GATE Material for Textile Engineering and Fiber Science

Engineering Mathematics

- Linear Algebra

- Calculus

- Complex variable

- Vector Calculus

- Differential Equations

- Probability - I

- Probability (continued)

- Numerical Methods
  (above topics are successfully completed in mathematics part)

Textile Fibers

Classification Of Textile fibres

Nos	Name	Fibre description
1	wool (1)	Fibre from sheep's or lambs' fleeces (Ovis aries)
2	alpaca, llama, cammel, kashmir, mohair, angora, vicuna, yak, guanaco, beaver, otter, followed or not by the name 'wool' or 'hair' (1)	Hair of the following animals: alpaca, llama, cammel, kashmir goat, angora goat, angora rabbit, vicuna, yak, guanaco, beaver, otter
3	animal or horsehair, with or without an indication of the kind of animal (e.g. cattle hair,	Hair of the various animals not mentioned under 1 or 2

	common goat hair, horsehair)	
4	silk	Fibre obtained exclusively from silk-secreting insects
5	cotton	Fibre obtained from the bolls of the cotton plant
6	kapok	Fibre obtained from the inside of the kapok fruit (Ceiba pentandra)
7	flax	Fibre obtained from the bast of the flax plant (Linum usitatissimum)
8	true hemp	Fibre obtained from the bast of hemp (Cannabis sativa)
9	jute	Fibre obtained from the bast of Corchorus olitorius and of Corchorus capsularis. For the purposes of this Directive, bast fibres obtained from the following species shall be treated in the same way as jute: Hibiscus cannabinus, Hibiscus sabdariffa, Abultilon avicennae, Urena lobata, Urena sinuata
10	abaca (Manila hemp)	Fibre obtained from the sheating leaf of Musa textilis
11	alfa	Fibre obtained from the leaves of Stipa tenacissima
12	coir (coconut)	Fibre obtained from the fruit of Cocos nucifera

| 13	broom	Fibre obtained from the bast of Cytisus scoparius and/or Spartium junceum
14	ramie	Fibre obtained from the bast of Bohemeria nivea and Bohemeria tenacissima
15	sisal	Fibre obtained from the leaves of Agave sisalana
16	Sunn	Fibre from the bast of Crotalaria juncea
17	Henequen	Fibre from the bast of Agave Fourcroydes
18	Maguey	Fibre from the bast of Agave Cantala
19	acetate	Cellulose acetate fibre wherein less than 92% but at least 74% of hydroxyl groups are acetylated
20	alginate	Fibre obtained from metallic salts of alginic acid
21	cupro (cuprammonium rayon)	Regenerated cellulose fibre obtained by the cuprammonium process
22	modal	A fibre of regenerated cellulose having a high breaking force and high wet modulus. The breaking force (BC) in the conditioned state and the force (BM) required to produce an elongation of 5% in the wet state are: $BC \text{ (centinewton)} \geq 1{,}3 \sqrt{T} + 2T$ $BM \text{ (centinewton)} \geq 0{,}5 \sqrt{T}$ where T is the mean linear density in decitex

23	protein (1)	Fibre obtained from natural protein substances regenerated and stabilized through the action of chemical agents
24	triacetate	Cellulose acetate fibre wherein at least 92% of the hydroxyl groups are acetylated
25	viscose	Regenerated cellulose fibre obtained by the viscose process for filament and discontinuos fibre
26	acrylic (1)	Fibre formed of linear macromolecules comprising at least 85% (by mass) in the chain of the acrylonitrilic pattern
27	chlorofibre	Fibre formed of linear macromolecules having in their chain more than 50% by mass of chlorinated vinyl or chlorinated vinylidene monomeric units
28	fluorofibre	Fibre formed of linear macromolecules made from fluorocarbon aliphatic monomers
29	modacrylic (2)	Fibre formed of linear macromolecules having in their chain more than 50% and less than 85% (by mass) of the acrylonitrilic pattern
30	polyamide or nylon (2)	Fibre formed of linear macromolecules having in their chain the recurring amide functional group
31	polyester	Fibre formed of linear macromolecules having in their chain at least 85% (by mass)

		of an ester of a diol and terephthalic acid
32	polyethylene (2)	Fibre formed of un-substituted aliphatic saturated hydrocarbon linear macromolecules
33	polypropylene (2)	Fibre formed of an aliphatic saturated hydrocarbon linear macromolecule where one carbon atom in two carriers a methyl side chain in an isotactic disposition and without further substituition
34	polycarbamide (2)	Fibre formed of linear macromolecules having in their chain the recurring ureylene (NH-CO-NH) functional group
35	polyurethane (2)	Fibre formed of linear macromolecules composed of chains with the recurring urethane finctional group
36	vinylal (m)	Fibre formed of linear macromolecules whose chain is constituted by poly(vinyl alcohol) with differing levels of acetilization
37	trivinyl (2)	Fibre formed of acrylonitrile terpolymer, a chlorinated vynil monomer and a third vinyl monomer, none of which represents as much as 50% of the total mass
38	elastodiene (2)	Elastofibre composed of natural or synthetic polyisoprene, or composed of one or more dienes polymerized with or without one or more vinyl monomers, and which, when stretched to three times its original length

		and released, recovers rapidly and substantially to its initial length
39	elastane	Elastofibre composed of at least 85% (by mass) of a segmented polyurethane, and which, when stretched to three times its original length and released, recovers rapidly and substantially to its initial length
40	glass fibre	Fibre made of glass
41	name corresponding to the material of which the fibres are composed, e.g. metal (metallic, metallized), asbestos, paper, followed or not by the word 'yarn' or 'fibre'	Fibres obtained from miscellaneous or new materials not listed above

(1) The name 'wool' in item 1 of this Annex may also be used to indicate a mixture of fibres from sheep's or lambs' fleeces and the hairs listed in the third column of item 2. This provision is applicable to the textile products listed in Articles 4 and 5 and to those referred to in Article 6, provided that the latter are partly composed of the fibres listed in items 1 and 2.

(2) The 'word' fibre is understood.
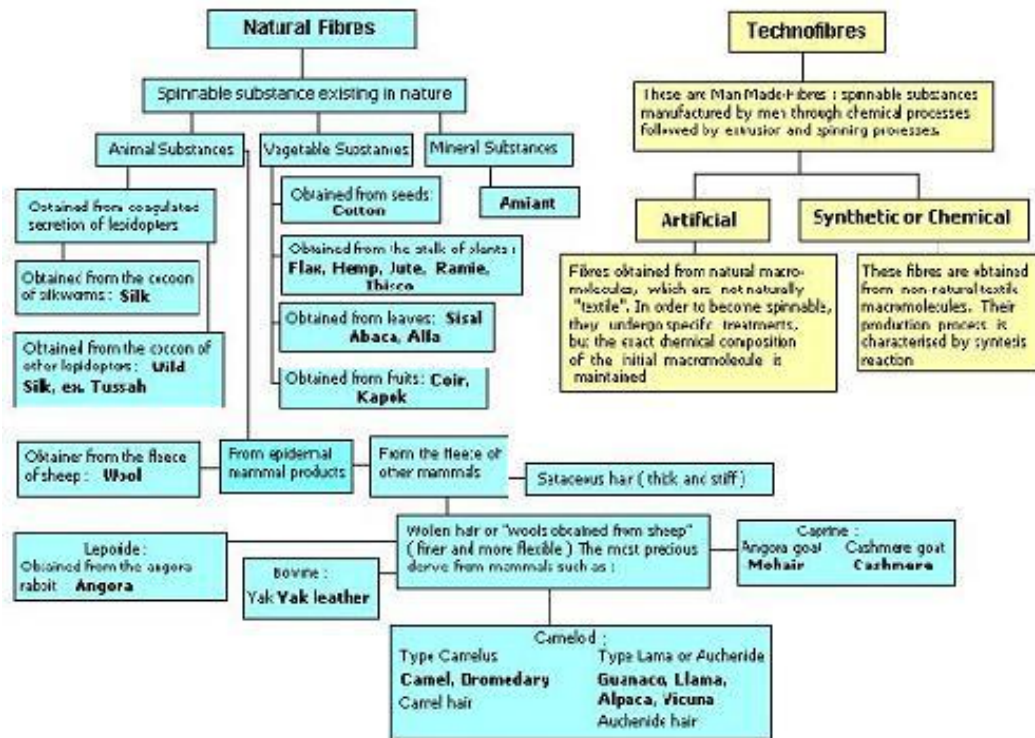
Essential Requirements Of Fibre Forming Polymers

Polymer Fundamentals:

Fiber Applications

Polymer science addresses the chemistry and physics of large, chain-like molecules. As with the molecules themselves, this technical pursuit is diverse and complicated. The following discussion provides an introduction to the manufacture and use of synthetic organic polymers for those with some knowledge of basic science. More advanced tutorial information on polymers is contained in the links displayed at the end.

What is a Polymer?

The term "polymer" is derived from the Greek "poly", meaning "many", and "mer", meaning "parts" — thus polymers are substances made of "many parts". In most cases the parts are small molecules which react together hundreds, or thousands, or millions of times. A molecule used in producing a polymer is a

"monomer" — mono is Greek for single, thus a monomer is a "single part". A polymer made entirely from molecules of one monomer is referred to as a "homopolymer". Chains that contain two or more different repeating monomers are "copolymers".

The resulting molecules may be long, straight chains, or they may be branched, with small chains extending out from the molecular "backbone". The branches also may grow until they join with other branches to form a huge, three-dimensional matrix. Variants of these molecular shapes are among the most important factors in determining the properties of the polymers created.

