Polymers

Polymers and Fibers

Chemistry in Context, Chapter 9

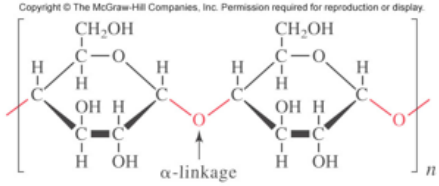
http://www.youtube.com/watch?v=PSxihhBzCjk

Some Definitions

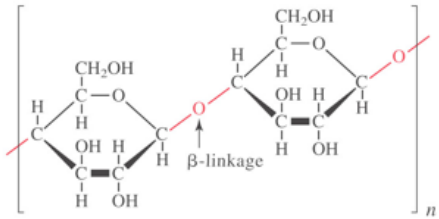
- **Polymer** – large molecules made of long chains of atoms, typically hundreds to thousands in lengths, usually synthesize from **monomers**, a small molecule that is repeatedly attached to the long chain. Polymers are also known as **macromolecules**.
- **Natural polymers** – polymers that occur in the natural world. Typically, they are of biological origin. Examples are starch, cellulose, proteins, RNA, DNA, and more specifically, cotton, flax fibers (linen), hemp, wood/paper, wool, and silk.
- **Synthetic polymers** – polymers that are synthesized by human devised synthetic processes. Typically, they are produced from low molecular weight petrochemicals. Sometimes they are called plastics. Examples are polyethylene (HDPE, LDPE), polypropylene, polystyrene (styrofoam), polyvinylchloride (PVC), polyester or polythethylene terephthalate (PET, Dacron), and nylon. Rubber is polyisoprene, a polymer derived from a natural monomer source.

Natural Fibers

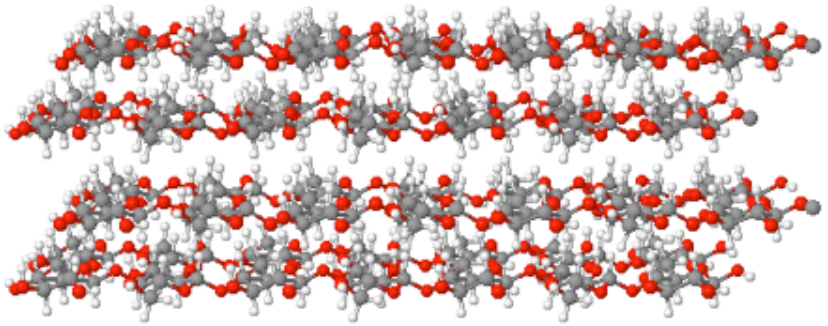
- **Cotton, flax, hemp, jute** are fibrous materials derived from plants. They are predominantly cellulose (polyglucose with beta-linkages).



