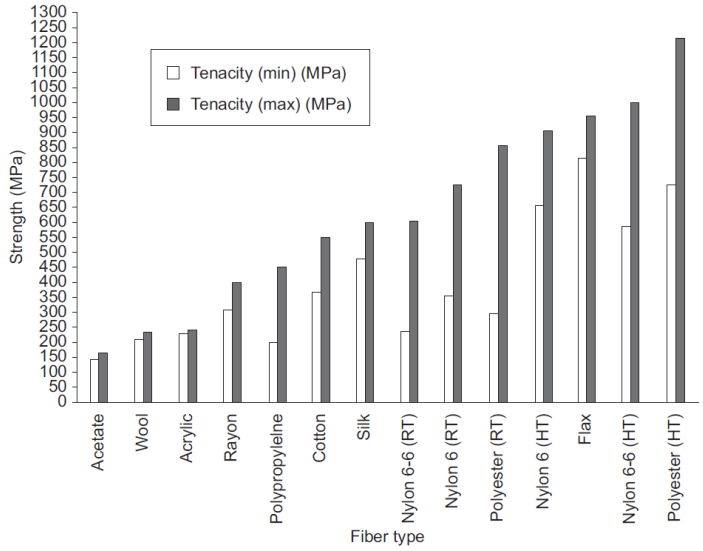
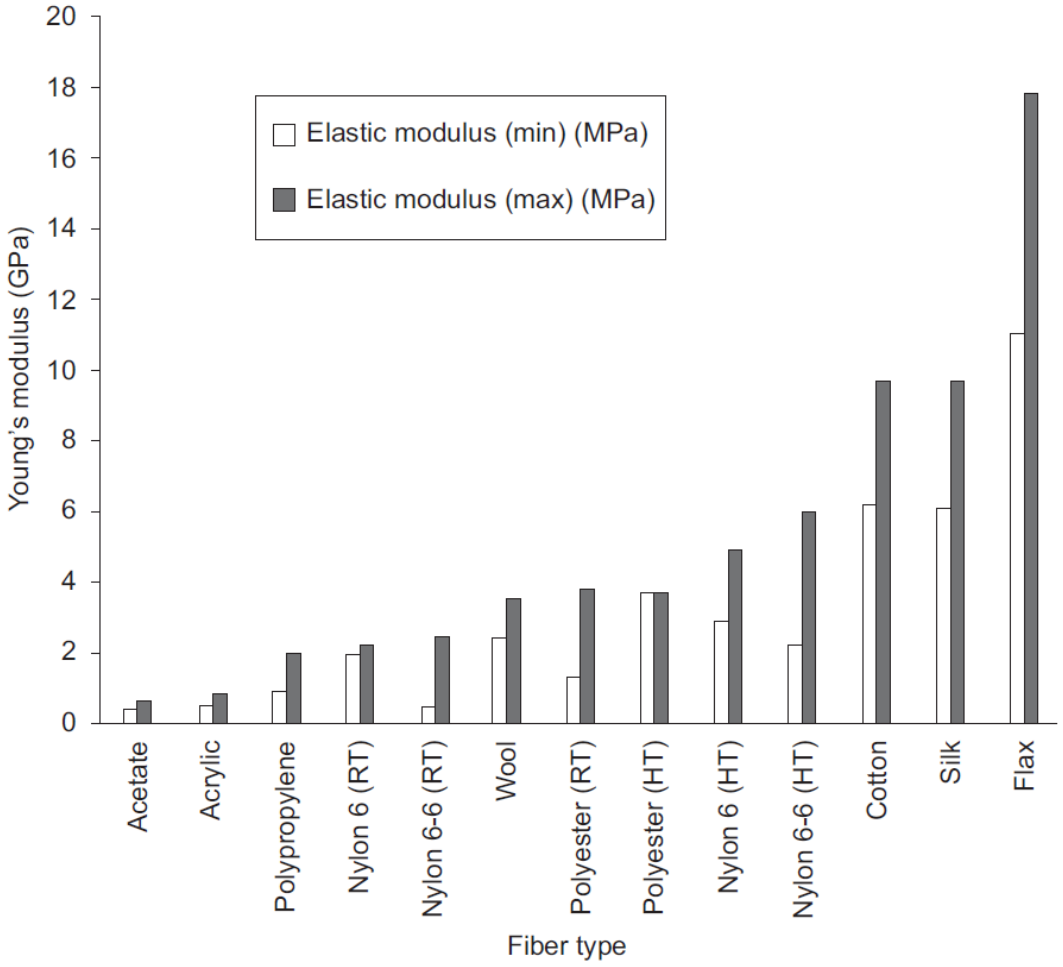
- The resistance to breaking, when a fiber is stretched, is called its 'tensile strength'.
  - ✓ Measured by exerting force, in the form of weights or springs, on the fiber or yarn.
  - ✓ Noting both the extension of the fiber when it reaches breaking point.
  - ✓ This is called 'elongation at break' or 'breaking elongation', and the force required to achieve this.