The size of polymer molecules is important. This is usually expressed in terms of molecular weight. Since a polymeric material contains many chains with the same repeating units, but with different chain lengths, average molecular weight must be used. In general, higher molecular weights lead to higher strength. But as polymer chains get bigger, their solutions, or melts, become more viscous and difficult to process.

Proteins and Carbohydrates

Life as we know it could not exist without polymers. Proteins, with large numbers of amino acids joined by amide linkages, perform a wide variety of vital roles in plants and animals. Carbohydrates, with chains made up of repeating units derived from simple sugars, are among the most plentiful compounds in plants and animals. Both of these natural polymers are important for fibers. Proteins are the basis for wool, silk and other animal-derived filaments. Cellulose as a carbohydrate occurs as cotton, linen and other vegetable fibers. The properties of these fibers are limited by the form provided in their natural state. Some, like linen and silk, are difficult to isolate from their sources, which makes them scarce and expensive. There are, of course, many other sources of proteins and cellulose, such as wood pulp, but natural polymers tend to be very difficult to work with and form into fibers or other useful structures. The inter-chain forces tend to be strong because of the large number of polar groups in the molecular chains. Thus, natural polymers usually have melting points that are so high that they degrade before they liquefy.

The most useful molecules for fibers are long chains with few branches and a very regular, extended structure. Thus, cellulose is a good fiber-former. It has few side

chains or linkages between the sugar units forcing its chains into extended configurations. However, starches, which contain the same basic sugar units, do not form useful fibers because their chains are branched and coiled into almost spherical configurations.

Synthetic Polymers

Synthetic polymers offer more possibilities, since they can be designed with molecular structures that impart properties for desired end uses. Many of these polymers are capable of dissolving or melting, allowing them to be extruded into the long, thin filaments needed to make most textile products. Synthetic polymer fibers can be made with regular structures that allow the chains to pack together tightly, a characteristic that gives filaments good strength. Thus, filaments can be made from some synthetic polymers that are much lighter and stronger than steel. Bullet-proof vests are made from synthetic fibers.

There are two basic chemical processes for the creation of synthetic polymers from small molecules (1) condensation, or step-growth polymerization, and (2) addition, or chain-growth polymerization.

Step-Growth Polymerization

In step-growth polymerization, monomers with two reactive ends join to form dimers (two "parts" joined together), then "trimers" (three "parts"), and so on. However, since each of the newly formed oligomers (short chains containing only a few parts) also has two reactive ends, they can join together; so a dimer and a trimer would form a pentamer (five repeating "parts"). In this way the chains may quickly great length achieve large size. This form of step-growth polymerization is used for the manufacture of two of the most important classes of polymers used for textile fibers, polyamide (commonly known as nylon), and polyester.

There are many different commercial versions of polyester in a wide variety of applications, including plastics, coatings, films, paints, and countless other products. The polymer usually used for textile fibers is poly(ethylene

terephthalate), or PET, which is formed by reacting ethylene glycol with either terephthalic acid or dimethyl terephthalate. Antimony oxide is usually added as a catalyst, and high vacuum is used to remove the water or methanol byproducts. High temperature ($>250^{o}C$) is necessary to provide the energy for the reaction, and to keep the resultant polymer in a molten state.

PET molecules are regular and straight, so their inter-chain forces are strong — but not strong enough to prevent melting. Thus, PET is a "thermoplastic" material; that is, it can be melted and then solidified to form specific products. Since its melting point is high, it does not soften or melt at temperatures normally encountered in laundering or drying. Another important property of PET is its T_g, or "glass transition temperature". When a polymer is above its glass transition temperature, it is easy to change its shape. Below its T_g, the material is dimensionally stable and it resists changes in shape. This property is very important for textile applications because it allows some fibers, and the fabrics made from them, to be texturized or heat-set into a given shape. This can provide bulk to the yarn, or wrinkle resistance to the fabric. These set-in shapes remain permanent as long as the polymer is not heated above its T_g. Because its chains are closely packed and its ester groups do not form good hydrogen bonds, polyesters are also hydrophobic (i.e., they do not absorb water). This property also requires special dyeing techniques.

There are also many important classes of synthetic polyamides (nylons) and they have a wide variety of commercial uses. These are usually distinguished from each other by names based on the number of carbon atoms contained in their monomer units. As with polyesters, polyamides are formed by step-growth polymerization of monomers possessing two reactive groups. Here, the reactive functions are acids and amines. The monomers used may have their two reactive functions of the same chemical type (both acids, or both amines), or of different types. Thus, nylon 6,6 — a very common fiber polymer — is made by reacting molecules of adipic acid (containing six carbons in a chain, with an acid function at each end) with hexamethylene diamine (also six carbon atoms, with amine functions at each end). In another variant the diamine contains ten carbons atoms, the product designated nylon 6,10.

The other common polyamide fiber polymer is nylon 6. Its monomer has six carbons in the chain, with an amine at one end and an acid at the other. Thus only

one form of monomer is needed to conduct the reaction. Commercial production of nylon 6 makes use of caprolactam, a derivative which provides the same result.

As with the polyesters, nylons have regular structures to allow good inter-chain forces that impart high strength. Both nylon 6 and nylon 6,6 have melting points similar to PET but they have a lower T_g Also, since the amide functions in nylon chains are good at hydrogen bonding, nylons can be penetrated by water molecules. This allows them to be dyed from aqueous media, unlike their polyester counterparts.

In addition to nylon, there is another commercially important group of synthetic polyamides. These are the aramids, which contain aromatic rings as part of their polymer chain backbone. Due to the stability of their aromatic structures and their conjugated amide linkages, the aramids are characterized by exceptionally high strength and thermal stability. Their usefulness for common textile applications is limited by their high melting points and by their insolubility in common solvents. They are expensive to fabricate, and they carry an intrinsic color that ranges from light yellow to deep gold.

Other step-growth polymers — the polyurethanes — are produced by the reaction of polyols and polyisocyanates. For fiber purposes, this class of linear polymers is formed from glycols and diisocyanates. Usually, the reactions are carried out to form block copolymers containing at least two different chemical structures — one rigid, and the other flexible. The flexible segments stretch, while the rigid sections act as molecular anchors to allow the material to recover its original shape when the stretching force is removed. Varying the properties of the segments, and the ratio of flexible to rigid segments controls the amount of stretch. Fibers made in this way are classified as spandex and they are used widely in apparel where stretch is desirable.

Chain-Growth Polymerization

Chain-growth polymerization occurs when an activated site on a chemical, such as a free radical or ion, adds to a double bond, producing a new bond and a new by activated location. That location then attacks another double bond, adding another

unit to the chain, and a new reactive end. The process may be repeated thousands, or millions, of times, to produce very large molecules. This is usually a high energy process and the intermediate species are so reactive that, in addition to attacking available monomer, they also may attack other chains, producing highly branched structures. Since these branches prevent the molecules from forming regular structures with other molecules, their inter-chain forces are weak. The resulting polymers tend to be low-melting and waxy.

The breakthrough in making chain-growth polymers useful for fibers and for most commercial plastics came with the development of special selective catalysts that drive the production of long, straight polymer chains from monomers containing basic carbon-to-carbon double bonds.

Ethylene and propylene form the simplest chain-growth polymers. Since their polymer chains contain no polar groups, these polyolefins must rely on close contact between the molecular chains for strength. Thus, the physical characteristics of polyethylene are very sensitive to even a small number of chain branches. Very straight chains of polyethylene can form strong crystalline structures which exhibit exceptional strength. Protective fabrics made from this type of highly structured polyethylene are virtually impossible to penetrate or cut.

Polypropylene is more complicated. Even without chain branching, each monomer unit adds one methyl group pendant to the chain. The arrangement of these side groups is described as the "tacticity" of the polymer. A random arrangement is considered "atactic", or without tacticity. Regular arrangement with all side groups on one side of the chain is "isotactic", and a regular alternating structure is "syndiotactic". Polypropylene molecules can only pack closely in an isotactic arrangement. Synthesis of these polymers was a major challenge, but several stereoselective catalysts are now available, and high-density polypropylene has become a commodity product. Fibers made from it are lightweight, hydrophobic and highly crystalline. Their resistance to wetting gives them good moisture wicking and anti-staining properties. This also makes them virtually undyeable, except when the dye is applied to the polymer in its molten state — a process know as "solution dyeing".

By contrast, the pendant nitrile functions in polyacrylonitrile are sufficiently polar to produce very strong inter-chain forces. Pure homopolymers from acrylonitrile are non-thermoplastic and difficult to dissolve or dye. Thus, for most commercial acrylonitrile polymers, small amounts of other monomers with bulky side chains are introduced to force the chains apart, to reduce the inter-chain forces. Common co-monomers for these fiber applications include vinyl chloride, vinyl acetate, acrylic acid, and methyl acrylate.

Specialty fiber polymers

There are also a number of complex, specialty fiber polymers with methods of synthesis that are not easily classified. These materials are occasionally used in high performance materials where the complex structures impart exceptional strength, thermal stability, electrical conductivity, and others desirable properties. They include (polybenzimidazole)and Their chemistry is beyond the scope of this introductory discussion.

Wool

Wool – The most important of the fibres of animal origin is wool, the hair of the sheep (**Ovis ales**). The characteristics ofwool fibres differ depending on the breed and general condition of the sheep.

