

Unit 3.1 Natural Fibres

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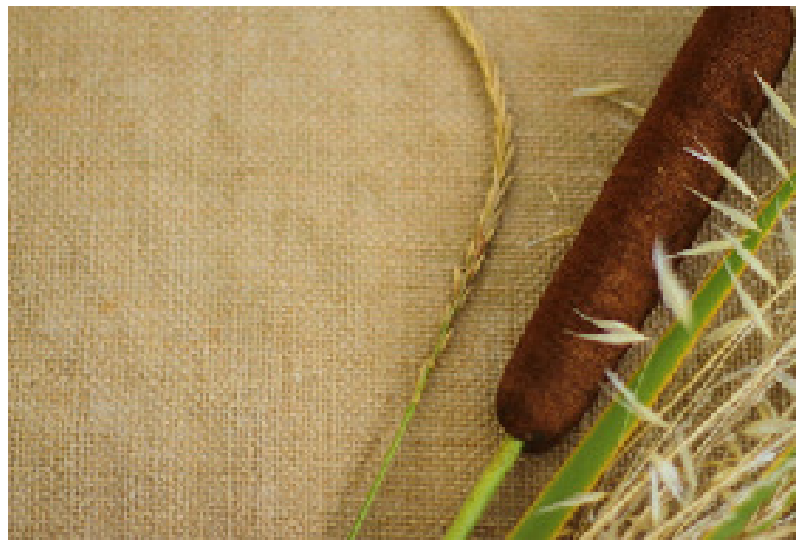
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3.1.1 Cellulose fibres

Fibers from plant or vegetable sources are more properly referred to as cellulose-based and can be further classified by plant source. They may be separated from the plant stalk, stem, leaf, or seed.^{1,2}

Cellulose is the basic scaffolding of all plants. It is formed through photosynthesis³.



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3.1.1.1 Seed hair: Cotton, Kapok

There are four different types of cotton, each with its own characteristics(Figure 1)^{1,2}:

Pima cotton. Considered the finest type of cotton in the world, pima cotton's fibers are extra soft and extra long. Pima cotton fabric is very highly-sought after, as it is resistant to fading, tearing, and wrinkling.

Egyptian cotton. Egyptian cotton is very similar to pima cotton. The two are even in the same scientific class: *Gossypium barbadense*. It has the same resistant qualities, but it is grown in the Nile River Valley in Egypt.

Upland cotton. Upland cotton has very short fibers and makes up about 90% of the world's total cotton production.

„Organic“ cotton. Eco cotton is any type of cotton that is grown without chemicals and from plants that are not genetically engineered.



Figure 1. Seed hair-cotton fibre^{1,2}

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Characteristics of Cotton fibre

- ▶ Cotton (Figure 2)^{1,2} has a number of distinguishing characteristics that make it such a popular fiber in the textile industry.
- ▶ Softness. The cotton plant is soft and fluffy and results in a fabric often retains that soft feel.
- ▶ Durability. The cotton plant's cellular structure is strong, creating a tough and wear-and-tear resistant fabric.
- ▶ Absorbency. Cotton fabric is very absorbent fabric because there is a lot of space between the cotton fibers.
- ▶ Holds dye well. Due to its absorbent nature, cotton takes dye very easily and can be made into a wide variety of colors.
- ▶ Breathability. The fiber structure of cotton makes it more breathable than synthetic fibers.
- ▶ No static cling. Cotton does not conduct electricity, therefore static is not an issue with cotton.



Figure 2. Cotton fibre^{1,2}

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Kapok fibre

Seed fibre from the Kapok tree.

Kapok fibre cannot be spun into yarns because they are very weak (Figure 3)^{1,2}. Their density is only 0.35 [g/cm³], due to the large air-filled lumen.

The fibres are water repellent, fine, soft, and lustrous.



Figure 3. Kapok fibre^{1,2}

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3.1.1.2 Bast fibres: flax, hemp, jute, ramie, nettle



Figure 4. Bast fibres^{1,2}

- ▶ Bast fibers are a great sustainable alternative to the synthetic materials we commonly use today. Here are three bast varieties that can make great eco-friendly towels and textiles.
- ▶ The bast fibers are gained from the vegetative part of the plant: stems of flax, linen or hemp plants. Consequently the quality parameters for these fibers are developed before the harvest of the fruits.

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Flax fibre

- ▶ Flax belongs to a class called the bast fibres, a name given to certain fibres obtained from the inner bark of different plants. Jute also is a bast fibre. The finer qualities of it look like flax, but, as we shall see, it is not chemically identical with cotton, as linen or flax is (Figure 5)^{1,2}.
- ▶ As a natural fibre, flax has passed through centuries without ever getting old. Due to the way it is grown, its appearance, its resistance and thermal qualities, it has been widely used in many industries. Flax is a plant recognised for its properties throughout its entire life cycle.



Figure 5. Flax fibre^{1,2}

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Hemp fibre

- ▶ Hemp fabric is a sustainable textile made of fibres of a very high-yielding crop in the cannabis sativa plant family. Historically used for industrial purposes, like rope and sails, hemp is known as one of the most versatile and durable natural fibres.
- ▶ Growing and processing of hemp fibre does not involve use of pesticides and other chemicals. This makes hemp fibre a natural and environmentally friendly product.

Its main properties are:

- ▶ Sustainable and environmentally friendly fibre;
- ▶ One of the strongest and most durable natural textile fibres;
- ▶ Absorbs moisture, prevents bacteria formation;
- ▶ Blocks ultraviolet rays;
- ▶ Superior durability;
- ▶ Easily recyclable.



Figure 6. Hemp fibre^{4,5}

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Jute fibre

- ▶ Jute is known as the 'Golden Fibre' due to its golden brown colour and its importance. In terms of usage, production and global consumption, jute is second only to cotton. It is the fibre used to make hessian sacks and garden twine.
- ▶ Jute is environmentally friendly as well as being one of the most affordable fibres;
- ▶ Jute plants are easy to grow, have a high yield per acre and, unlike cotton, have little need for pesticides and fertilizers. Jute is a bast fibre, like flax and hemp, and the stems are processed in a similar way.



Figure 7. Jute fibre^{3,6}

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Ramie fibre

- ▶ The fibre is very fine like silk, and being naturally white in colour does not need. Ramie is often blended with cotton to make woven and knit fabrics that resemble fine linen to coarse canvas.
- ▶ Ramie is one of the strongest natural fibres. It exhibits even greater strength when wet.
- ▶ Ramie fibre is known especially for its ability to hold shape, reduce wrinkling, and introduce a silky luster to the fabric appearance.