Flexibility & Stiffness

- Fiber flexibility is a function of the chemical and physical structure of the fiber, and in particular the thickness and cross-sectional shape of the fiber.
  - 'Modulus' is a way of assessing the stiffness or flexibility of a fiber by measuring the fiber's initial resistance to a tensile force. It is measured in units of stress, i.e. force per unit area.
  - Units of measurement Include N/tex, GPa or Mpa. GPa and MPa stand for gigapascals and megapascals.



Elasticity & Resiliency

ELASTICITY

- If a fiber is stretched and then released, it will tend to recover some, or all, of its original length, depending upon the degree of stretch and the inherent elasticity of the fiber. There are two basic types of 'recovery':
  - ✓ Elastic recovery, which occurs virtually instantly after the stress is removed
  - ✓ Creep recovery, which occurs gradually after the stress is removed
- Quantified by measuring the reduction in extension of a fiber once a particular amount of applied force is removed, e.g. 50% recovery after 5% stretch.
- An elastomeric fiber is defined as having high extensibility, with rapid and substantially complete elastic recovery. Fibers with similar elongation can have different degrees of elastic recovery.

RESILIENCY

- Resiliency is a measure of the ability of a fiber to recover its original position after it is distorted, e.g. by bending, twisting or compression.
- A high elastic recovery is often associated with good resiliency.
  - ✓ Nylon has a good tensile modulus, elongation, recovery and resiliency, which make it ideal as a hosiery fabric, stretching easily to provide a close but comfortable fit, and recovering its original shape without wrinkling or bagging.

Abrasion Resistance

- Abrasion is the rubbing or friction of fibers against one another or other materials.
- Abrasion resistance is related to 'toughness', which is a function of the tenacity and elongation to break of a fiber. fibers and fabrics can be subjected to three main types of abrasion:
  - ❖ Flat abrasion, as a result of surface rubbing
  - ❖ Flex abrasion, as a result of bending, flexing or folding
  - ❖ Edge abrasion, such as wear of the fabric edges at collars, cuffs, and so on
- Some fibers have better abrasion resistance than others. For example Nylon and wool.

Moisture Absorbency

- 'Moisture regain' is the ability of a dry fiber to absorb moisture under set conditions of humidity.
  - fibers divided into two groups:
    - ✓ Those with a high regain, which absorb water or moisture easily and are known as 'hydrophilic' (i.e. water loving) fibers.
    - ✓ Those with a low regain, which absorb water or moisture less easily, or not at all, and are known as 'hydrophobic' (i.e. water hating) fibers.