Wool, the hair of various breeds of sheep, is a warm springy fibre. It's scaly structure led in the past to unwanted felting (matting of fibres) and shrinkage in laundering but modern finishing treatments have now overcome these difficulties; similarly, attack by the clothes moth is no longer a problem.
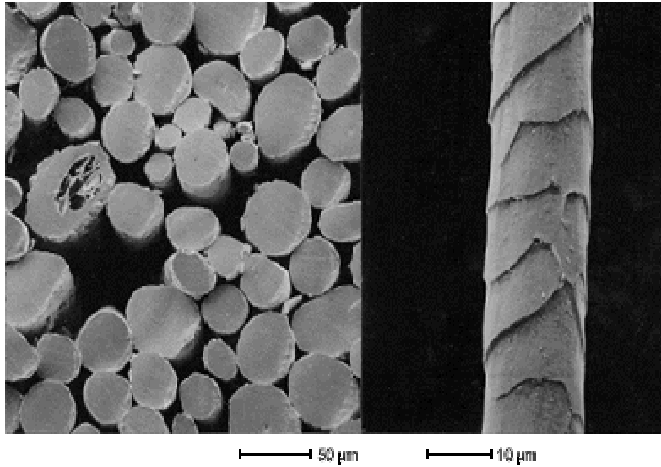
Wool has a natural crimpiness, which gives it good elasticity, bulk, crease-resistance and durability. Its strength when wet is less than when it is dry. Important properties of wool are a drystrength of 11.5 to 13 cN/tex, a breaking elongation of 30 to 40% and a moisture regain of 16 to 18%.

Technologically, the diameter, or fineness, of the wool fibre is probably the most important property. It is determined to a large extent by the grade assigned to a lot, or batch, of wool. Diameters range from 16 microns in the finest Merinos to over 40 microns in the coarsest long-wool types. Staple length generally increases with increasing fibre diameter, ranging from four to eight centimetres for fine Merino up to 35 centimetres for coarse Cotswold wool. Staple length is lower than mean fibre length because of the crimp that results in a helical configuration in an individual fibre and an uni-planar wave in the staple.

Wool fibres are hygroscopic, absorbing water from a moist atmosphere in a reversible way. Because most fibres are dependent on moisture content, this characteristic is extremely important, especially in numerous processing steps, including carding, combing, spinning and weaving. Relative humidity in the processing plants must be controlled for optimum processing conditions. Upon uptake of water , the fibre swells anisotropically (unequally), increasing up to 16% in diameter while the change in length is only about 1.2 to 1.5%. The ability of wool fibres to absorb and release moisture contributes to wearing comfort in garments made of wool.

In the UK alone there are 34 main breeds of sheep and a further 43 rare breeds and hybrids. When wool fibres have been processed it is not possible to say with

confidence from what breed of sheep or country they have originated because wool fibres from several breeds have the same microscopical appearance. There are four main types of wool fibre: fine, coarse, outercoat and kemps. Each type has a characteristic scale pattern so that it is possible to distinguish between types, although it is not possible to assign a type to a breed of sheep.

Wool fibres are generally white, with the finer fibres having acircular cross section and the coarse fibres being more irregular in contour. Kemp fibres are usually chalky white in appearance, very coarse and brittle, with a long tapering tip and a taper over a short distance to the root end.

An important aspect of the environmental impact of wool processing is the use of pesticides on sheep. Although the problem has been minimised over recent years with the introduction of tighter restrictions or even bans on the use of some formulations, this is still a major concern since these toxic chemicals make their way into rivers.

Another impact at this early stage which is maybe less obvious, is the methane generated globally by the many hundreds of millions of sheep. Methane is a powerful greenhouse gas and contributes to the effect of global warming.

Again, as with cotton there is also the effect of transporting huge quantities of textiles across the globe with the associated fuel usage and fume generation problems.

The scouring of the raw wool, the next stage, is a process which produces a liquid effluent with a very high organic load and solids content and varying levels of pesticide contamination. The highly polluting nature of this waste and the strict discharge consents associated with the process means that scourers have to treat their effluent on-site.

Another environmental problem is that many of the dyestuffs available for obtaining good dark shades on woollen fabric or yarn are mordant dyes containing chromium. The discharge of chromium is strictly controlled and so companies are being forced into using alternatives or consider on-site effluent treatment.

In the carpet industry permethrin, another pesticide, is added to the yarn that goes into making contract carpets, this is a quality requirement to protect the wool from

moth attack. The effluent from this process must therefore be treated and continually monitored.

Silk

Silk – In Old English, silk was **sioloc**. The name is thought to have originated from the Greek seres, meaning the people from Eastern Asia i.e. the Chinese. The term sericulture derives from this Greek root.

Silk has a long and fascinating history, starting over 4000 years ago with the development by the Chinese of the art of rearing silkworms to make a textile fibre. Since that time silk has remained highly valued for its luxurious qualities but, because its main uses have been in very expensive apparel and other luxury goods, demand has been considerably more variable than for many other fibres.

There are several species of silk producing worms but most of the world's silk results from the worm of the moth **Bombyx mori** which lives exclusively on the leaves of **Morus alba** the white mulberry tree. Other silkworms include the wild or semi-wild varieties, such as Atlas, Eri, Tussah and Muga, which are found mainly in India and Asia.

The silkworms are reared in large numbers at silk farms, where plantations of bush-like mulberry trees are cultivated to provide leaves which are fed to the worms in special rearing rooms. From the day it hatches to the time it stops feeding, a period of 25 to 30 days, the worm gains in weight about 10,000 times. During this time it eats some 22g of leaves and converts more than 70% of its intake of nitrogenous material into silk. To produce 1kg of raw silk about 6.25 kg of fresh cocoons are necessary, while for raising 6.25 kg of cocoons about 104 kg of mulberry leaves containing 26 kg of solid matter are required. On average 75% of the fresh 'green' cocoon, by weight is chrysalis. The outer layer of floss and the inner layer are collected as silk waste and used in spun silk manufacture. Wild silks such as Tussah are also generally used for spun silk as the cocoons are seldom in a reelable condition.
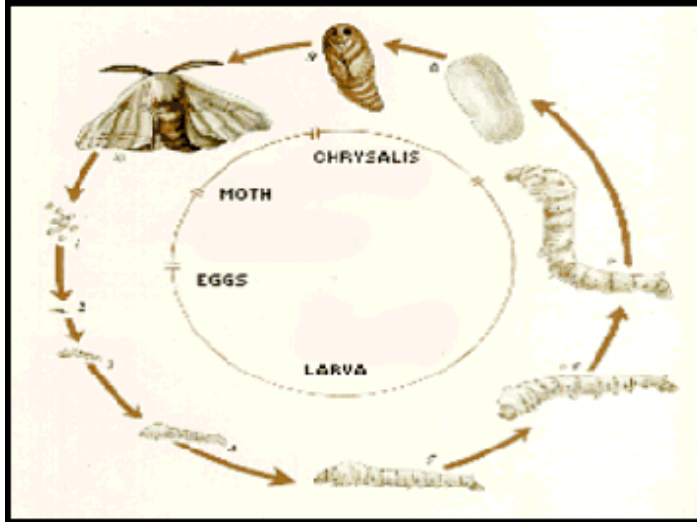
Tussah, a kind of wild silkworm, comes in two varieties monovoltine and bivoltine. It lives and multiplies wherever oak trees or leaves of the Mongolian oak, rubber trees or Chinese toon trees are available. There is one main type of tussah silkworm, **Antheraea pernyi**, and one general type of oak tree on which it feeds, **Quercus serrata**.

Tussah Moth

The Tussah chrysalis and cocoon are larger than those of the mulberry silkworm, but the cocoon shell is thinner, has a lower layer ratio and yields less silk. The Tussah cocoon is reddish-brown in colour, while the mulberry cocoon is white. Tussah silk's seracin or protein content, is 13.3%, which is lower than that of mulberry silk. The fibroin, or fibre itself, accounts for the remaining 86.7% and is composed of 15 amino acid residues.

Silk is a fairly strong fibre and although it does not compare with nylon and polyester in this respect its strength makes it suitable for use in sewing thread in high quality articles, particularly those made from silk. Silk absorbs more moisture from the surrounding air than do most of the synthetic fibres, and this property confers considerable advantages; it prevents a clammy feeling where fabric is in contact with the skin, since moisture can be absorbed without the fibre becoming noticeably damp, and transmitted through the material and into the atmosphere.

Silk has a fairly high natural resistance to creasing. Attempts to improve on this and also to apply easy-care treatments have not been very successful, as they

impair the unique handle, or feel, of silk which is one of its most valuable properties.

The environmental impact of silk processing is relatively minor in its initial stages when compared to cotton or wool. The cocoons are cooked to kill off the insects and then the fibre is washed in synthetic detergents to remove most of the sericin (gum) in readiness for dyeing.

Subsequent processing, through spinning, weaving, dyeing and finishing have an impact on the environment similar to most of the other fibres. Noise and dust is produced in weaving and a complex effluent with variable BOD/COD, pH and solids content is produced in finishing.

Cotton

Cotton – Cotton fibres are the seed hairs of the plant**Gossypium**. They are usually off-white in colour although some varieties have been bred to incorporate a natural colour. Each fibre is formed by the elongation of a single cell from the surface of the seed. The word cotton is derived from it's Arabic name pronounced kutan, qutn or qutan depending on the dialect.

Under a microscope , a cotton fibre appears as a very fine, regular fibre, looking like a twisted ribbon or a collapsed and twisted tube. These twists are called convolutions.

Almost half of the world's requirements for textile fibres are met by cotton. It is grown in many parts of the world where a hot dry climate is to be found, the main

producers being USA, the former USSR, China, India, Egypt, Africa and South America.

Cotton consists typically of between 88 to 96% cellulose with the rest being protein, pectic substances (congealed gum-like carbohydrates), ash and wax. After scouring and bleaching, cotton is then about 99% cellulose. The fibres are weakened and destroyed by acids but are resistant to alkalis.