Figure 8. Ramie fibre^{7,8}

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Table 1. Properties of Plant Natural Fibre²

| Properties | Fibre | | | |
|--|----------|---------|---------|-------|
| | Flax | Hemp | Jute | Ramie |
| Density, g/cm ³ | 1.4 | 1.48 | 1.46 | 1.5 |
| Tensile Strength* 10E6, N/m ² | 800-1500 | 550-900 | 400-800 | 500 |
| E-modulus, GPa | 60-80 | 70 | 10-30 | 44 |
| Elongation at Failure, % | 1.2-1.6 | 1.6 | 1.8 | 2.0 |
| Moisture Absorbtion, % | 7 | 8 | 12 | 12-17 |

*Tensile strength strongly depends on type of fibre, being a bundle or single filament

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Nettle fibre

- ▶ Nettle fibres have been labelled the material of the future, being ecologically friendly, sustainable(Figure 9)^{7,8}.
- ▶ The fibres come from the nettle plant stem. The stem is cut and the bark removed allowing the fibre to be extracted with all the thorn-like stinging hairs removed.
- ▶ These fibres are then carded and spun producing a very strong cord useful for string, rope or fishing nets. For yarns, these fibres are usually blended with cotton or wool.



Figure 9. Nettle fibre^{9,10}

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3.1.1.3 Leaf and other cellulose fibres: sisal, manila, coir, peat



Leaf fibers or hard fibers are a type of plant fibre mainly used for cordage (producing rope). They are the toughest of the plant fibres which is most likely due to their increased lignin content when compared to the other groups of plant fibres.

They are typically characterized as being very tough and rigid lending them towards being used in rope production over clothing or paper like other plant fibre.

Figure 10. Leaf fibres^{1,2}

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Sisal fibre

- ▶ Sisal fibre is a vegetable fiber having specific strength and stiffness that compare well with those of glass fiber.
- ▶ Leaf fibre from the leaves of the sisal plant, a type of agave.
- ▶ Sisal fibres have a high strength and abrasion resistance. They are white in colour, easy to dye, and have good resistance to sea water.

Applications: Sisal is used for ropes, carpets, nets, and matting.



Figure 11. Sisal fibre^{1,2}

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Manila fibre



Leaf fibre from the leaves of a type of banana (Abaca).

Manila fibre e have stronger than sisal. They are very resistance to sea water.

Manila is used for teabags, banknotes and reinforced plastics, for marine cables and other ropes, also for nets and matting.



Figure 12. Manila fibre^{1,11}

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Coir fibre

Seed fibre from coconut palm. Coir fibre have a very high abrasion resistance, are very durable and have good elasticity. They do not soil easily, are good insulators and are resistant to rotting. They are often used in the raw form.

Coir is used primarily for padding materials in the automobile industry, but also for stair-carpets, doormats, floor coverings, stuffed furniture backings, and brushes.



Figure 13. Coir fibre^{1,2,11}

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Peat fibre

- ▶ Peat fibre is an ecologically sustainable Finnish alternative with a low carbon footprint, and it allows energy-efficient production.
- ▶ Peat fibre is naturally mould-resistant, requiring no added chemicals to prevent mould fungus growth. When it dries, it becomes water-repellent.
- ▶ Peat fibre is also a suitable ingredient for different construction, decoration and acoustic boards as well as nonwoven fibre fabrics, compression molding products and composites.

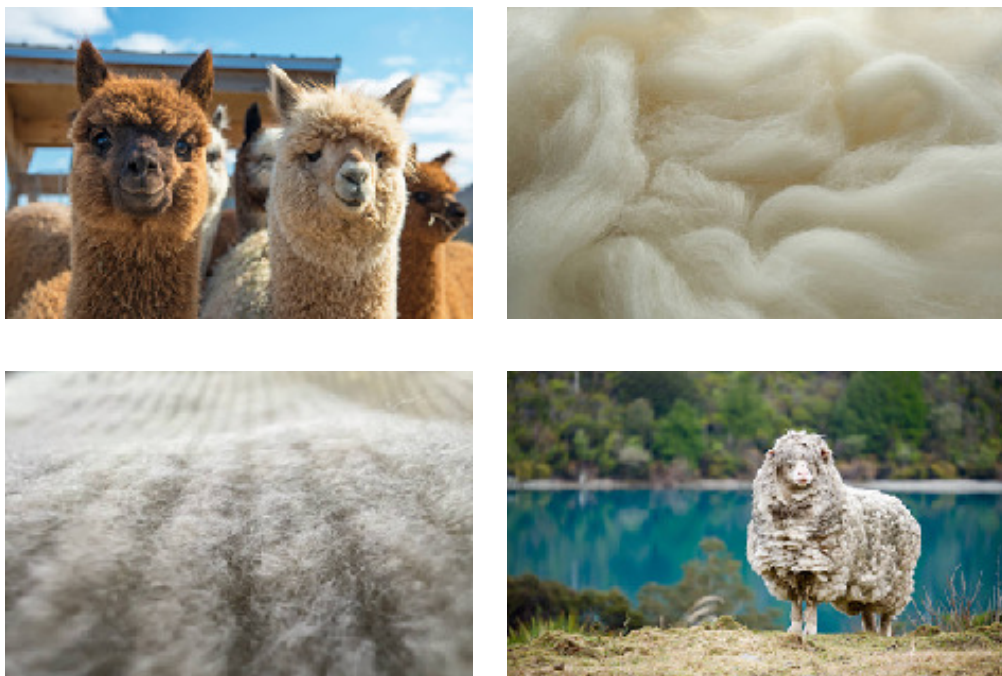


Figure 14. Peat fibre¹²

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3.1.2 Protein fibres

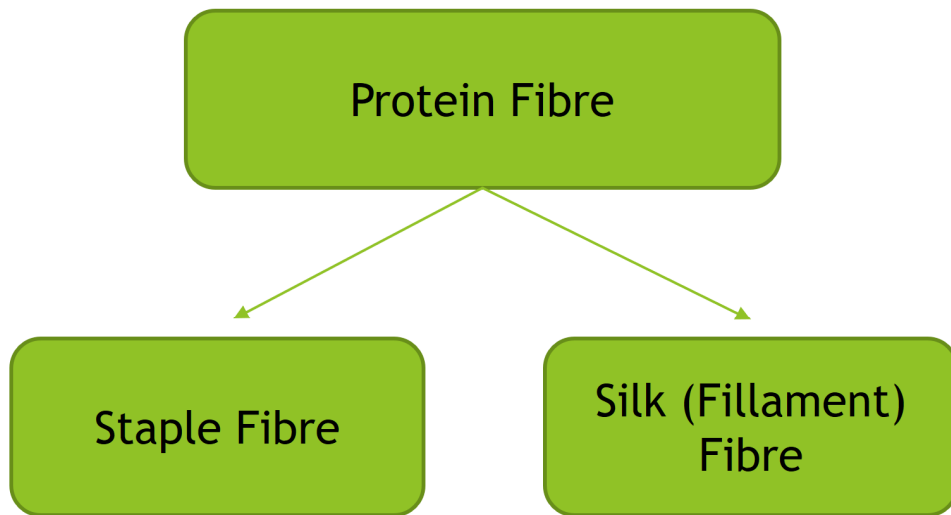


- ▶ Natural fibers include those produced by plants, animals, and geological processes. They are biodegradable over time. They can be classified according to their origin.
- ▶ Fibers from animal sources are more properly known as protein-based fibers. They are harvested from an animal or removed from a cocoon or web.