- Determined by using the following equation:

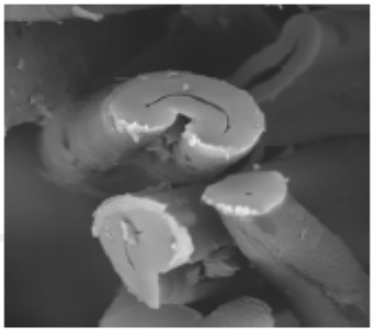
$$\text{Regain } (\%) = \frac{\text{Mass of conditioned specimen} - \text{Mass of dry specimen}}{\text{Mass of dry specimen}} \times 100$$

Thermal Properties of fibers

- The response of fibers to heat depends on their chemical composition.
- Fibers can be divided into two broad categories:
  - ✓ Thermoplastics, which soften and then melt at higher than certain temperatures, the actual temperature depending on the fiber.
  - ✓ Non-thermoplastics, which tend to char and become brittle, rather than soften or melt, at high temperature.
- The application of heat to a fiber results in a loss of strength in the fiber. This can be measured by relating fiber strength to temperature and/or time:
  - ✓ Thermoplastics: An example would be ‘retains 50% of its strength at 150 °C’.
  - ✓ Non-thermoplastics: An example would be ‘retains 50% of its strength after 50 h at 150 °C’.

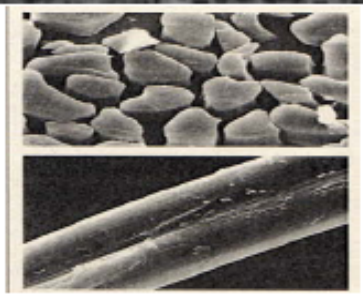
Fiber characteristics - I

Cotton: Strong, absorbent, comfortable and versatile. Wrinkles easily. May shrink unless treated. Sensitive to mildew and to silverfish (common insect pest that causes damage to cellulosic textile fibers is the "**silverfish").**

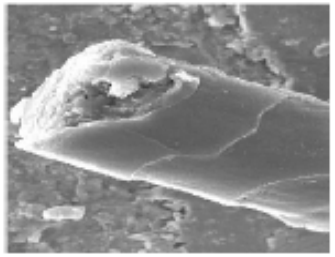


Linen: Very absorbent, strong and durable. Sometimes stiff and wrinkles easily. Generally resist insects. Sensitive to mildew.

Silk: Strong, absorbent, soft and lightweight. Resists soil and wrinkling. Sensitive to perspiration (sweat), moths and beetles. Some silks may water spot.

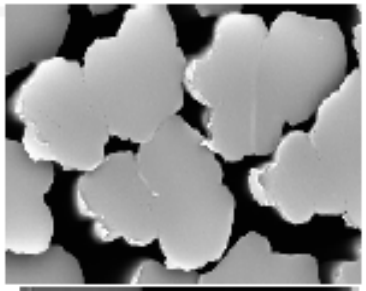


Wool: A natural insulator, can be easily molded and shaped, absorbent, resilient and wrinkle resistant. Sensitive to mildew, moths and beetles.

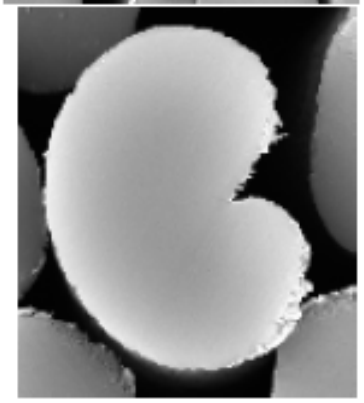


Fiber characteristics - II

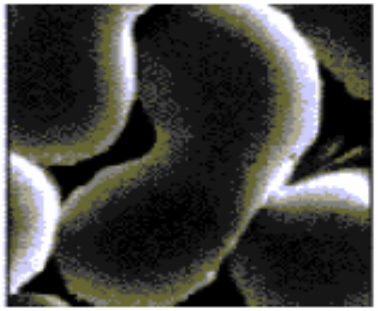
Acetate: Silk-like, soft and drapable. Relatively fast drying. Shrink and moth resistant. Sensitive to heat, silverfish, mildew and acetone (nail polish remover).



Acrylic: Soft, warm, bulky properties resembling wool. Retains shape, dries quickly and wrinkle resistant. Resists sunlight, mildew and insects. Sometimes has the tendency to pill. Sensitive to heat.