The fibre length varies with the type and quality, within the range 10 to 65mm; the fibre diameter ranges from 11 to 22 ————————————¼m. Cotton is a relatively strong fibre with a strength of 25 to 35 cN/tex and a breaking elongation of 7 to 9%. It is stronger when wet. Cotton also absorbs moisture readily, which makes cotton clothes comfortable to wear in warm weather (water retention of 50%, moisture regain of 7%).

Cotton fibre burns readily and is not inherently resistant to oxidising agents, and biodegradation, as well as acids. Despite these shortcomings cotton has a good wear life. Its properties can also be readily modified by chemical finishes which provide enhanced performance, e.g. crease resistance and flame resistance.

It is used in both 100% form and in blends with other fibres for household textiles and apparel. Synthetic fibres have largely replaced its use in industrial textiles.

The environmental impact of the cotton manufacturing process starts in the field with the fertilisers and insecticides used in the growing of the cotton plant. These have a direct impact on the land and the local flora and fauna. The US alone spends about 500 million dollars a year on pesticides for protection against the bollworm and other harmful bugs. These pesticides also have an effect on people living in the viscinity of cotton fields. Nausea, diarrhoea and throat irritation being the most common complaints. It is also interesting to note that the gas leak at Bhopal , India which killed over 3,000 people came from a pesticide used in the spraying of cotton crops.

The ginning or separation of the seed from the fibre is a dusty process that has serious health implications on cotton workers in developing countries, where the separation is carried out using traditional methods. The fibre is then packaged and transported across the globe. The production of natural fibres is conducted in many

separate locations, transportation of the cotton bales has therefore a significant impact on the environment.

The spinning process introduces another set of significant impacts, producing more dust, noise and waste fibre and is also a relatively large consumer of electricity (as much as 2½ tonnes of oil per tonne of yarn). Relative humidity in the processing plant must also be controlled to minimise breakages, another consumer of energy. Weaving creates a similar set of impacts plus the added effect of using size and biocides has to be considered on the aqueous environment. Sizes are either natural, like starches or synthetic such as polyvinyl alcohol. The new sizes make weaving on the faster modern machinery a lot easier, but they have the drawback of being harder to biodegrade from the waste water.

Cotton preparation, that is singeing, desizing, scouring, bleaching and mercerising impacts on both the air and water. Singeing produces a dusty odorous emission, whilst the other preparative processes are the major contributors to BOD/COD in a textile effluent. There is also the problem of pentachlorophenol (pcp) on imported fabric which is washed out during preparation. This is an eco-toxic rot-proofing chemical with a very low discharge consent (maximum allowable concentration).

Cotton is by far the most popular fibre in use today, at least in terms of volume of production. The most widely used class of dyestuff on cotton are reactive dyes, which unfortunately are also the most poorly exhausted, producing a more coloured effluent. Colour consents on discharges have therefore been enforced in certain areas where there are significant numbers of cotton dyers.

The main pollution problem associated with cotton finishing processes is that of formaldehyde emissions from resin and other finishes. Low formaldehyde formulations have improved over the past few years but not far enough to eliminate the need for abatement on many stenters.

Attempts have been made to reduce the impact of cotton growing by eliminating pesticide use and by growing coloured strains of cotton so that the preparation and dyeing of the cotton is minimised. The bollworm can be eliminated by imposing a three month fallow period at the end of the growing season, and certain short fibre coloured cottons used by Indians in Central America have been cross bred with long fibre strains by a company in the US called Foxfibre. However, the amount of

organic cotton grown in the US is still only a tiny fraction of the global output (by the mid-1990's, 80 cotton growing countries were producing about 85 million bales of cotton).

Synthetic Fibre

Synthetic fibers are the result of extensive research by scientists to improve upon naturally occurring animal and plant. In general, synthetic (manmade) fibers are created by forcing, usually through extrusion, fiber forming materials through holes (called spinnerets) into the air, forming a thread. Before synthetic fibrers were developed, artificial (manufactured) fibers were made from cellulose, which comes from plants.

The first artificial fiber, known as artificial silk from 1855 onwards, became known as viscose around 1894, and finally rayon in 1924. A similar product known as cellulose acetate was discovered in 1865. Rayon and acetate are both artificial fibers, but not truly synthetic, being made from wood. Although these artificial fibers were discovered in the mid-nineteenth century, successful modern manufacture began much later (see the dates below).

Nylon, the first synthetic fiber, made its debut in the United States as a replacement for silk, just in time for World War II rationing. Its novel use as a material for women's stockings overshadowed more practical uses, such as a replacement for the silk in parachutes and other military uses.

Common synthetic fibers include:

- Rayon (1910) (artificial, not synthetic)

- Acetate (1924) (artificial, not synthetic)

- Nylon (1939)

- Modacrylic (1949)

- Olefin (1949)

- Acrylic (1950)

- Polyester (1953)

- PLA (2002)

Specialty synthetic fibers include:

- Vinyon (1939)

- Saran (1941)

- Spandex (1959)

- Vinalon (1939)

- Aramids (1961) - known as Nomex, Kevlar and Twaron

- Modal (1960's)

- PBI (Polybenzimidazole fibre) (1983)

- Sulfar (1983)

- Lyocell (1992)

- Dyneema/Spectra (1979)

- M-5 (PIPD fibre)

- Orlon

- Zylon (PBO fibre)

- Vectran (TLCP fiber) made from Vectra LCP polymer

Other synthetic materials used in fibers include:

- Acrylonitrile rubber (1930)

Modern fibers that are made from older artificial materials include:

- Glass Fiber is used for:
  - industrial, automotive, and home insulation (Fiberglass)
  - reinforcement of composite and plastics
  - specialty papers in battery separators and filtration

- Metallic fiber (1946) is used for:

  - adding metallic properties to clothing for the purpose of fashion (usually made with composite plastic and metal foils)

  - elimination and prevention of static charge build-up

  - conducting electricity to transmit information

  - conduction of heat

in the horticulture industry synthetics are often used in soils to help the plants grow better. exampes are
expanded polystyrene flakes
urea-formaldehyde foam resin
polyurethane foam
phenolic resin foam

Nylon-6

Nylon 6 is an awful lot like our friend nylon 6,6. You can look at the picture if you don't believe me.
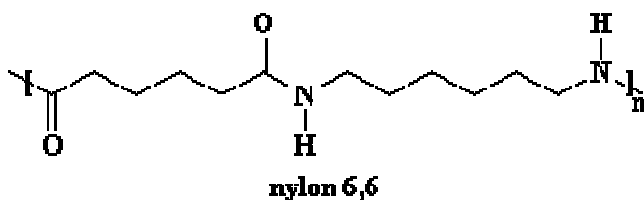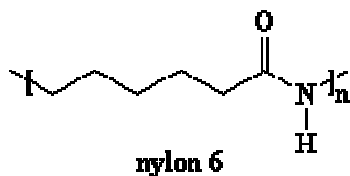
nylon 6

nylon 6,6

But making nylon 6 is lot different from nylon 6,6. First of all, nylon 6 is only made from one kind of monomer, a monomer called caprolactam. Nylon 6,6 is made from two monomers, adipoyl chloride and hexamethylene diamine.
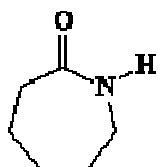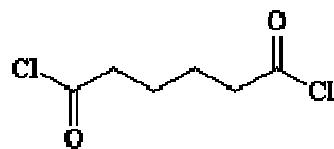
ε-caprolactam

adipoyl chloride

hexamethylene diamine

If you want to see caprolactam in 3-D,

But enough small talk. Let's get on with the business of turning caprolactam into nylon 6. Nylon 6 is made by heating caprolactam to about 250 $^{\circ}$C with about 5-10% water thrown in. So what happens to caprolactam when there's water around? The carbonyl oxygen looks around, and sees a water molecule, and sees how easy it would be to steal one of the water's hydrogen atoms. Now as is often the case, a little thing like this that seem harmless enough can grow into something much bigger. If you watch, you'll see that caprolactam's greed is going to get the better of it.
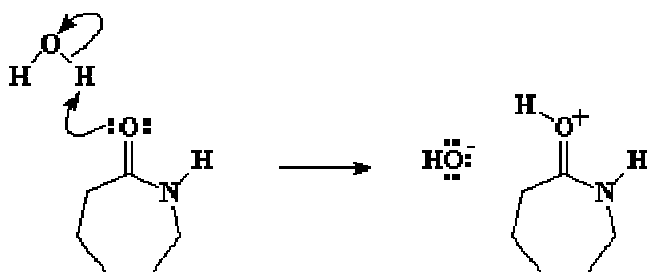
It starts off as just an innocent prank. The carbonyl oxygen shoplifts a proton from a nearby water molecule.

The carbonyl oxygen donates a pair of electrons to the hydrogen atom of water, thus stealing the hydrogen from the water. This gives us a protonated carbonyl, and a free hydroxyl group. Keep this hydroxyl group in mind, because it is going to come back to haunt greedy ol' caprolactam. But first, let's remember that the carbonyl oxygen now has a positive charge. It doesn't like this, so it swipes a pair

of electrons from the carbonyl double bond, leaving the positive charge on the carbonyl carbon atom.
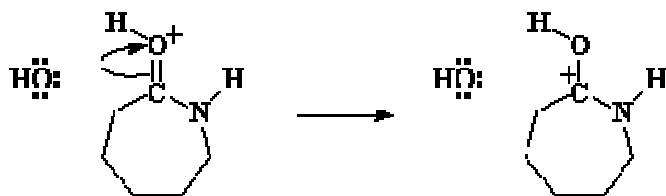
The electrons shift around to give a carbocation.