Figure 15. Protein fibres^{1,2,11}

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- ▶ Wool and silk fibers differ in many perspectives. Wool fiber is formed by keratin protein and growth from an outer skin layer like from a sheep or goat. Silk fiber is a protein fiber from silk glands of an insect.
- ▶ Protein-based fibers are from animal sources, most commonly the hair of the animal. Animal-hair fibers are long-staple fibers, ranging in length from 2.5 to 10 inches or more.
- ▶ Silk is a natural protein fiber extruded by the silk worm. With a length of over 500 yards, it is classified as a filament fiber.

Figure 16. Protein fibres classification^{1,11}

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Keratin fibres: sheep, goat, camel, alpaca, lama and other wool

Keratin fibres, such as wool, alpaca and human hair, have complex structures and morphologies. The fibre surface is covered with scales (Figure 17), which are collectively referred to as cuticles.

Fibers from animal sources are more properly known as protein-based fibers. They are harvested from an animal or removed from a cocoon or web.

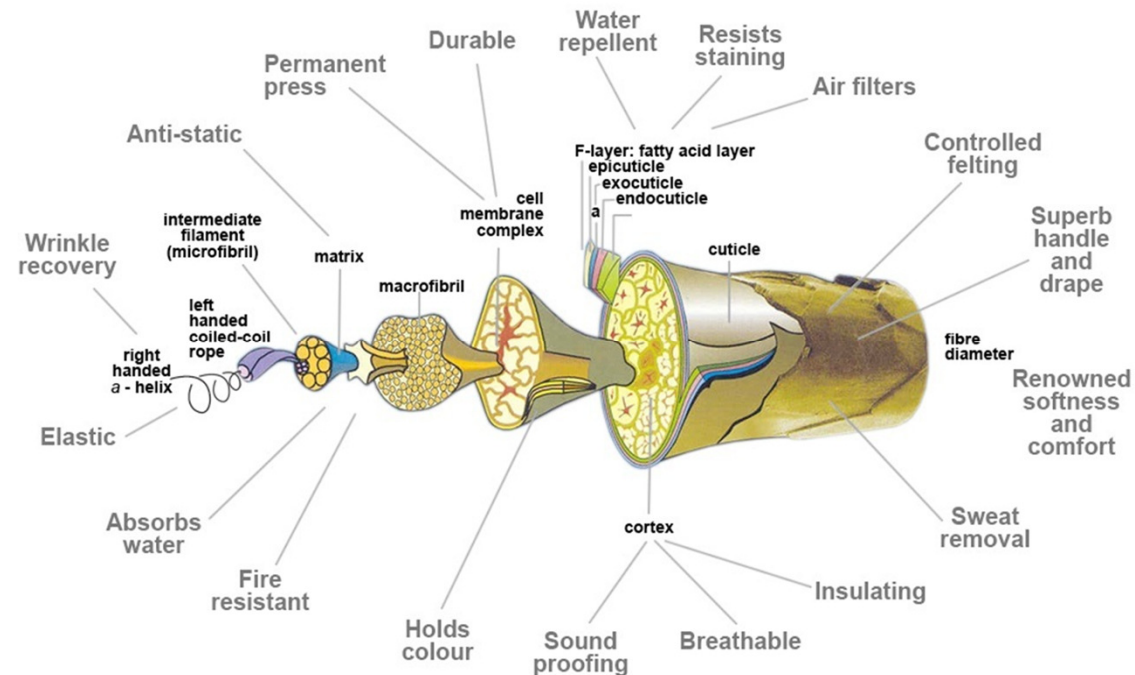
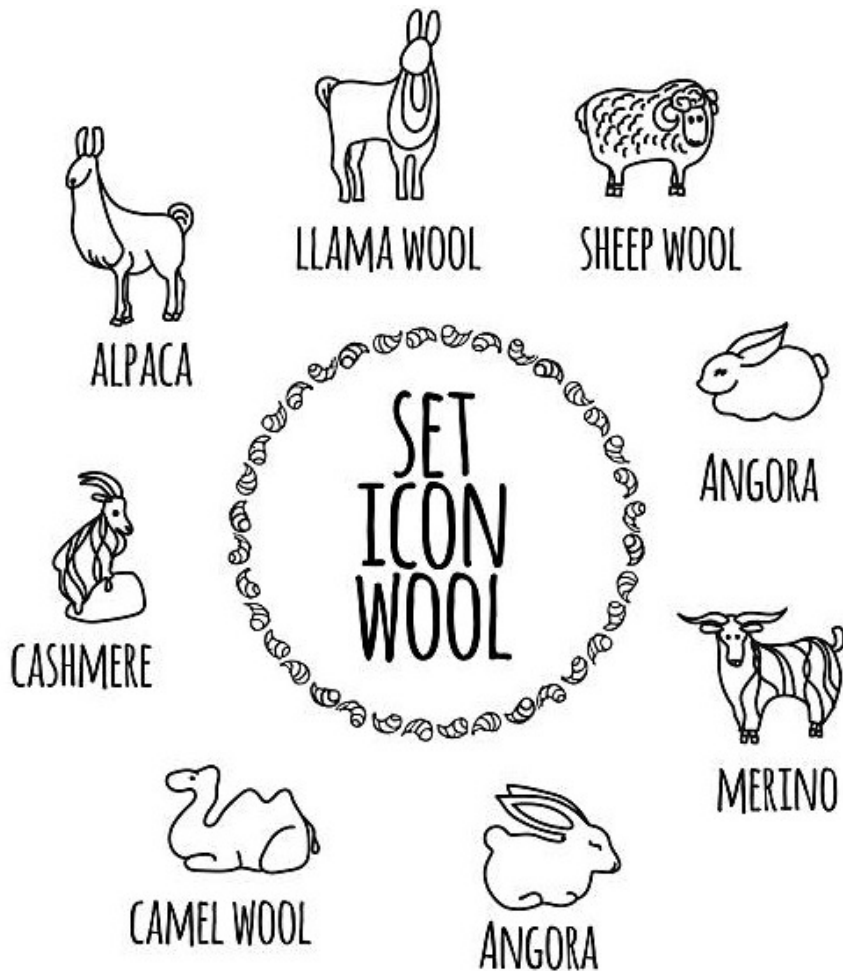


Figure 17. Structure of wool fibre¹³

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Wool is a fine hair fiber from sheep. In labeling, the term “wool” also may be used to identify fibers from other fleece animals, such as the Angora goat, Cashmere goat, camel, alpaca, llama.