(a) Starch



(b) Cellulose

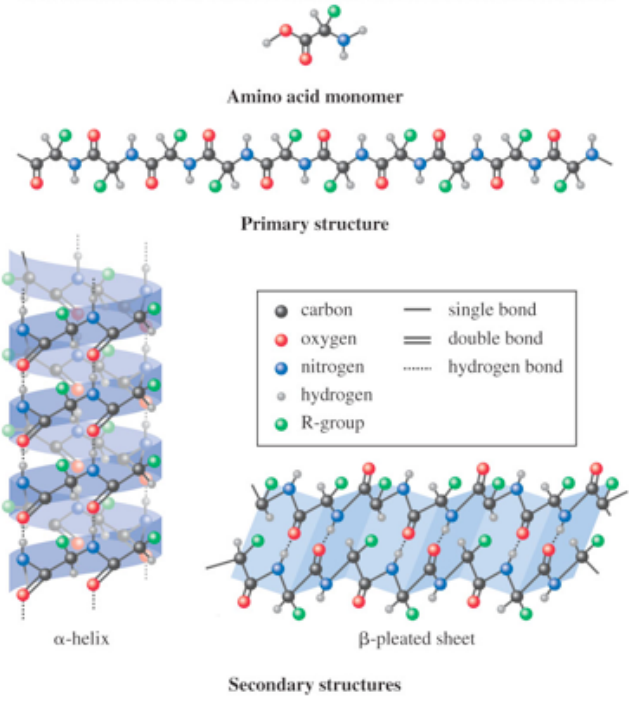


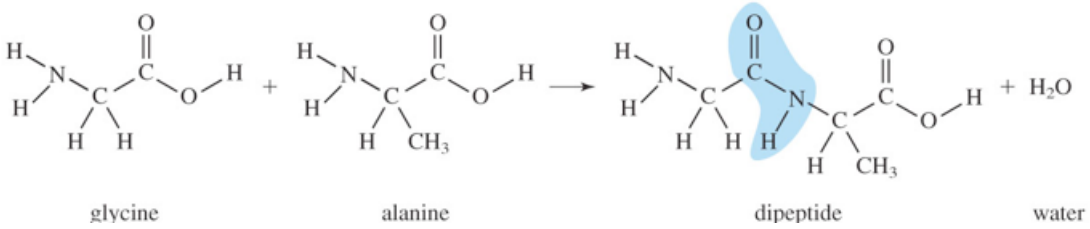
- **Rayon –** made from cellulose (semi-synthetic)

- **Lignin –** a complex irregular aromatic containing biopolymer cross-links the cellulose polymer chains. This cross-linking produces a stiffer polymer. Wood contains lots of lignin. Cotton very little. Other cellulose based fibers are in between.
- Cellulose is a condensation polymer of glucose.

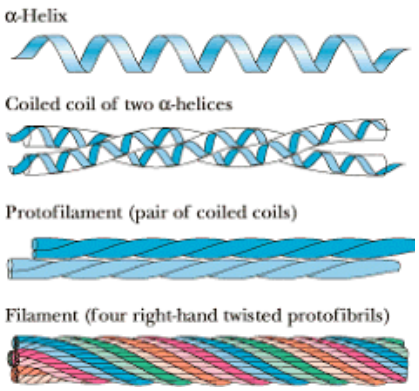
Natural Fibers

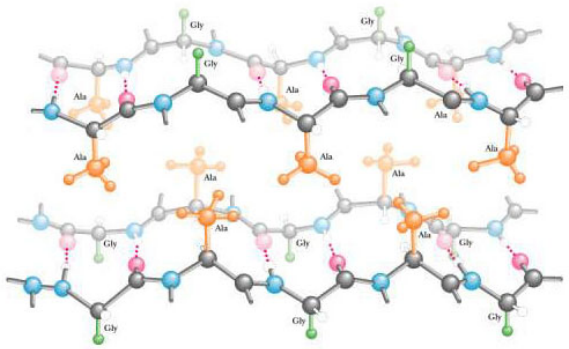
- **Wool** is a fibrous material derived from sheep (and other similar animals) hair. It is made from a class of proteins called alpha-keratins which are predominantly alpha-helical in structure.
- **Silk** is a fibrous material derived from the silkworm cocoon. It too is made of protein, silk fibroin, and is predominantly beta-sheet in structure.





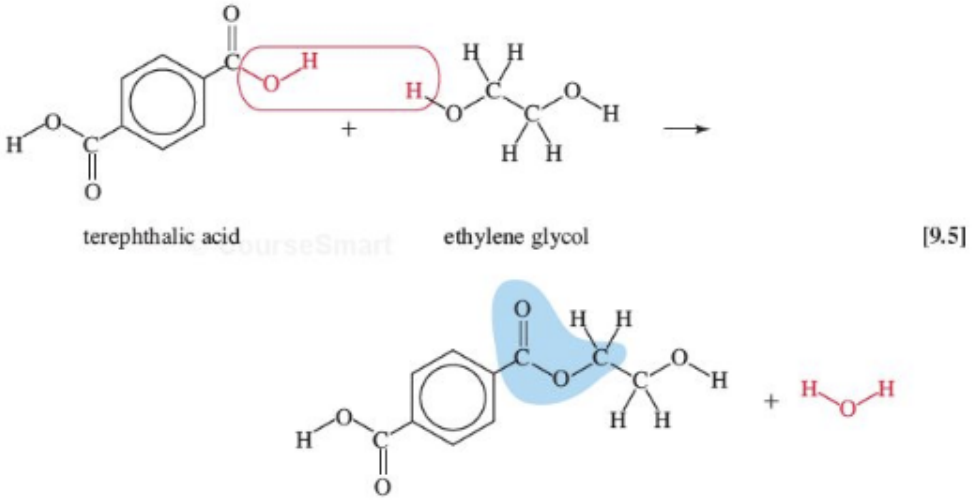
- Amino acids are the monomers.
- Polymer is formed by a condensation reaction.