But carbocations are not happy critters. Putting a carbocation in a molecule is just begging for some nucleophile to come along and attack it. Nucleophile? Did someone say nucleophile? I think there's one nearby. It's that old hydroxide ion that was left when caprolactam stole the proton from the water molecule. This little hydroxide ion never really worked through the negative emotions of having lost its proton to caprolactam. Still harboring a lot of hostility, it attacks the carbocation.
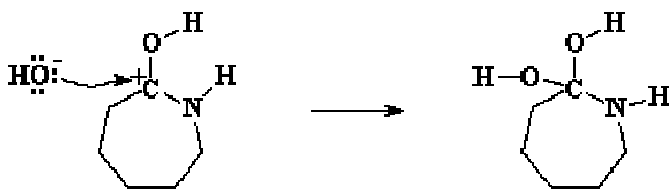
The hydroxy group attacks to give an unstable diol.

The molecule formed is now an unstable gem diol. Unstable? Of course. Didn't I tell you that caprolactam's greed would be its undoing? A mad reshuffling of electrons happens next. The nitrogen atom donates a pair of electrons to a hydrogen atom on one of the hydroxyl groups, stealing it away. The electrons that the hydrogen shared with its oxygen shift to form a double bond between the oxygen and the carbon atom. And lastly, the electrons shared by the carbon and the nitrogen shift completely to the nitrogen, severing the carbon-nitrogen bond.
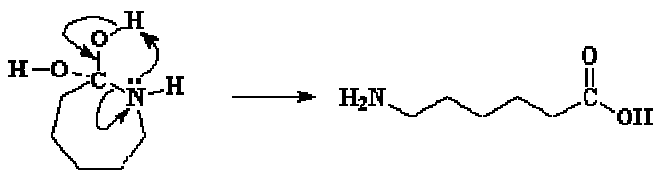
A flurry of electron shuffling breaks the
circle and forms a linear amino acid.

Alas, the circle is broken, and caprolactam is no more! Like many junk bond dealers in the eighties, it has paid dearly for its greed. What we're left with is a linear amino acid.

But our story is far from over. You see, that linear amino acid can react with a caprolactam molecule, a lot like the water molecule did. Caprolactam molecules aren't very bright. Witnessing one of their own destroyed by greed doesn't make them any less greedy. They just try to steal what they can from their fallen sibling, like greedy little buzzards. Ever avaricious, a caprolactam molecule will steal the acid hydrogen form the linear amino acid. The carbonyl oxygen donates a pair of electrons to that hydrogen, stealing it away from the amino acid.
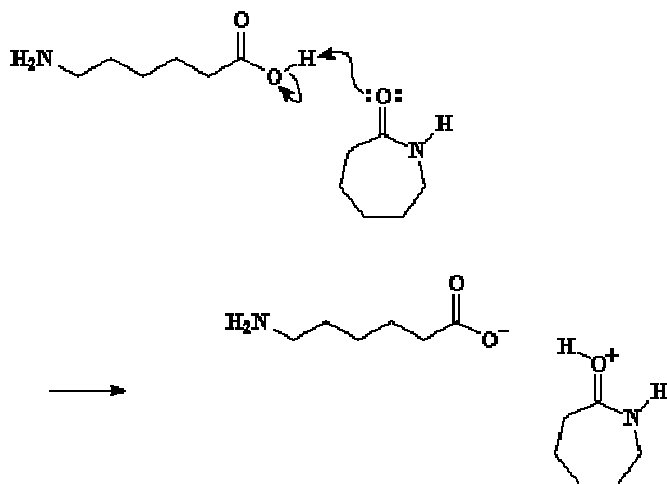

The newly formed amino acid quickly has
a proton stolen by a carbonyl oxygen

And as expected, the electrons rearrange to form the carbocation, just as before:
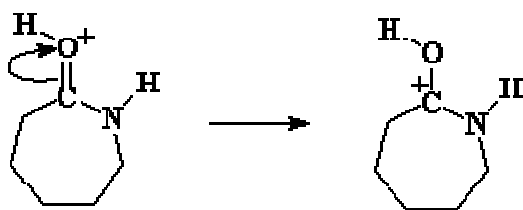
A little bit of electron shuffling gives us a carbocation, which is an open invitation to attack by a nucleophile.

This carbocation is still an open invitation to any nucleophile around, but this time, there's a new nucleophile on the block. That's the amino acid that just lost its acid hydrogen. It too has a lot of hostility towards the thieving caprolactam, and attacks just like we saw the hydroxide ion attack earlier.
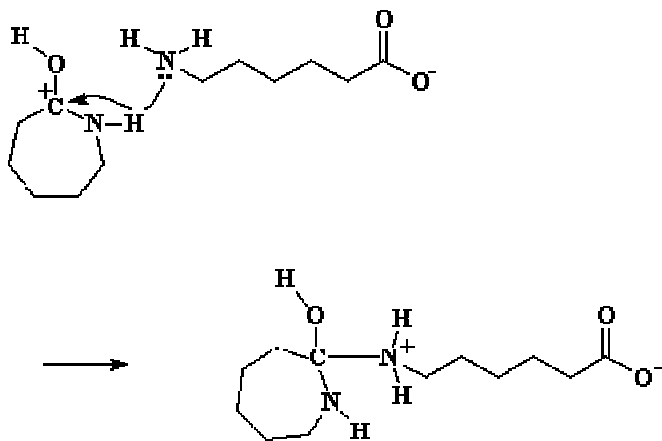

The linear amino acid attacks and gives this ammonium species.

This gives us an ammonium species, and this particular one is very unstable. The electrons play musical chairs. Showing no elemental loyalty, the ring nitrogen steals a hydrogen from the ammonium nitrogen. In addition, the bond joining the carbon and the nitrogen is severed, opening the ring. Another greedy caprolactam molecule bites the dust.
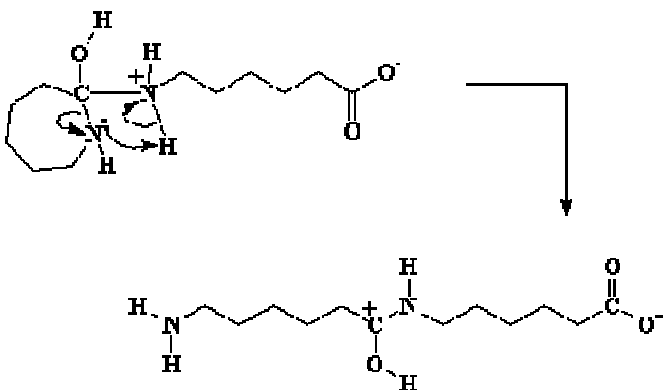
Another mad electron dance opens the ring
of the monomer, giving us a linear molecule

But we're not through yet. That carboxylate group at the end of the molecule is going to sweep around and steal the alcohol hydrogen.
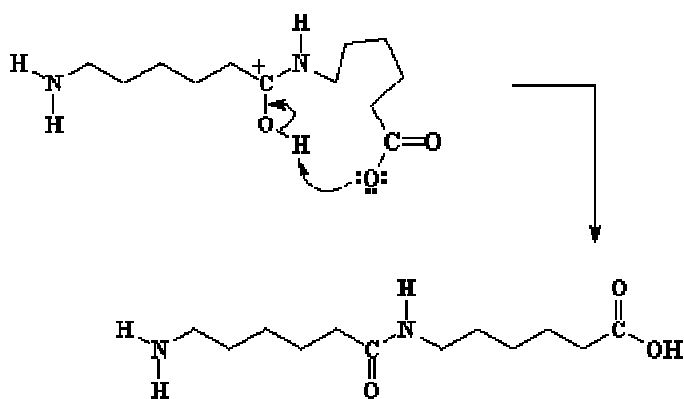
Then the caboxylate oxygen swipes a
hygrogen, and we have our complete dimer.

This makes a new carbonyl group in the middle of the molecule, and regenerates the carboxylic acid. (Here's a little secret: No one really knows the order of the last two steps. They might happen in the reverse order. We just know that both of them happen before everything is over.) If you want to see a movie of the whole propagation process, . (Remember, this is a step growth polymerization.)

Now that we have an acid again, it is sure to react with another avaricious caprolactam molecule, and then another, and another, until we get long chains of nylon 6.
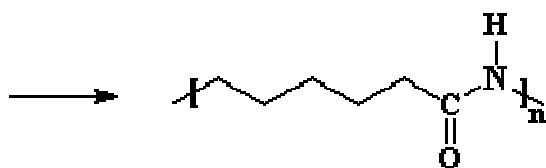
The dimer reacts with more monomer,
and eventually we get nylon 6.

Polypropylene

Polypropylene is one of those rather versatile polymers out there. It serves double duty, both as a plastic and as a fiber. As a plastic it's used to make things like dishwasher-safe foodcontainers. It can do this because it doesn't melt below 160°C, or 320°F. Polyethylene, a more common plastic, will anneal at around 100°C, which means that polyethylene dishes will warp in the dishwasher. As a fiber, polypropylene is used to make indoor-outdoor carpeting, the kind that you always find aroundswimming pools and miniature golf courses. It works well for outdoor carpet because it is easy to make colored polypropylene, and because polypropylene doesn't absorb water, like nylon does.

Structurally, it's a vinyl polymer, and is similar to polyethylene, only that on every other carbon atom in the backbone chain has a methyl group attached to it. Polypropylene can be made from the monomer propylene by Ziegler-Natta polymerization and by metallocene catalysis polymerization.
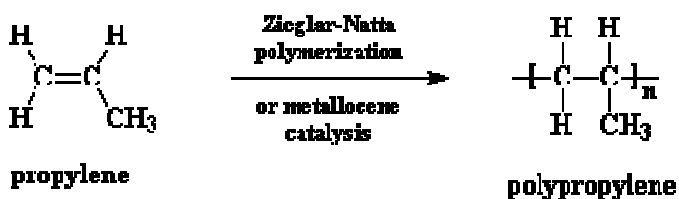

This is what the monomer propylene really looks like:

Wanna know more?