Figure 18. Types of wool¹⁴

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Sheep-wool fibre

Sheep-wool fiber can be sheared from the living animal or pulled from the hide after slaughtering. Sheared or clipped wool is superior to pulled wool.

Sheep normally are sheared only once a year. Lamb's wool is wool from sheep under 8 months of age.

“Virgin wool” (or “new wool”) comes from the first shearing of the animal and is most highly prized.

The term “virgin wool” is also used to mean wool that has never previously been processed.



Figure 18. Sheep wool fibre^{1,2}

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Sheep Wool SEM Images

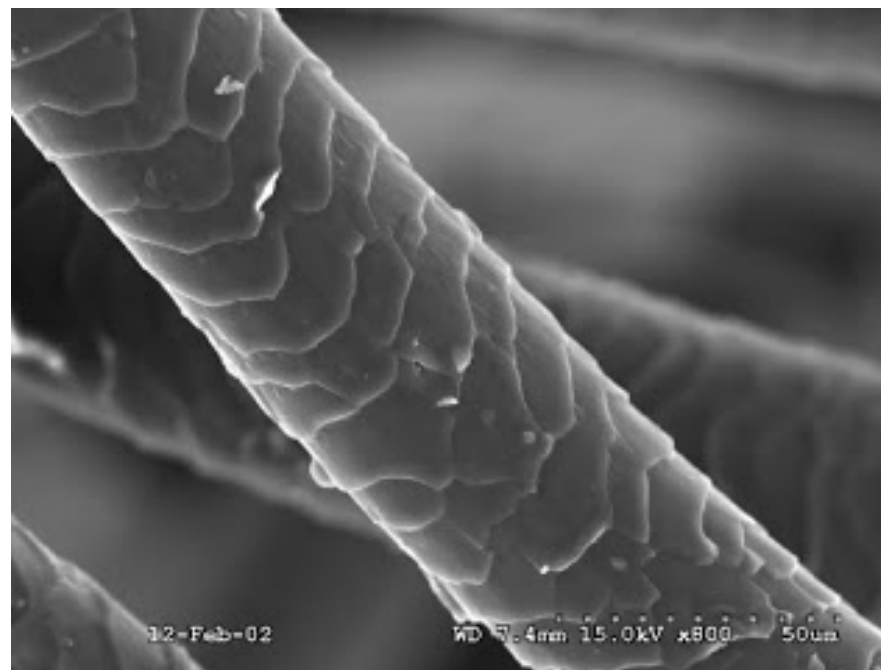


Figure 19. Sheep wool SEM image^{1,2,15}

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Merino wool fibre



Figure 20. Merino wool fibre^{1,2}

Merino wool is a natural fiber grown by Merino sheep. It's thinner and softer than regular wool—making it easy to wear next to skin.

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Alpaca fibre



Alpaca is the long, fine hair fiber from the alpaca, which is a relative of the camel native to South America.

It is shorn from the animal once every two years.

The soft, fine undercoat is used in textiles.

Figure 21. Alpaca fibre^{1,2}

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Alpaca SEM Image

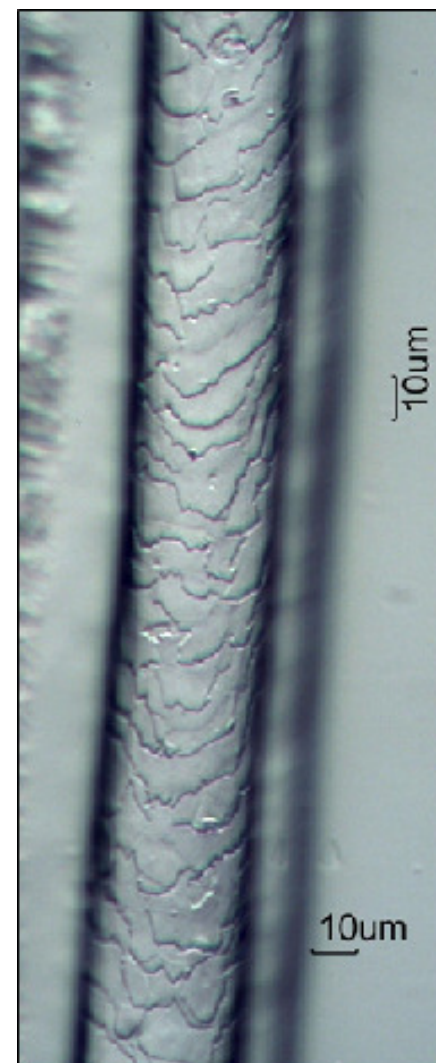


Figure 22. Alpaca SEM image^{1,2,16}

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Cashmere wool



Cashmere is the soft hair fiber from the cashmere goat. The fiber is harvested by combing the animal. A single goat produces only about 114 grams of fiber a year.

Cashmere is considered a luxury fiber.

