Materials: Cloth, Paper, and Wood

Fibers

Plant fibers have been used for millennia to make cloth, rope, paper, and numerous other articles

The most valuable fibers are those that are nearly pure cellulose and white; cellulose is an extremely strong material with tensile strength that rival that of steel

Types of fibers

Animal fibers, such as wool or silk, have a protein makeup; plant fibers are composed mainly of cellulose

Fibers can be classified according to use

- Textile fibers are woven to produce cloth
- Cordage fibers are used in making rope
- Filling fibers are used as stuffing in upholstery or mattresses

Plant fibers can be classified according to where they are found on a plant (see table 18.1)

- Surface fibers are found on the covering of seeds, leaves, or fruits (e.g., cotton fibers)
- Bast or soft fibers are clusters of phloem fibers found in the inner bark of dicot stems (e.g., fibers used for linen and ramie)
- Hard fibers or leaf fibers are obtained from the vascular bundles or veins in leaves (e.g., sisal and Manila hemp)

Extracting fibers

- Surface fibers are usually separated mechanically from plant material by ginning – machines tear the fibers loose
- Many soft fibers are extracted from stems by retting – microbial action degrades away the soft tissue leaving the tough fiber strands intact and freed
- Hard fibers are commonly extracted by decortication – unwanted tissues are scraped away by hand or by machine

Spinning into yarn

Once fibers have been freed from the source material, they are cleaned of plant materials and dirt

The fibers are then combed and laid parallel to each other to form a strand

The strand is stretched or pulled and the individual strands are twisted together to form the yarn or thread (see fig. 18.1)

King cotton

The process of rendering cotton fibers into cloth was discovered independently during prehistoric times in both the Old and New Worlds

Cotton was harvested from wild populations in coastal Peru as early as 10,000 years ago and domesticated by 4,500 years ago; it was also grown and used by native peoples of the American Southwest

Old World cotton cloth dates back 5,000 years on the Indian subcontinent

Cotton became a Muslim industry in the Near East in the 9th and 10th centuries; Arabs introduced cotton cultivation to Muslim Spain

Cotton was introduced into Florida in 1556; less than 100 years later it was a significant crop in the southern colonies

New World varieties were introduced into Europe in the 18th century

The cotton plant

Today, cotton is the most popular natural fiber, accounting for half of the world's textiles

The cotton plant belongs to the genus *Gossypium* in the mallow family (hibiscus family)

The fruit is a capsule (called a boll in commercial circles), and when it splits open along five seams, reveals a white mass of fibers (see fig. 18.2)

Two types of seed hairs cover the seed surface – the lint or staples are long slender fibers; linters are shorter, fuzzy hairs

High-quality cotton is made from the longest lints

The purity of cellulose and its natural twist (see fig. 18.3) make cotton an excellent fiber for spinning into yarn

Old and New World varieties

Old World cottons are diploid ($2n = 26$) and produce short lint

New World species are tetraploid ($2n = 52$)

Gossypium hirsutum (upland cotton) is the predominant cotton grown in the world today; lint from upland cotton varies from short to long

Gossypium barbadense (cultivars include Sea Island, pima, and Egyptian cotton) has especially long and silky lint, and its fibers are used to produce high-quality, luxury cotton cloth

The cotton gin (see fig. 18.4)

During ginning, the lint is removed from the seeds

Eli Whitney's gin made it possible to separate cotton fiber from seeds much more quickly

Whitney's gin had its greatest effect in the cotton-growing states of the South

Before 1790, the growing of long-staple cotton varieties, those that could be ginned most easily by hand, was limited to coastal regions in the South

The soil and climate of the Southern interior were suitable only for the cultivation of short-staple varieties; the cotton gin made production of short-staple cotton economically feasible and expanded the Cotton Belt in the South

Cotton seed can be used to make livestock feed; also, the seeds are the source of cottonseed oil used as a cooking oil

Finishing and sizing

The finishing process may be applied to either the yarn or woven cloth; finishes may alter the appearance or modify the function of the textile

Most plant fibers are bleached to remove the natural color and cotton is no exception

Mercerization is a finishing process in which the flat cotton fibers swell into a round shape and become stronger, more lustrous, and more easily dyed

Sizing is the application of materials to the yarn or fabric that produce stiffness and firmness

Bioengineering cotton

Bollard is the trade name for a transgenic cotton plant created by Monsanto that has incorporated the toxin-producing genes from *Bacillus thuringiensis*

It was hoped that this Bt cotton would be resistant to insect pests of cotton, but it has not been able to ward off assaults by the cotton bollworm

Another biotechnology company, Agracetus, is working on transgenic cotton plants that fill the hollow middle of the cellulose seed hairs with a small amount of polyester material producing a cotton-polyester blend fiber

Linen: an ancient fabric

The oldest plant fiber used to make cloth may be flax; the stem fibers have been woven to make linen for at least 10,000 years and ancient Egypt was known as the land of linen

The flax plant (see fig. 18.5)

Two types of flax are grown commercially – one for its seed oil (linseed oil) and one for its fibers

Linseed oil is used in the manufacture of paints, stains, varnishes, and linoleum