Research is being conducted on using metallocene catalysis polymerization to synthesize polypropylene. Metallocene catalysis polymerization can do some pretty amazing things for polypropylene. Polypropylene can be made with different

tacticities. Most polypropylene we use is isotactic. This means that all the methyl groups are on the same side of the chain, like this:

isotactic polypropylene
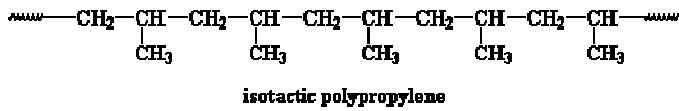
But sometimes we use atactic polypropylene. Atactic means that the methyl groups are placed randomly on both sides of the chain like this:

atactic polypropylene
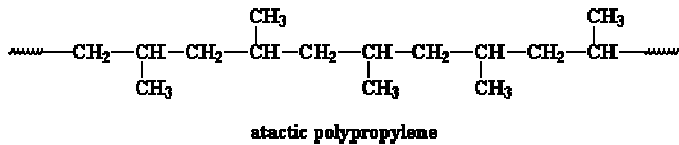
However, by using special metallocene catalysts, it's believed that we can make polymers that contain blocks of isotactic polypropylene and blocks of atactic polypropylene in the same polymer chain, as is shown in the picture:

—

This polymer is rubbery, and makes a good elastomer. This is because the isotactic blocks will form crystals by themselves. But because the isotactic blocks are joined

to the atactic blocks, the little hard clumps of crystalline isotactic polypropylene are tied together by soft rubbery tethers of atactic polypropylene, as you can see in the picture on the right.

To be honest, atactic polypropylene would be rubbery without help from the isotactic blocks, but it wouldn't be very strong. The hard isotactic blocks hold the rubbery isotactic material together, to give the material more strength. Most kinds of rubber have to be crosslinked to give them strength, but not polypropylene elastomers.

Elastomeric polypropylene, as this copolymer is called, is a kind of thermoplastic elastomer. However, until the research is completed, this type of polypropylene will not be commercially available.

The polypropylene that you can buy off the shelf at the store today has about 50 - 60% crystallinity, but this is too much for it to behave as an elastomer.

Spinning Processes

Synthetic and Cellulosic

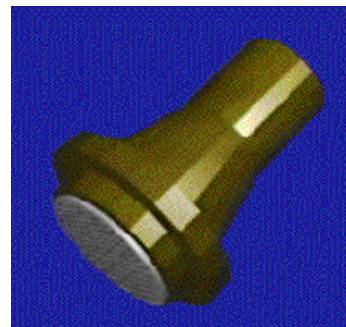### Fiber Formation Technology

Courtesy of AKZO Nobel
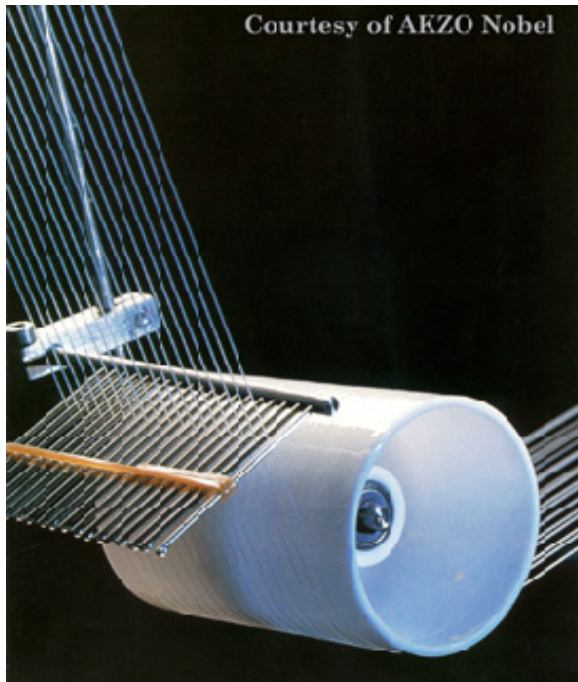
Most synthetic and cellulosic manufactured fibers are created by "extrusion" — forcing a thick, viscous liquid (about the consistency of cold honey) through the tiny holes of a device called a spinneret to form continuous filaments of semi-solid polymer.

In their initial state, the fiber-forming polymers are solids and therefore must be first converted into a fluid state for extrusion. This is usually achieved by melting, if the polymers are thermoplastic synthetics (i.e., they soften and melt when heated), or by dissolving them in a suitable solvent if they are non-thermoplastic cellulosics. If they cannot be dissolved or melted directly, they must be chemically treated to form soluble or thermoplastic derivatives. Recent technologies have been developed for some specialty fibers made of polymers that do not melt, dissolve, or form appropriate derivatives. For these materials, the small fluid molecules are mixed and reacted to form the otherwise intractable polymers during the extrusion process (if you are interested in the latest information on extrusion,

The Spinneret

The spinnerets used in the production of manufactured fibers are similar, in principle, to a bathroom shower head. A spinneret may have from one to several hundred holes. The tiny openings are very sensitive to impurities and corrosion. The liquid feeding them must be carefully filtered (not an easy task with very viscous materials) and, in some cases, the spinneret must be made from very expensive, corrosion-resistant metals. Maintenance is also critical, and spinnerets must be removed and cleaned on a regular basis to prevent clogging.

As the filaments emerge from the holes in the spinneret, the liquid polymer is converted first to a rubbery state and then solidified. This process of extrusion and solidification of endless filaments is called spinning, not to be confused with the textile operation of the same name, where short pieces of staple fiber are twisted into yarn. There are four methods of spinning filaments of manufactured fibers: wet, dry, melt, and gel spinning.

Wet Spinning

Courtesy of AKZO Nobel

Wet spinning is the oldest process. It is used for fiber-forming substances that have been dissolved in a solvent. The spinnerets are submerged in a chemical bath and as the filaments emerge they precipitate from solution and solidify.

Because the solution is extruded directly into the precipitating liquid, this process for making fibers is called wet spinning. Acrylic, rayon, aramid, modacrylic and spandex can be produced by this process.
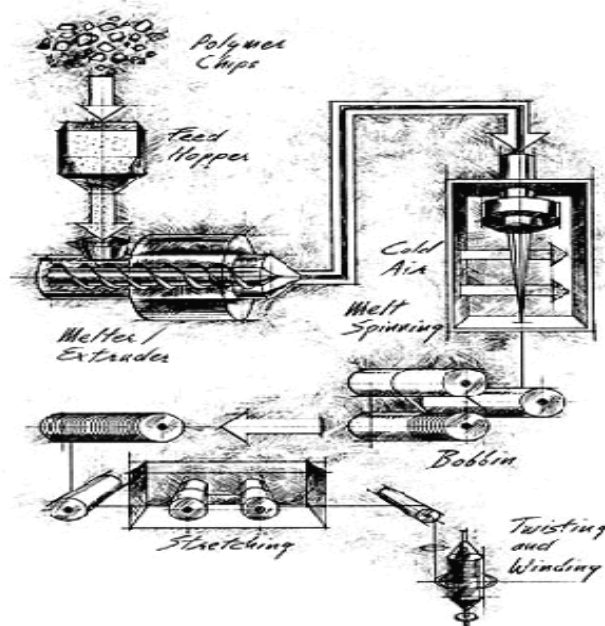
Dry Spinning

Dry spinning is also used for fiber-forming substances in solution. However, instead of precipitating the polymer by dilution or chemical reaction, solidification is achieved by evaporating the solvent in a stream of air or inert gas.

The filaments do not come in contact with a precipitating liquid, eliminating the need for drying and easing solvent recovery. This process may be used for the production of acetate, triacetate, acrylic, modacrylic, PBI, spandex, and vinyon.

Melt Spinning

In melt spinning, the fiber-forming substance is melted for extrusion through the spinneret and then directly solidified by cooling. Nylon, olefin, polyester, saran and sulfar are produced in this manner.

Melt Spinning Polymer from Chip
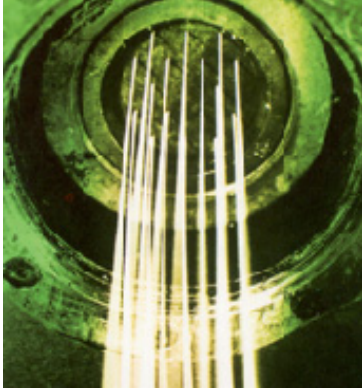
Melt spun fibers can be extruded from the spinneret in different cross-sectional shapes (round, trilobal, pentagonal, octagonal, and others). Trilobal-shaped fibers reflect more light and give an attractive sparkle to textiles.

Pentagonal-shaped and hollow fibers, when used in carpet, show less soil and dirt. Octagonal-shaped fibers offer glitter-free effects. Hollow fibers trap air, creating insulation and provide loft characteristics equal to, or better than, down.

Detailed production flowcharts:

- Acrylic • Nylon(Polyamide) • Polyester

Gel Spinning

Gel spinning is a special process used to obtain high strength or other special fiber properties. The polymer is not in a true liquid state during extrusion. Not completely separated, as they would be in a true solution, the polymer chains are bound together at various points in liquid crystal form. This produces strong inter-chain forces in the resulting filaments that can significantly increase the tensile strength of the fibers. In addition, the liquid crystals are aligned along the fiber axis by the shear forces during extrusion. The filaments emerge with an unusually high degree of orientation relative to each other, further enhancing strength. The process can also be described as dry-wet spinning, since the filaments first pass through air and then are cooled further in a liquid bath. Some high-strength polyethylene and aramid fibers are produced by gel spinning.