Figure 23. Cashmere wool fibre^{1,2}

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Cashmere fiber SEM image

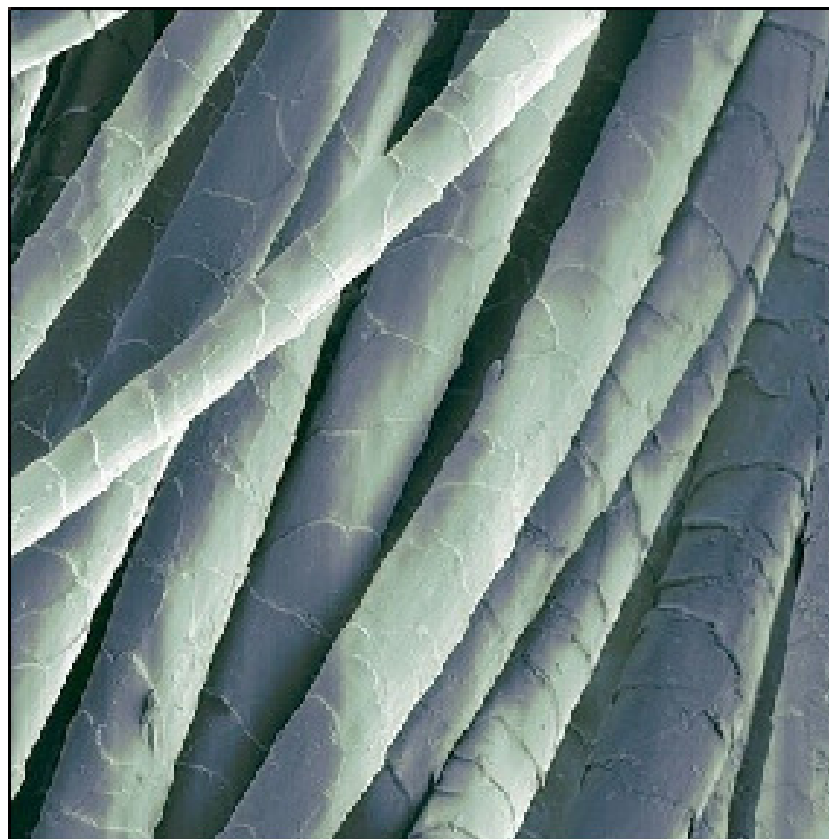


Figure 24. Cashmere fibre SEM image^{1,2,15}

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Mohair wool

Mohair wool is a type of textile derived from the hair of the Angora goat.

Mohair fibre, like wool, is composed chiefly of the protein substance keratin. Fibre structure is similar to that of wool, although the outer layer, or epidermis, has about half the number of scales found in fine wools. Because the scales lie almost flat, with little overlapping, the fibre surface is fairly smooth.



Figure 25. Mohair fibre^{1,2, 11}

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Camel wool

- ▶ Camel wool made of camel wool are not very common in everyday life but nevertheless our overview of wool yarn types would be incomplete without it.
- ▶ Camel hair is an animal fiber collected from the camel. There are two types of camel wool – the outer protective one called guard hair, which is coarse and inflexible, and the fine, shorter fiber of the insulating undercoat



Figure 26. Camel wool fibre^{1,2,17}

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Camel Wool SEM Image

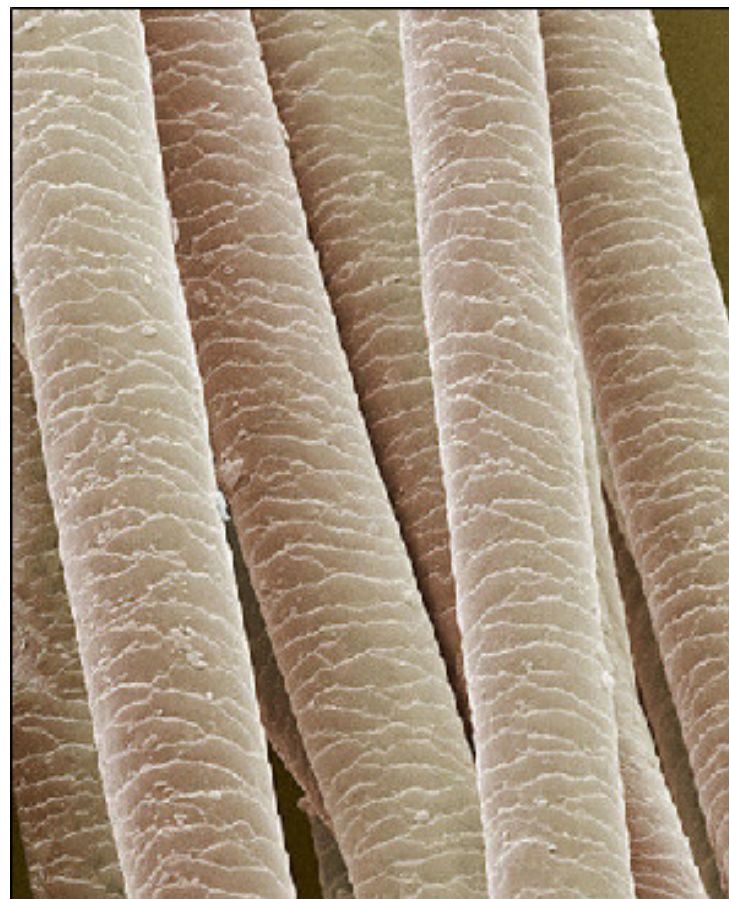
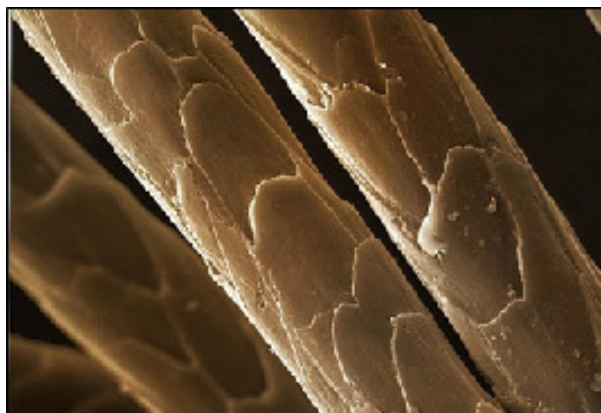


Figure 27. Camel Wool SEM Image^{1,2,15}

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Llama fibre



- ▶ Llama hair fibers are shorn from the animal once a year. They are similar to alpaca fibers, but weaker.