Unbranched varieties of flax are grown for linen production (see fig. 18.6a); the stems reach a height of 1 meter (3 feet) and have fibers as long

Processing flax

Retting extracts the fibers from the stem by employing microbial decomposition to break down the outer part of the stem

After the retted fibers have been dried, they are processed these days mainly by machines that crush the dried and retted flax as it passes through rollers

Any shives, or stem particles, that remain are scraped off during scutching (see fig. 18.6b)

The now-freed fibers are hackled, or combed, to separate the short fibers (tow) from the long fibers (line)

The flax fibers are then bleached and spun into yarn

Flax fibers and linen

Flax fibers consist of about 70% cellulose, with the balance made up of waxes and pectins

Flax fibers are naturally lustrous (due to the waxes) and extremely long; linen is durable and is used for both clothing and home furnishings such as drapes and upholstery

Other bast fibers

Ramie, hemp and jute are, like flax, bast fibers

Ramie fibers are some of the longest, strongest, and most lustrous fibers; however, the fibers are somewhat brittle, and removing the pectins and gums in the stem is difficult

Jute fiber (see fig. 18.7) is used to make burlap, ropes, wall coverings, carpet backing, upholstery lining, and inexpensive clothing

Hemp fibers are used primarily to make industrial fabrics such as canvas, ropes, and twines; industrial hemp was an agricultural staple for hundreds of years – its cloth was used in sailing ships and covered wagons

Miscellaneous fibers

Manila hemp

Most Manila hemp (not related to the *Cannabis* hemp) is grown and produced in the Philippines

The fibers have been used to make lightweight clothing, cigarette filters, and teabags; today, most is used for marine rope

Pineapple cloth (see fig. 18.8)

Shirts, shawls, scarves, and other traditional apparel of the Philippines are made of a gossamer-like material from the leaf fibers of the pineapple plant

Sisal (see fig. 18.9)

Leaf fibers from the desert *Agave* originally were used to make rope and coarse garments; today, sisal fiber is used primarily for making rope, string, and floor mats

Kapok

Kapok, a surface fiber found in the pods of the tropical rain forest kapok tree, was once the stuffing for life preservers

A coating of cutin makes the fibers waterproof, and a large lumen makes them lightweight

Kapok fibers are too fine and slippery to be spun; they are used for padding and stuffing in upholstered furniture, mattresses, and pillows because they are nonallergenic

Coir from coconuts (see fig. 18.10)

Coir is a seed fiber from coconuts that is valued for its durability in items such as ropes and door mats

Rayon: "artificial silk" (see fig. 18.11)

The first synthetic fiber was rayon, which is made of pure cellulose

The original source of cellulose was cotton linters; wood fibers are commonly used today

Because rayon is a synthetic fiber, manufacturers can modify the size and shape of the fibers

The strength and elasticity of rayon fibers are low; rayon tends to wrinkle and stretch easily

Like cotton, rayon has good moisture absorbency, which makes it easy to dye and comfortable to wear

Bark cloth (see fig. 18.12)

Rendering bark into cloth is an age-old craft that developed independently in several regions

In Polynesia, the general term for such cloth is tapa

In the Hawaiian Islands, bark cloth is known as kapa

The soft flannel-like cloth is used to make bed sheets, draperies, wall hangings, and a variety of clothing for men and women – e.g., loin cloths, sarongs, skirts, capes

Wood and Wood Products

Wood and wood products rank right behind food in overall importance to society

Construction materials, furniture, musical instruments, paper, fuel, charcoal, and synthetic materials are just a few of the products that come directly or indirectly from trees

About one-third of Earth's surface is covered by forests that supply the wood and wood products used by humans

Forestry scientists estimate that 30% to 50% of the world's forests have already been destroyed

Only about 13% of the world's forest land is being managed, and only about 2% of the world's forests are protected in forest reserves

Most tropical forests are cleared for agriculture and ranching; the majority of trees that are cut for wood tend to be used locally for fuel, with less than 15% used as lumber

Hardwoods and softwoods

Wood is secondary xylem consisting largely of dead cells involved in the transport of water and minerals as well as support

Hardwood refers to angiosperm trees; softwood refers to gymnosperm trees or conifers

The centermost region of secondary xylem in a tree is known as heartwood; it is relatively dry and the cells often contain tannins, gums, and resins, which accumulate in this older area and help prevent decay (see fig. 18.13)

The region outside the heartwood is sapwood, which functions in both support and conduction; sapwood cells are normally wet (see fig. 18.13)

For lumber use, heartwood is preferred because it is resistant to decay and less likely to shrink and warp because it is drier

Many characteristics of wood are determined by the thickness of the cell walls and the proportion of vessels, thracheids, and fibers

The frequency and distribution of these components are distinctive for various species and contribute to the characteristic grain

The prominence of annual rings and the direction of cutting (see fig, 18.14) also contribute to grain, and another important feature is the presence of knots

Lumber, veneer, and plywood (see fig. 18.15)

About half of the wood harvested in the U.S. is used as lumber, primarily for construction, with a considerable amount used to make furniture

The greatest use of softwood lumber is for home construction; pine is valued because it is light but strong

Douglas fir is another desired tree for plywood and large beams; other important softwoods include spruce, hemlock, bald cypress, and red cedar

The oaks are the most economically important hardwoods in the U.S.