Stretching and Orientation

While extruded fibers are solidifying, or in some cases even after they have hardened, the filaments may be drawn to impart strength. Drawing pulls the molecular chains together and orients them along the fiber axis, creating a considerably stronger yarn.

Texture Mapping

Texture mapping is a method for adding detail, surface texture, or colour to a computer-generated graphic or 3D model. Its application to 3D graphics was pioneered by Dr Edwin Catmull in his Ph.D. thesis of 1974.

Contents

- 1 Texture mapping

- 2 Perspective correctness

- 3 See also

- 4 References

- 5 External links

Texture mapping

A **texture map** is applied (mapped) to the surface of a shape, or polygon. This process is akin to applying patterned paper to a plain white box.

Multitexturing is the use of more than one texture at a time on a polygon. For instance, a light map texture may be used to light a surface as an alternative to recalculating that lighting every time the surface is rendered. Another multitexture technique is bump mapping, which allows a texture to directly control the facing direction of a surface for the purposes of its lighting calculations; it can give a very good appearance of a complex surface, such as tree bark or rough concrete, that takes on lighting detail in addition to the usual detailed coloring. Bump mapping has become popular in recent video games as graphics hardware has become powerful enough to accommodate it.
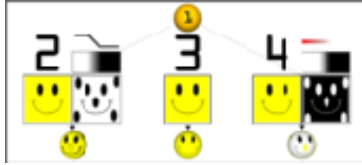
Examples of multitexturing
1. Untextured sphere 2. Texture and bump maps 3. Texture map only 4. Opacity and texture maps

The way the resulting pixels on the screen are calculated from the texels (texture pixels) is governed by texture filtering. The fastest method is to use the nearest-neighbour interpolation, but bilinear interpolation or trilinear interpolation between mipmaps are two commonly used alternatives which reduce aliasing or jaggies.
In the event of a texture coordinate being outside the texture, it is either clamped or wrapped.

Perspective correctness

Because affine texture mapping does not take into account the depth information about a polygon's vertices, where the polygon is not perpendicular to the viewer it produces a noticeable defect.

Texture coordinates are specified at each vertex of a given triangle
(for graphics hardware, polygons are generally broken down into triangles for rendering), and these coordinates are interpolated using an extended Bresenham's line algorithm. If these texture coordinates are linearly interpolated across the screen, the result is affine texture mapping. This is a fastcalculation, but there can be a noticeable discontinuity between adjacent triangles when these triangles are at an angle to the plane of the screen (see figure at right).

Perspective correct texturing accounts for the vertices' positions in 3D space, rather than simply interpolating a 2D triangle. This achieves the correct visual

effect, but it is slower to calculate. Instead of interpolating the texture coordinatesdirectly, the coordinates are divided by their depth (relative to the viewer), and the reciprocal of the depth value is also interpolated and used to recover the perspective-correct coordinate. This correction makes it so that in parts of the polygon that are closer to the viewer the difference from pixel to pixel between texture coordinates is smaller (stretching the texture wider), and in parts that are farther away this difference is larger (compressing the texture).

Affine texture mapping directly interpolates a texture coordinate u_α between two endpoints u_0 and u_1:

$$u_\alpha = (1 - \alpha)u_0 + \alpha u_1$$
where $0 < \alpha < 1$

Perspective correct mapping interpolates after dividing by depth z, then uses its interpolated reciprocal to recover the correct coordinate:

Most modern graphics hardware implements perspective correct texturing, but when games still relied on software rendering, perspective correct texturing had to be used sparingly because of its computational expense. Several different techniques were developed to hide the defect of affine texture mapping. For instance, , *Doom* restricted the world to vertical walls and horizontal floors/ceilings. This meant the walls would be a constant distance along a vertical line and the floors/ceilings would be a constant distance along a horizontal line. A fast affine mapping could be used along those lines because it would be correct. A different approach was taken for Quake, which would calculate perspective correct coordinatesonly once every 16 pixels of a scanline and linearly interpolate between them, producing a compromise between the speed of affine texturing and perspective correctness.

Another technique was subdividing the polygons into smaller polygons and using an affine mapping on them. The distortion of affine mapping becomes much less noticeable on smaller polygons. Yet another technique was approximating the perspective with a faster calculation such as a polynomial. Finally, some programmers extended the constant distancetrick used for Doom by finding the line of constant distance for arbitrary polygons and rendering along it.

Yarn manufacture and yarn structure & properties

Yarn manufacture

The conversion of fibre to yarn – the spinning process – is themost important link in the textile production chain.To meet the growing demand and qualitative requirements for the yarn – and to remain an active player in the ever-increasing competition on the global textile markets – continuous improvements are vital.

As a leading manufacturer of power transmission and conveyor belting, Forbo Siegling has for decades kept pace with the diverse developments in yarn and textile production in close co-operation with the customers. This has provided the foundation for our successful alliance with textile machinery manufacturers and producers in the short and long staple sectors, as well as in the man-made fibre industry throughout the world.

In yarn manufacture Forbo Siegling provides the following products:

Power transmission belts

Extremultus high-efficiency flat belts are characterized by their long service lives, highly uniform RPM speeds, high effectiveness > 98% and good damping properties.

Several shafts can be driven simultaneously in the same andopposite directions. Furthermore, Extremultus powertransmission belts can be turned at an angle to the axis of the running direction (mule drive) and are also suitable for use on conical pulleys (taper-cone drive).

Extremultus P line

Extremultus high-efficiency flat belts of the P line are available with friction coatings/coverings of highly wear-resistant elastomer G or chrome-tanned leather on both sides. The polyamide tension member is characterized by its good elastic property/ behaviour, which dampens impacts and oscillations.

The elastomer G friction coating is used for all standard drives in carding machines, drawing frames, fan and main drive belts for spinning frames and twister operating under dry or dusty conditions.

The chrome leather L friction coating is used for all standard drives in carding machines, drawing frames, flyer spinning frames and for main and secondary drive belts in twister and texturing machines, especially where oil and grease factors play a role. On taper-cone drives the belt can be shifted easily thanks to its particularly stiff edges and the good sliding and wear properties of the chrome leather friction covering.
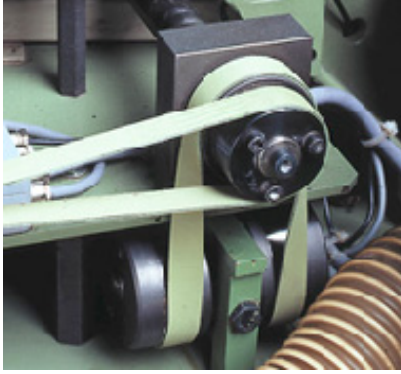
Extremultus E line

Extremultus high-efficiency flat belts of the innovative E line have highly wear-resistant friction coatings of elastomer G on both faces and are well suited for use on either simple two-pulley drives or multiple-pulley drives. Various polyester tension members and a large operational elongation range of 1.0 – 2.5% make individual power transmission possible byappropriate selection of elongation at fitting.

The flexible belt construction makes the Extremultus E line a universal drive belt, in particular for mule or torsional drives and for applications with small pulley diameters. The symmetrical belt design and the smooth Z-splice ensure exact belt tracking with minimal angular velocity oscillation.

The thermoplastic, flexible tension member helps save energy and is also largely unaffected by fluctuations in ambient conditions, ensuring no maintenance.
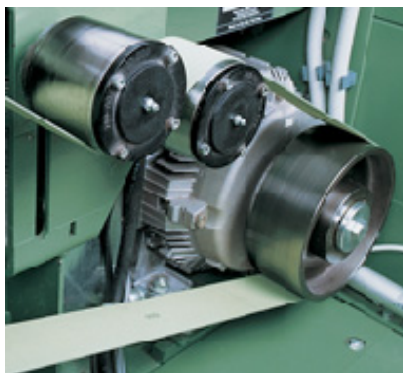
Spindle tapes

Extremultus spindle tapes are designed for classical ringspinning frames and double twisters with two, four or eight spindle drive as well as for the newest high-speed ring spinningframes and high performance twisters.

Extremultus spindle tapes have

- a permanent antistatic property

- coating on pulley face made of wear-resistant polyurethane

- impregnated, wear-resistant fabric construction on the wharve face

The new high-efficiency spindle tape **UT 8E**with an energy-saving tension member of a new type of high-strength polyester blended fabric (E) can transmit an exceptionally high amount of power. This ability makes it suitable not only forhigh-speed ring spinning frames with spindle speeds of up to 25,000 RPM but also for the heavy twisters for synthetic yarns.

The two-ply standard spindle tape**UT 5P**with its strong butflexible tension member of polyamide blended fabric can beused for the transmission of larger amounts of power, even under heavy-duty operational conditions.

Tangential belts

Sectional tangential belt drives

These types of drive place high demands and the tangential belt:

- the ability to withstand high mechanical and thermal stress on the belt surfaces – especially during spindle stop and acceleration

- precise belt tracking with little oscillation

- greatest possible belt flexibility as well as a simple,reliable endless splice

The properties of the Extremultus A + E line are used to their fullest advantage on this application. The highly-modular,flexible belt design saves energy and minimizes RPM variations in the section of spindles. The precise Z-splice ensures that the belt tracks with little oscillation, treating the machinery gently. Yarn quality and service lives of the drive components increase, energy and maintenance costs drop.

Conventional tangential belt drives

Whether it is twisters, texturing machines, ring spinning frames, double twisters or cover spinning frames the following requirements are increasingly important for the tangential belt:

- greatest possible transmission of effective pull while using the technical properties to the fullest

- reduced noise generation as speeds increase

- functional reliability, ensuring high productivity

Highly-modular tangential belts of the Extremultus A + E line are being used increasingly more often, in addition to the reasonably-priced, tried-and-tested Extremultus P line tangential belts.

