Manufactured Fibers

- **Regenerated fibers** are manufactured from materials found in nature by modifying the polymer (e.g., cellulose) to a derivative that can be spun and then changed back to its original chemistry.
  - Regenerated cellulose/cellulose derivative fibers are made from wood chips, bamboo, and cotton linters. Derivative cellulose fibers remain chemically altered.
  - Regenerated protein fibers are made from soybeans and milk. Azlon is the only generic fiber in this category.

- **Synthetic fibers** are synthesized from non-fibrous materials. The majority are made from petroleum-based chemicals. Some of the newer bio-based polymers are synthesized using chemicals derived from corn or castor beans.

- **Rubber** is made from natural and synthetic rubber.

- **Mineral fibers** are inorganic fibers manufactured from metal and glass.
Raw Materials for Regenerated Fibers

For Regenerated Cellulosic Fibers
- eucalyptus and other trees
- bamboo

For Regenerated Protein Fibers
- soybean
- milk

Important – regenerated protein fibers are manufactured in very limited quantities.
Raw Materials for Synthetic Fibers

- pellets synthesized from petroleum-based chemicals
- corn used to synthesize bio-based polymer
- soda bottle chips for recycled fibers
- used garments for recycled fibers
Thermoplastic Fibers

- **Thermoplastic fibers** are manufactured fibers that melt when heated.

- Acetate, triacetate, nylon, polyester, olefin and acrylic are thermoplastic fibers.

- The ability to melt when heated is a very important characteristic used extensively in the manufacturing process. Examples include:
  - Crimping and heat setting for staple fiber production
  - Texturing filament yarns
  - Thermally bonding nonwoven fabrics
  - Heat setting fibers and fabrics
  - Applying thermal finishes (e.g., permanent pleats)
  - Sealing raw edges
  - Threadless stitching
Representation of the Heat Setting Process for Thermoplastic Polymers

- Bonds between polymer molecules in a fiber
- The distorted fiber with strained bonds
- The bonds loosen on heating
- New bonds form on cooling
Fiber Manufacturing Process

- Manufactured fibers require the conversion of solid polymers into a viscous liquid for extrusion through a spinneret and then solidification of the fibers.

- There are three commonly used “spinning methods” to convert a solid polymer into a viscous liquid, extrude it to form filaments, and then return the material to solid form. They are:
  - melt spinning
  - dry spinning
  - wet spinning

- Gel spinning is a comparatively new technology used for manufacturing certain high-performance fibers.

- The spinning method employed depends on the polymer properties of the fiber.
Extrusion of Fibers through the Spinneret

Photo courtesy Celanese Acetate Products
Melt Spinning

- Melt spinning is used for nylon, olefin, polyester and other thermoplastics.

- The shape and size of the fiber can be easily changed by changing the shape and size of the spinneret holes.

The following steps are required for this process:

1. melting the polymer chips/pellets
2. filtering the fluid
3. extruding the fluid through the spinneret
4. solidifying the fiber by cooling
5. stretching or drawing the partially cooled fiber

Source - *Dictionary of Fiber and Textile Technology*. Figure adapted with permission.
Dry Spinning

- Dry spinning is used for acetate, acrylic, modacrylic, spandex and other materials that can easily be dissolved in a solvent and then recovered by removing the solvent without changing the polymer properties.

- After extrusion the fiber’s cross-section changes because the fiber shrinks when the solvent evaporates.

The following steps are required for this process:
1. dissolving the fiber-forming substance in a solvent
2. filtering the fluid
3. extruding the fluid through the spinneret
4. solidifying the fiber by evaporating the solvent using warm air (solvent is recovered and reused)
5. stretching or drawing the partially solidified fiber

Source - Dictionary of Fiber and Textile Technology. Figure adapted with permission.
Wet Spinning

● Wet spinning is used for rayon, spandex, some acrylics and other materials that require a complex process because they cannot easily be dissolved in a solvent or melted.
  ○ Fibers are produced by chemically reacting raw material to form a soluble derivative, extruding it, and solidifying the soluble derivative through its reaction with the chemicals in a chemical bath.

● The fiber’s cross-section changes as the fiber collapses due to reaction in the chemical bath. It is difficult to control the cross-section.

The following steps are required for this process:
1. reacting the raw material
2. filtering the soluble derivative
3. extruding the soluble derivative
4. solidifying the fiber in a chemical bath
5. stretching or drawing the partially solidified fiber

Source - Dictionary of Fiber and Textile Technology. Figure adapted with permission.
Fiber Modifications

- Manufactured fibers can be engineered during the manufacturing process to produce fibers for specific end uses.

- Polymer properties and physical structure are modified to produce fibers with varying physical, chemical, and other properties.

- The modifications impact the performance and care of fabrics.

- Fibers engineered during the manufacturing process are being used for “performance textiles.”
  - Note: Performance textiles is a term used for textiles that have been engineered to meet a technical or functional need.
Fiber Modifications

- **Microfibers** are fibers that are less than 1 denier in size (smaller than a single filament of silk).
  - Microfibers are used for all-weather coats, suits, pants, hosiery, upholstery fabrics, floor mops, and lens cleaner cloths.
  - Special bicomponent fibers are commonly used to produce microfibers.