White oak has very heavy, durable, attractive wood and is widely used in furniture, cabinets, flooring, trim, and whisky barrels

Black oak is not as strong as white oak; it is used for general construction, flooring, furniture, posts, and railroad ties

Other important hardwood trees are black walnuts, hickories, maples, sweetgums, tulip trees, and birches

Veneer is a very thin sheet of a desired wood that is glued to a base of less expensive lumber

Some of the most popular woods for veneers are black walnut, black cherry, bird's eye maple, mahogany, and teak

Plywood consists of three or more layers of thick veneer glued together with grains of alternating layers at right angles to each other

This makes the sheet or board more uniformly strong compared to a piece of solid wood; the result is a lightweight but strong building material

Fuel

Throughout the history of human civilization, wood has been the chief source of fuel until relatively recent times

About 1.5 billion people depend on wood or charcoal for 90% of their energy needs for heating and cooking; another billion people use wood for about 50% of their energy needs

It is estimated that each year 50% of the world's harvested wood goes to fuel

Wood can be converted to charcoal, which is almost pure carbon and burns at much higher temperatures than wood

Other products from trees

Resins include a broad collection of compounds that are composed of polymerized terpenes mixed with volatile oils

The best-known commercial resins are extracted from conifers

Crude exudate (pitch) collected from the trees is heated and the volatile components are condensed to form turpentine; the remainder is known as rosin

Another nonwood product of trees is cork (see fig. 18.16)

Commercial sources of cork are from the bark of an evergreen oak native to the western Mediterranean region, with the greatest production from Portugal and Spain

Wood pulp

Wood pulp is a watery suspension of pulverized wood

In industrialized nations, about 50% of the harvested wood goes into wood pulp, with the vast majority of pulp used to make paper

In addition, wood pulp is used to make cardboard and fiberboard as well as rayon, cellophane, and cellulose acetate

Cellophane and cellulose acetate are made by treating dissolved cellulose with acetic acid or acetic anhydride; the resulting material can be spun into fibers or rolled into sheets

Cellulose acetate is often used to make molded "plastics" such as glass frames, toothbrush handles, combs, car steering wheels, and pens

Paper

Early writing surfaces

Clay tablets, prisms, and cylinders were the writing surfaces used by Sumerians about 5000 years ago

Papyrus (made from a sedge plant) was the writing surface used by Egyptians about 4500 years ago (see fig. 18.17); the Greeks and Romans used papyrus until the 4th century when parchment became the main writing surface

Parchment is prepared from the skins of sheep, calves, or goats; vellum is a finer quality parchment from kids, lambs, and young calves

The art of papermaking

Paper is prepared from pulp, a slurry of plant cells that are separated and dispersed in a watery suspension; today, most paper is prepared from wood pulp

The cells are matted into a thin layer that may be filled with clay or talc for added body, coated with sizing such as starch for smoothness, and then compressed

According to tradition, paper was first made in the year A.D. 105 by Ts'ai Lun, a eunuch attached to the Eastern Han court of the Chinese Emperor Ho Ti; for about 500 years, papermaking remained a Chinese property

Papermaking was introduced into Japan in 610, to Central Asia in 750, and to the Near East and Egypt around 800

The Moors introduced the use of paper to Europe, and the first European paper was made in Spain around 1150

The introduction of movable type by Johann Gutenberg in the mid 15th century provided a major stimulus for the papermaking trade

Alternatives to wood pulp

For hundreds of years, cotton and linen have been used to produce writing paper; other sources include rice straw, bamboo, bagasse from sugar cane, and hemp; hemp was one of the earliest plants used by the ancient Chinese papermakers

There is renewed interest in using hemp for paper production; it is fast growing even on poor soils, it requires little or no pesticides or herbicides, bleaching is unnecessary, and the archival potential is excellent (paper produced from wood pulp has a shelf life of 25-100 years while hemp paper will hold up for 1,500 years)

One of the most promising alternatives is kenaf, a plant in the mallow/hibiscus family; it grows from seed to mature size (about 12 feet) in 4-5 months (southern pine takes 7-15 years to reach harvesting size), and the fiber yield from one acre is three to five times the yield for an acre of pine

Another source of pulp is recycled paper; less than 50% of the paper used in the U.S. is recycled; if all Americans recycled all of the Sunday newspapers, we could save more than 500,000 trees each week, or 26 million per year

Bamboo

More than 1,000 applications for this tree-like grass have been described

Within China, two-thirds of the bamboo production is mao chu or hairy bamboo, which is used to make furniture and even reinforcement rods in heavy construction

The Chinese export 5,000 tons of Tonkin bamboo each year; it is used for garden stakes, ski poles, fishing rods, and furniture

Bamboo has a long history in papermaking and today is the source of pulp for about two-thirds of all paper made in India

This lecture outline was prepared mainly from *Plants and Society*, by Levetin and McMahon, 2003 (3rd edition), and may contain phrases or entire sentences taken verbatim from that source.