Synthetic Polymers

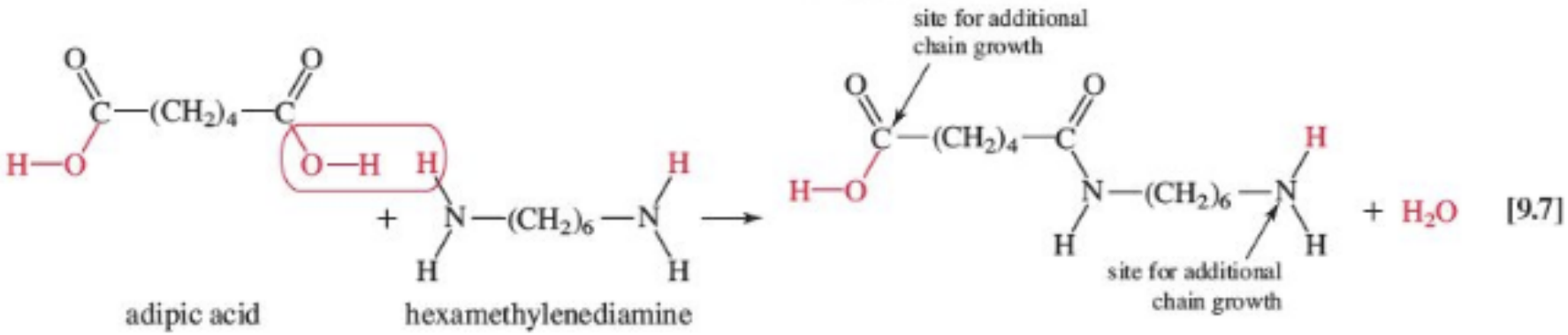
- **Polyesters** are copolymers produced by the condensation reaction of a di-alcohol (such as ethylene glycol) and a dicarboxylic acid (such as terephthalic acid). Polyethylene terephthalate (PET) is the most common and is used in plastics (plastic beverage bottle, Dacron fabrics, carpet)



terephthalic acid + ethylene glycol [9.5]

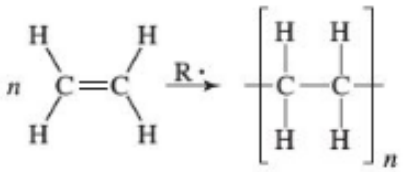
Synthetic Polymers

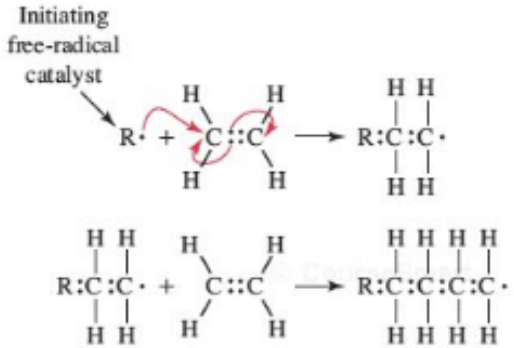
- **Nylons** are copolymers produced by the condensation reaction of a diamine (such as hexamethylenediamine) and a dicarboxylic acid (such as adipic acid). Nylon has many of the properties of silk but is stronger, more stable, and rot resistant.

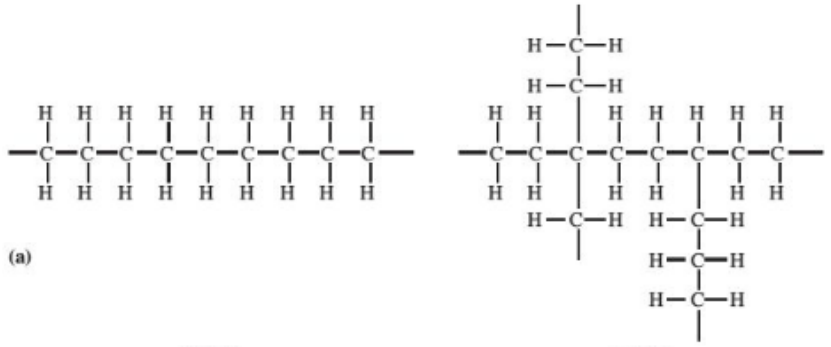


Synthetic Polymers

- **Polyethylene** is an addition polymer produced from ethylene, a two carbon monomer hydrocarbon containing a double bond between the two carbons. A free radical initiator is required to the polymerization reaction. The reaction continues until monomer is used up or until two chains (or one chain and an unreacted initiator molecule) combine.