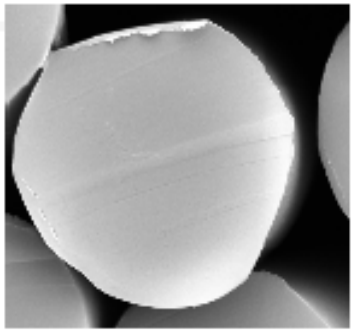


Modacrylic: Soft, resilient, quick drying and flame-resistant. Resists mildew and moths. Sensitive to heat and acetone, collects static electricity, may pill excessively and non-absorbent.

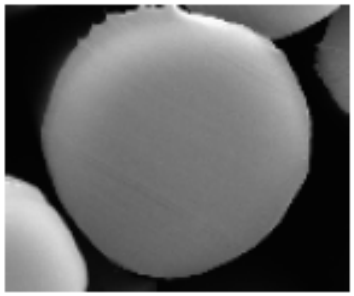


Fiber characteristics - III

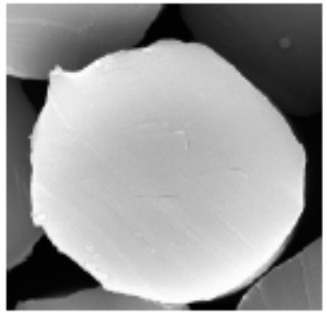
Polyamides: Exceptionally strong and durable. Abrasion resistant, retains shape and resistant to moths and mildew. Absorbs and holds body oils, collects static electricity, tends to yellow, may pill and has low moisture absorbency. Sensitive to some insects (ants).



Olefin: Strong, lightweight, comfortable and good insulator. Abrasion-resistant and quick drying. Resistant to mildew, insects, soils and stains. Sensitive to heat and may pill.



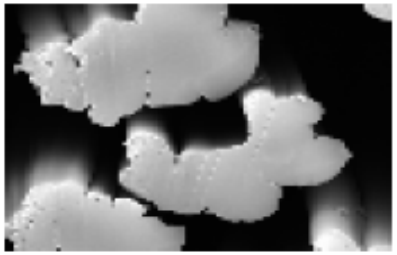
Polyester: Strong and resists wrinkling, abrasion, shrinking, stretching and mildew. Generally insect resistant. Collects static electricity, sensitive to heat, absorbs and holds body oils and may pill.



Fiber characteristics - IV

Viscose (Rayon): Highly absorbent, soft, comfortable and drapable. Some rayons wrinkle easily and become weak when wet. Sensitive to mildew and silverfish.

Spandex: Strong, durable, lightweight and high degree of stretch. Resists wrinkling, abrasion and body oils. Tends to yellow with time.



Triacetate: Drapable. Resists shrinking, stretching and wrinkling. Low strength. Sensitive to heat, mildew, silverfish and acetone.

Abbreviations

In Czech	ISO standard (DIN)	Czech standard (ČSN) not valid	In English
vlněné	WO	vl	Wool
Přírodní hedvábí	SE	ph	Natural silk
bavlněné	CO	ba	Cotton
lněné	LI	ln	Linen/Flax
konopné	HA	ko	Hemp
jutové	JU	ju	Jute
ramiové	RA	ra	Ramie
alginátové	ALG	al	Alginate
viskózové	CV	VS	Viscose
akrylové	PAN	PAN	Acrylic
teflonové	PTFE	-	Fluorofiber
polyamidové	PA	PAD	Polyamide (nylon)
aramidové	AR	-	Aramid
polyesterové	PES	PES	Polyester
polypropylenové	PP	POP	Polypropylene
polyetylénové	PE	POE	Polyethylene
polyuretanové	EL	PUR	Elastane
skleněné	GL	-	Glass fiber
kovové	MTF	ko	Metal fiber

References

- R. Sinclair, Understanding Textile fibers and their Properties: What is a Textile fiber? Textiles and Fashion, Materials, Design and Technology, Woodhead Publishing Series in Textiles, 2015, Pages 3-27.
- Identification of Textile Fibers,1st Edition, Editors: M M Houck, Woodhead Publishing in Textiles, January 2009, ISBN: 9781845695651.