Tangential belt drives with concave/ convex drive geometry

For the economical mass production of textile machinery, the design of the spindle section with concave or convex drive geometry has proven itself time and time

again. The elimination of pressure rollers, the small pulley diameters, the short take-up ranges and in some cases the fluctuating ambient conditions shape the requirements for:

- precise tracking and low-noise belt operation

- belts which save energy and are flexible

- highly-modular tension member largely unaffected by climate, and long belt life

The innovative Extremultus E line provides the greatestbenefits possible for application technology, setting a new cost/benefit standard for operating and maintenance costs.

Rotor drive belts for OE machines

Since the infancy of OE spinning technology, high-efficiency tangential belts from Forbo Siegling have been closely associated with rapid increase in rotor speeds. Under the trademark Extremultus GG 20..., milestones have been set in the development of rotor drive belt technology:

- the extremely wear-resistant black OE coating

- the precise SV splice

- the precise HP ground texture.

Conveyor and processing belts

Transilon conveyor and processing belts make economical, automated flow of material in modern spinning systems and the subsequent processing of textiles possible. Transilon conveyor belts also contribute significantly to quality assurance and flexibility in the production process thanks to:p

gentle conveying during the delivery of bales, the delivery of fibres in the cards and drawing frames, the blending and cleaning of flock and when feeding fibre to the ring spinning frame, reliable conveying of trash and crosswound bobbins in OE spinning frames increased productivity in the conveying of empty bobbins, cops or

cop trays in fully-automatic linkage systems, on winders and twisters, right up to the intermediate storage and packaging of cross-wound bobbins.

Depending on belt construction and coating, Transilon is

- antistatic
- conductive on top in accordance with ISO/DIN
- low-noise
- resistant to oil mist and other chemical factors
- adhesive or with low drag
- smooth or textured
- wear-resistant
- treats material gently
- resistant to soiling
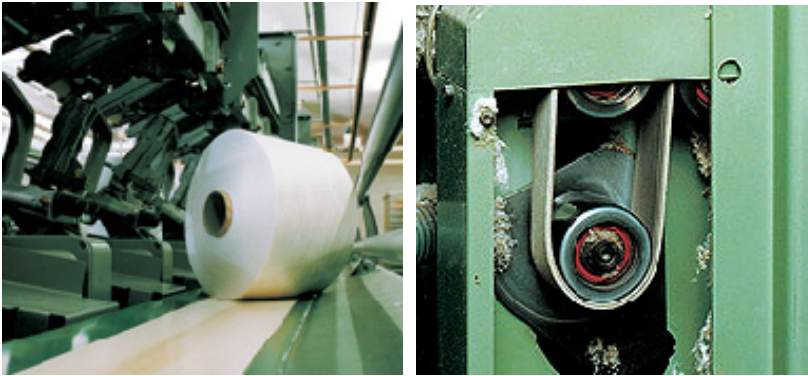
yarn structure
"Yarn" is a general term that I use to refer to that string stuff you use to knit with. When I use the term **"yarns"**, it is because I am referring to all the different **VARIETIES** of yarn. Bouclé, DK, chenille, slub, etc... I believe the same applies to "wool" (meaning fleece) and "wools" (meaning all the types of fleeces out there, not just sheep's wool). It is strange, I know, and I don't even know if it is grammatically correct, but that's how I (and many other singular folk) talk about it.
Yarn is what your garment will be made up of when you have finished your project, and **it is important to know the properties of the yarn you are using, for it will be these properties that will affect the ultimate look and feel of a garment.**

A lot of important information about a particular skein, hank or ball of yarn can be found on the **label**, which is often found in the form of a collar or band around it. Here you will learn fiber content, weight, type of yarn, washing instructions, and approximately how many yards or metres of yarn you have. There will also be a **dye lot** number, which is important. **Yarn is dyed in lots, or batches, and these batches differ slightly from one another, although they areconsidered to be batches of the same color.** Buy enough yarn to complete your project, usually a skein more than thepattern asks for, so you can complete a single garment from a single dye lot.

Hopefully, you have read the section on fibers, and know that different fibers have vastly different properties. But **it is not the fiber alone that will determine the look of a yarn, and how it will knit up. There are many different methods for turning fiber into yarn, and many different treatments applied to fibers that can change their initial properties**.

Yarns spun from "**filaments**" are generally smooth and shiny. This is because **filaments are continuous strands of fiber**that can be many miles long, if we are talking about extruded, synthetic filament fibers. The only natural filament fiber is silk, which can measure over 1500 yards/metres. Filaments are often cut into shorter strands for spinning.

Shorter lengths are referred to as "staple". Staple lengths range from fibers that are 1-2 inches (angora rabbit and chiengora) to fibers that are several inches long (Egyptian cotton, Merino wool). Longer staple will spin into smooth, lustrous yarn, and it tends to be softer and more sought after than its shorter staple counterparts. Longer staple also lends strength and resilience to a yarn. Yarns made of short staple will tend to have a fuzzy appearance, and is generally blended with a strong fiber, like a synthetic filament fiber, to give it strength.

Sheep's wool is divided into two categories when referring to the resulting yarn, depending on the length of the fibers and the way they are handled before spinning: "**worsted**" and "**woolen**". Worsteds are spun from longer, combed fibers, so the resulting yarn is smooth and firm. Woolens are spun from uncombed wool, and is fuzzier and not as strong (Icelandic Lopi and Shetland yarns). Both kinds are desirable types of yarn, used to create different effects in the finished garment.

So how does one go from a handfuls of fuzz and fiber to yarn? The answer is "**spinning**". There are many different methods to spin fiber into yarn, but basically, **the prepared fluff is drawn out and twisted using a spindle or other spinning device, such as a spinning wheel, or the industrial equivalent.** The twist lends strength to the yarn. The twist can be a "**Z twist**" which runs upwards and to the right, formed by spinning the yarn in a clockwise direction. The "**S twist**" is formed by spinning counterclockwise, the resulting twist runs upwards and to the left. **The twist in the yarn for Z and S runs in the same direction as the diagonal used to form these letters!**

When the yarn is first spun, it forms a "**single**". These singles are often "**plied**" together to form 2-ply, 3-ply and 4-ply yarns.**Plying makes the yarns stronger, and more uniform**. Each ply is a single, and these singles are generally plied together using a twist that is opposite to the one used in the initial spinning of the strands. That is, a plied yarn that is a Z twist is made up of single strands that have been spun with an S twist. The heaviness, or weight, of the resulting yarn depends not on the amount of plies in the yarn, but on the thickness of the singles. Two fat singles will result in a yarn much heavier than a 4-ply made of very fine ones.

Yarn Weight: Yarn thickness is often referred to as "**weight**" and it ranges from the very fine "fingering" weight or "baby" yarn, to the "bulky" and "chunky" yarns. In between there are many different terms, and their definitions are guidelines, for people use the same term to define different weights of yarn. Also, people in different countries will use different terms to describe their yarn, so a fingering weight (USA) yarn from the UK will be labeled 4-ply. I will try to define these terms here to the best of my abilities, but the different resources from which I did my research also have differing points of view.

Laceweight, or 2-ply/3-ply: Although some sources say differently, generally speaking, 2-ply/3-ply yarns are very fine, almost threadlike yarn that are used for lacy garments such as shawls and scarves, and baby clothes.

Fingering Yarn, or 4-ply: Also called "5-ply" in Australia andNew Zealand, this yarn is also used for baby clothes and lacy garments, but is also used for Fair Isles and adult garments. (Granted, adult garments will take a

long time to complete with such a fine yarn!) Since this yarn is fine, greater detail can be achieved when knitting a picture or motif into the garment. (In a different resource book, fingering weight yarn wasconsidered the same as 2-ply and 3-ply yarn.)

Sportweight, or DK (Double Knitting): This yarn is also "8-ply" in Australia and New Zealand. This versatile yarn is used for all types of garments worn from infancy through adulthood. It can be knitted up into lacy garments as well as garments with lots of texture and cables, and everything in between. There are many patterns available for this weight of yarn and it is very popular. It comes in many colors, and is also available with different effects, i.e. tweed (different flecks of color), heather (colors that are finely blended with paler shades for a gently speckled effect), brushed (fuzzy effect), and others.

Aran, Worsted, or Triple: Also referred to as "knitting worsted" or 12-ply in Australia and New Zealand, this yarn is generally used for heavily textured garments involving cables and other such texture techniques. It used to only be available in natural unbleached shades of creamy white and ivory, but it is now available in many colors although the white is the traditional choice for the knitting of an Aran sweater.

Chunky, or Bulky: 14 ply in Australia or New Zealand, this is heavy yarn that knits up quickly on large needles, and is often the choice of beginners since it is easy to handle and fast work. It comes in a wide range of colors, and is popular for oversized sweaters, jackets, and children's wear.

Yarn Structure: Besides yarn weight, there are many other ways to describe a yarn's appearance.   These ways are categorized under "yarn structure". The way yarns are plied and spun can result in many different variations, as you will soon see!

Bouclé: Bouclé is formed when two threads are plied using different tensions and held together using a binder thread.

There are many different variations on this method, producing different, yet similar results. This method is also used to produce
Loop yarn which is an exaggerated version of bouclé. See below!

Chenille: This popular yarn is best described to be formed like pipecleaner. Two very fine binding strands are plied together tightly, holding the velvety pile between them.

Chenille can look very different if the length and texture of the pile is changed. There are many different variations of chenille on the market. Chenille can knit up like a fake fur or a with a fine, subtle velvety appearance, depending on the pile.