Figure 28. Llama fibre^{1,2}

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Unit 3.1 Natural Fibres

Llama SEM image

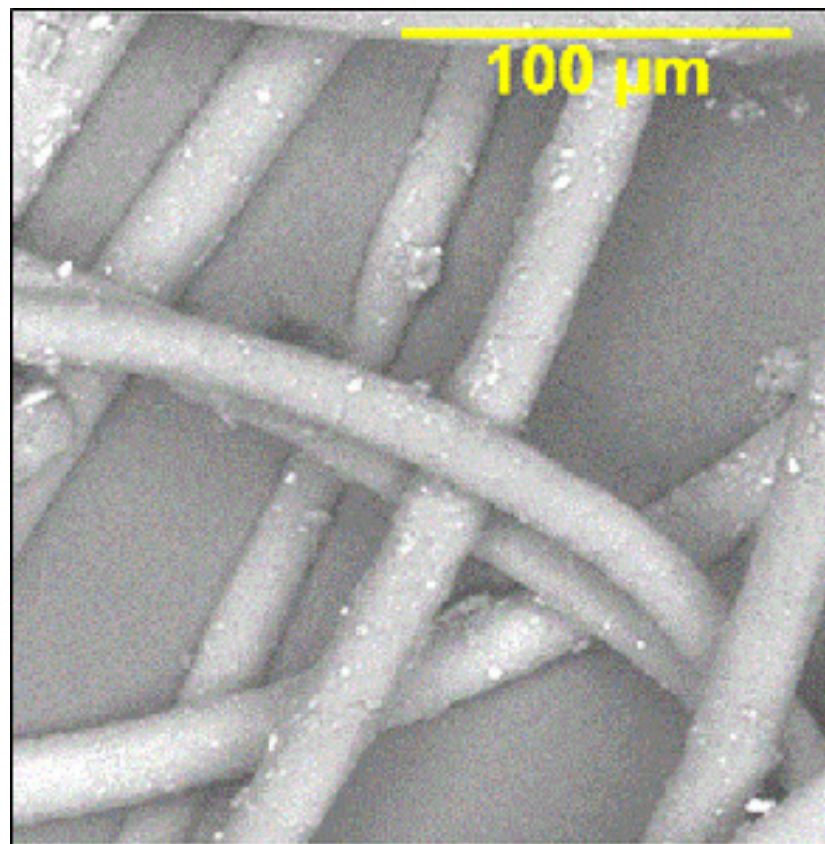


Figure 29. Llama SEM image^{1,2,18}

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Angora fibre

Angora is the long, fine hair fiber from the Angora rabbit. Angora rabbits are raised domestically. The fur is combed and clipped from the rabbit every three months.



Figure 30. Angora fibre^{1,2,11}

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Rabbit SEM image



52 μm

Figure 31. Rabbit Hair SEM image^{1,2,15}

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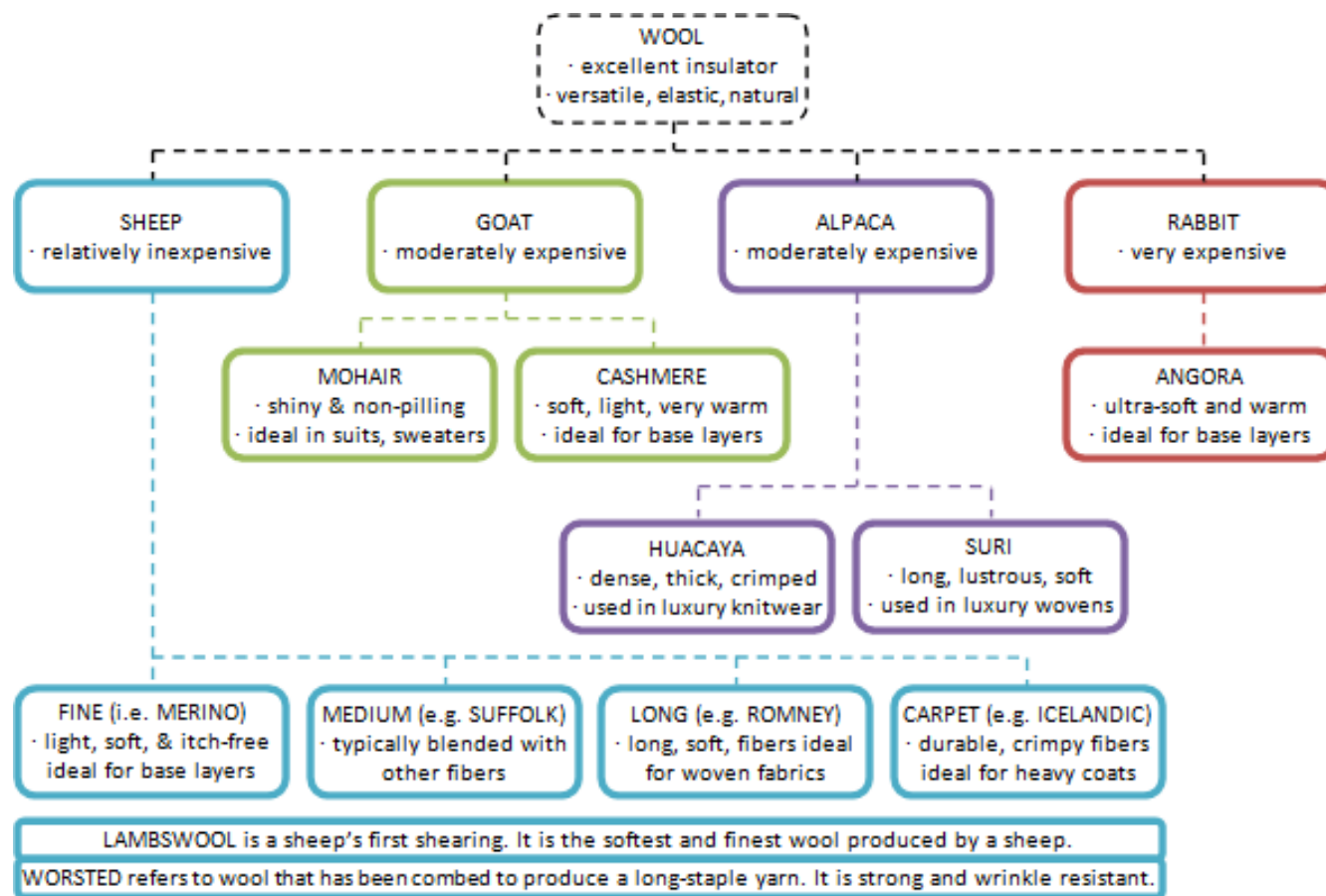