- **Nanofibers** are extremely fine fibers with fineness measured in nanometers.
  - Nanofibers are used for medical textiles, protective clothing, membranes and other applications.
  - Electrospinning and other special manufacturing processes are required to make nanofibers.
A bicomponent fiber is “a manufactured fiber made from two different polymer components, which may be composed of different polymer types or variants of the same polymer. The two polymers may be combined in several ways.

- **Matrix fiber:** Micro-filaments of one polymer are extruded in a matrix of the other polymer.
  
  When the matrix polymer is dissolved, ultrafine filaments of the second polymer remain.

- **Matrix-fibril fiber:** Short, fine fibrils of one polymer are randomly distributed through a matrix of the second polymer.

- **Sheath-core fiber:** One polymer forms a core and the other surrounds it as a sheath.

- **Side-by-side fiber:** The two are extruded in a bilateral relationship. Also called bilateral fiber.”

(Source - *Dictionary of Fiber and Textile Technology*).
Schematic Diagrams of Bicomponent Fibers

One polymer is surrounded by the other polymer

Two polymers divided along the length of the fiber

One polymer is extruded in the matrix of the other polymer

The two polymers alternate along the length of the fiber

Sheath-Core

Side-by-Side

Matrix or Islands-in-the-Sea

Pie Wedge and Hollow Pie Wedge

Source - Dictionary of Fiber and Textile Technology. Figure adapted with permission.
Cross-sections of Bicomponent Fibers

37 islands
16 segmented pie
Customized

Metal core
Sheath core
Concentric

Note: The unique cross-sections included in this image are used to engineer new fibers. Photo courtesy Hills Inc.
Examples of Uses for Bicomponent fibers

- Side-by-side bicomponent fibers with two types of acrylic are used to produce crimped fibers.
  When the fiber is heated, acrylic with a lower melting point shrinks to create the crimp.

- A sheath-core arrangement is used to produce fibers for which the sheath has a low melting point.
  The low melting point enables the outer layer of the fiber to melt and bond when heated.

- A sheath-core arrangement is used for applications where a less expensive polymer is used as the core to reduce cost.

- Pie wedge, hollow pie wedge, and islands-in-the-sea (same as matrix) are the arrangements used to produce microfibers.
Photomicrographs of 75% Polyester/25% Nylon Microfibers (Extruded as a bicomponent fiber)

Note: Pie configuration was used to produce bicomponent microfibers. The larger wedges are polyester and the thinner are nylon.
Fiber Modifications

- **Fibers with microcapsules** have microcapsules embedded into a fiber matrix.
  - These fibers are used to produce phase change materials (PCMs) that regulate body temperature.
    - Outlast® Thermocules® are spun into viscose and acrylic fibers to produce PCMs.

- **Flame resistant fibers** are produced by altering the fiber composition of manufactured fibers.
  - Lenzing FR® and Avora® FR are examples of fibers with built-in flame resistance.

- **High tenacity fibers** are created by increasing the polymer chain length and/or stretching the fibers after extrusion to increase fiber orientation.
  - Dyneema® and Cordenka® are examples of high tenacity fibers.
Micrograph of Outlast® Acrylic Fibers

Thermocules™ phase change material

Courtesy Outlast Technologies
Micrograph of Outlast® Viscose Fiber

Thermocules™ phase change material

Courtesy Outlast Technologies
Fiber Modifications

- **Cross-sections** of manufactured fibers, especially melt spun fibers, can be changed by altering the shape of the spinneret holes.
  - A **round** cross-section is the easiest to manufacture and is the most commonly used cross-section.
  - The **triangular** cross-section, similar to that of silk, is used to enhance luster as the three-sided fiber reflects more light than a round one.
  - A **trilobal** cross-section is commonly used for carpet fibers, as the lobes are effective in hiding dirt.
  - **Hollow** cross-section fibers are used for items (including comforters, pillows, and jackets) that require high bulk but low weight. Hollow fibers are also used for carpet fibers to reduce the appearance of soil.
Examples of Manufactured Fiber Cross-sections

- circular
- triangular
- trilobal
- hollow
- hollow
- flat

Courtesy Intertek Testing Services
Other Modifications

- **Reducing the polymer chain length** produces low-pilling fibers.
  - Shorter chains have reduced strength and abrasion resistance. Thus, the fiber forming the pill breaks away easily.
  - Low-pilling fibers are used for sweaters and other knits for which high strength is not required.

- Fibers with **low melting points** are produced by altering molecular structure.
  - Fibers melt and bind with other fibers when heat and pressure are applied.
Fiber Modifications

Other Modifications (Continued)

● Fiber dyeability is increased by modifying the molecular structure of the fiber so that it has the ability to react with the dye molecule.

● **Delusterant is added** to dull manufactured fibers.
  o Titanium dioxide pigments are often used as delusterants.
  o The degree of luster can be varied by changing the amount of delusterant.

● **Pigment is added** to produce solution dyed fibers.
  o Solution dyeing is used to dye fibers for end uses that require excellent colorfastness properties.
  o It is used for difficult-to-dye fibers.