Figure 32. Wool classification and properties¹⁹

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Horse Hair SEM Image

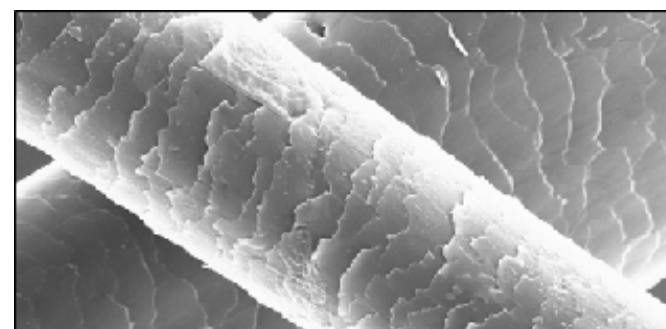
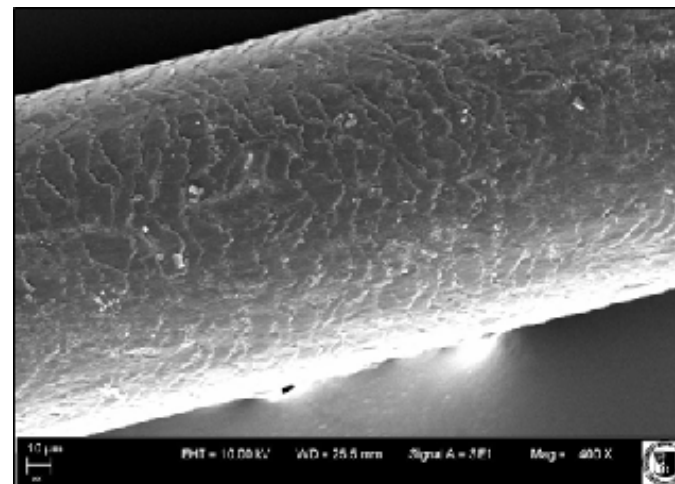


Figure 33. Horse Hair SEM Image 1,2,15

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Human Hair SEM Image

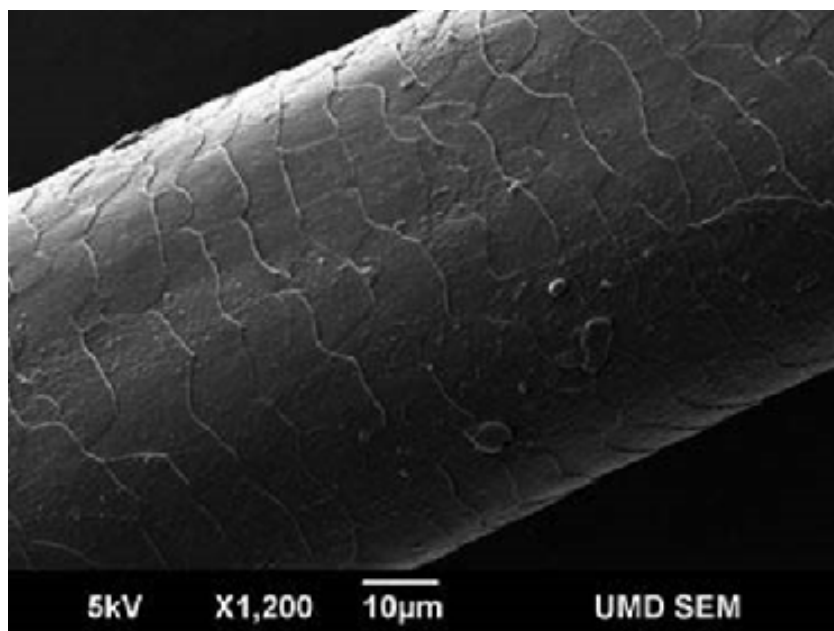


Figure 34. Human Hair SEM Image ^{2,15}

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Properties of wool (I)

- ▶ Wool is 100% natural.
- ▶ KERATIN fibres
- ▶ 100% biodegradable. When a wool fibre is disposed of, it will naturally decompose in soil in a matter of years, slowly releasing valuable nutrients back into the earth.
- ▶ 100% renewable.
- ▶ Warm and cool. In contrast to synthetics, wool is an active fibre that reacts to changes in body temperature. So it helps you stay warm when the weather is cold, and cool when the weather is hot.
- ▶ Wrinkle resistant. At microscopic level, each wool fibre is like a coiled spring that returns to its natural shape after being bent.
- ▶ Innovative. Fashion designers and activewear brands can choose from a range of innovative treatments and manufacturing techniques to create unique textures and finishes on wool garments.
- ▶ Naturally breathable. Wool fibres can absorb large quantities of moisture vapour then move it away to evaporate into the air²⁰.

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Properties of wool (II)

- ▶ Odour resistant. In contrast to synthetics, wool can absorb moisture vapour which means less sweat on your body. Wool even absorbs the odour molecules from sweat, which are only released upon washing.
- ▶ Soft on skin. Wool fibres are extremely fine, enabling them to bend far more than traditional, coarser wool fibres. This makes wool feel soft and luxuriously gentle next to body skin.
- ▶ Naturally elastic. Natural elasticity helps wool garments stretch with you, yet return to their original shape.
- ▶ Fire resistant. Wool's inherent chemical structure makes wool naturally flame resistant. It is a highly trusted natural fibre in public areas such as hotels, aircraft, hospitals and theatres. Whilst cotton catches alight at 255°C, the temperature must reach 570-600°C before wool will ignite; while polyester melts at 252-292°C and nylon succumbs at an even lower 160-260°C, wool never melts so it can't stick to the skin like many common synthetics.
- ▶ UV resistant. Wool clothing provides good protection from the sun, compared with the protection from other fibres²⁰.

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3.1.2.2 Fibroin fibres: natural silk, spider silk

Natural spider silk is a natural protein biomaterial secreted by spiders through their silk glands. It belongs to a type of bioelastic fibre. It is one of the best materials produced in nature.

Silkworm silk is mainly known as a luxurious textile. Spider silk is an alternative to silkworm silk fibres and has much more outstanding properties. Silk diversity ensures variation in its application in nature and industry.



Figure 35. Natural and spider silk fibres²¹

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Natural silk

The silk fibroin is a natural fibroin protein with semicrystalline structure, providing fiber stiffness and strength. The sericin binder acts as an adhesive binder to hold the structure of the fiber. The silk fiber has been chosen as a reinforcement in biopolymer recently, especially in tissue engineering and medical industries.

Silk is a natural fiber known for its luster, shine, strength, and durability, and it has a long trading history across the world. Silk is the epitome of luxury due to its high cost to produce, soft feel, and elegant appearance, and it is thus a popular textile in high-end and couture fashion design.

Silk is considered a more sustainable fiber. It is a renewable resource, can biodegrade, and uses less water, chemicals, and energy than many other fibers.



Figure 36. Natural silk fibre^{22,23}

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Spider silk

Another type of the silk fiber was produced by a spider. Six types of different silk fiber can be produced by a single spider: major ampullate silk, minor ampullate silk, flagelliform silk (capture core threads), aciniform silk, tubuliform silk (outer eggsac), and piriform silk. Figure 37 has showed the spider silk glands, silk types, and its uses.

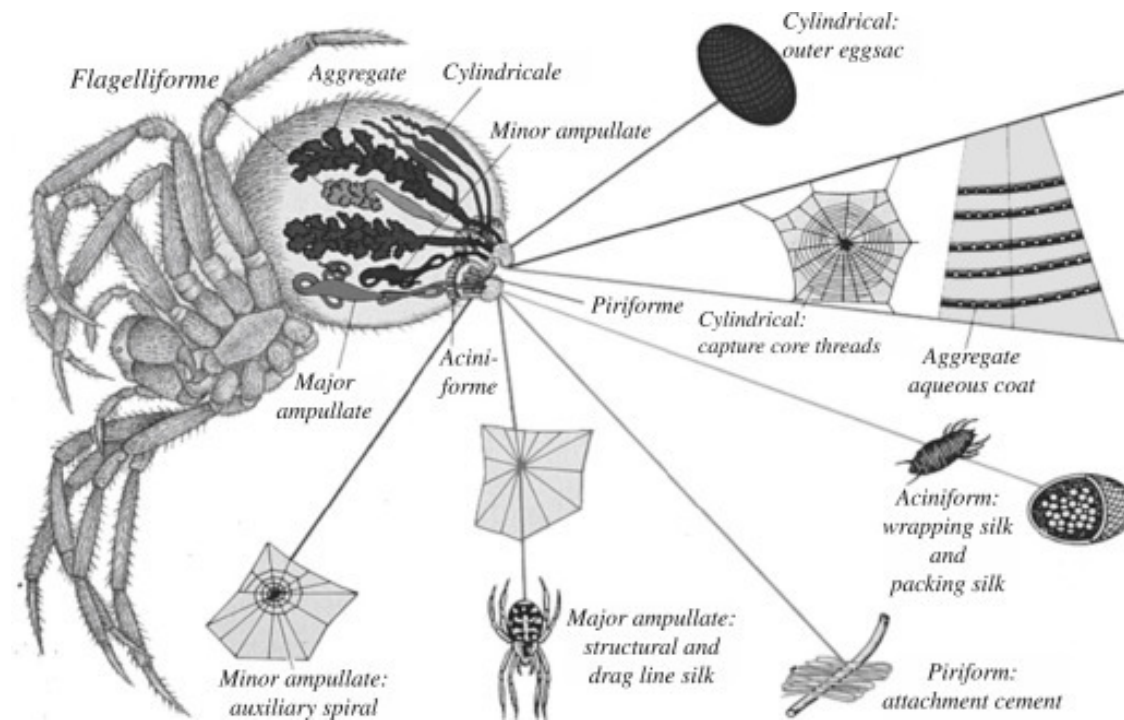


Figure 37. Spider silk fibre²³

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Textile Fibers SEM Images

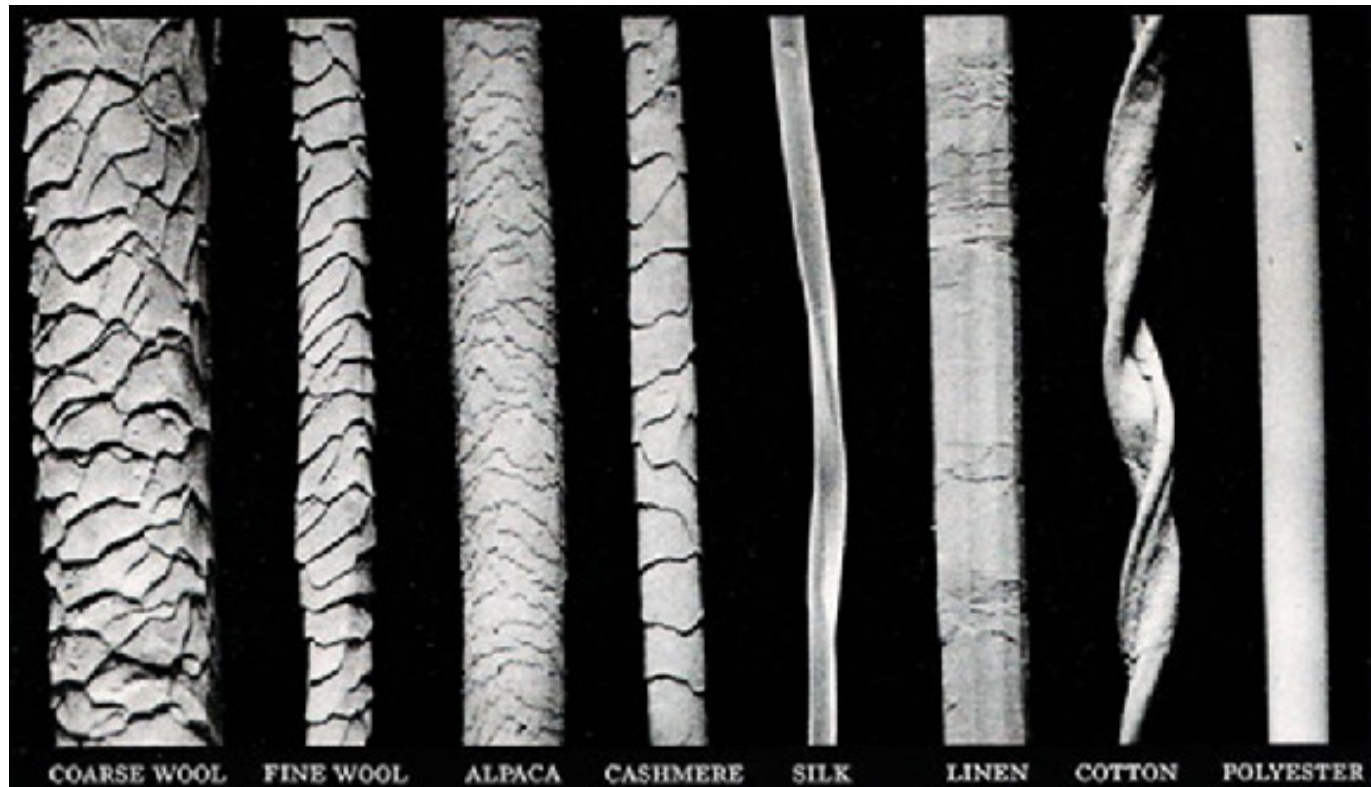


Figure 35. Textile Fibers SEM Images²⁴

MODULE 3 Sustainable Fibre/Material Resourcing

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Eco Friendly Fibers – Natural fibers

- ▶ Many are organic, but all of them take more time and care to create products with less impact on the environment. There are communities of hand spinners all over the world, making natural fiber yarn from raw materials. Small, sustainable farms and ranches are providing a lot of the eco friendly fibers that create handspun slow yarn.
- ▶ Eco friendly fibers means more than a label. In this modern age of technology and quick results, there are always a few people who are keeping alive the old ways of doing things²⁵.



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