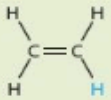
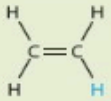
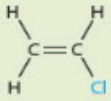
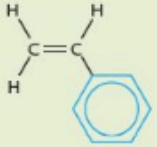
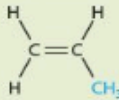
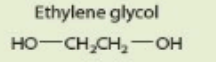
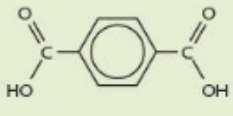




Synthetic Polymers

- **Polypropylene**, **polystyrene (styrofoam)**, and **polyvinylchloride (PVC)** are also addition polymers produced from propylene, styrene, and vinylchloride similar to polyethylene. Propylene has a methyl ($-CH_3$) sidechain; polystyrene has an aromatic ($-C_6H_6$) sidechain; polyvinyl chloride has a chlorine atom (-Cl) sidechain. These groups affect the properties of the polymer.

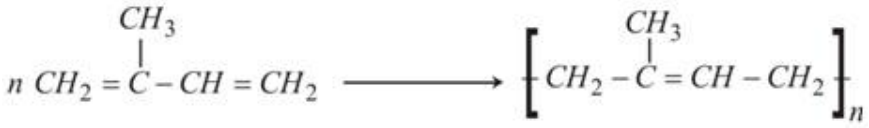
Table 9.1 The Big Six

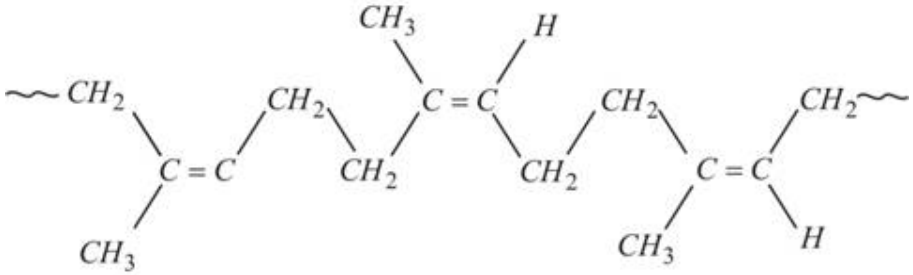
Polymer	Monomer	Properties of Polymer	Uses of Polymer
Polyethylene (LDPE)  LDPE	Ethylene 	Translucent if not pigmented. Soft and flexible. Unreactive to acids and bases. Strong and tough.	Bags, films, sheets, bubble wrap, toys, wire insulation.
Polyethylene (HDPE)  HDPE	Ethylene 	Similar to LDPE. More rigid, tougher, slightly more dense.	Opaque milk, juice, detergent, and shampoo bottles. Buckets, crates, and fencing.
Polyvinyl chloride  PVC, or V	Vinyl chloride 	Variable. Rigid if not softened with a plasticizer. Clear and shiny, but often pigmented. Resistant to most chemicals, including oils, acids, and bases.	Rigid: Plumbing pipe, house siding, charge cards, hotel room keys. Softened: Garden hoses, waterproof boots, shower curtains, IV tubing.
Polystyrene  PS	Styrene 	Variable. "Crystal" form transparent, sparkling, somewhat brittle. "Expandable" form lightweight foam. Both forms rigid and dissolve in many organic solvents.	"Crystal" form: Food wrap, CD cases, transparent cups. "Expandable" form: Foam cups, insulated containers, food packaging trays, egg cartons, packaging peanuts.
Polypropylene  PP	Propylene 	Opaque, very tough, good weatherability. High melting point. Resistant to oils.	Bottle caps. Yogurt, cream, and margarine containers. Carpeting, casual furniture, luggage.
Polyethylene terephthalate  PETE, or PET	Ethylene glycol  Terephthalic acid 	Transparent, strong, shatter-resistant. Impervious to acids and atmospheric gases. Most costly of the six.	Soft-drink bottles, clear food containers, beverage glasses, fleece fabrics, carpet yarns, fiber-fill insulation.

Note: The structures of the first five monomers differ only by the atoms shown in blue.

Synthetic Polymers

- **Rubber** is also addition polymer produced from isoprene (latex) a naturally occuring substance produced by the rubber plant.





Recycling

- 4.5 lbs (2.0 kg) per person per day of garbage.

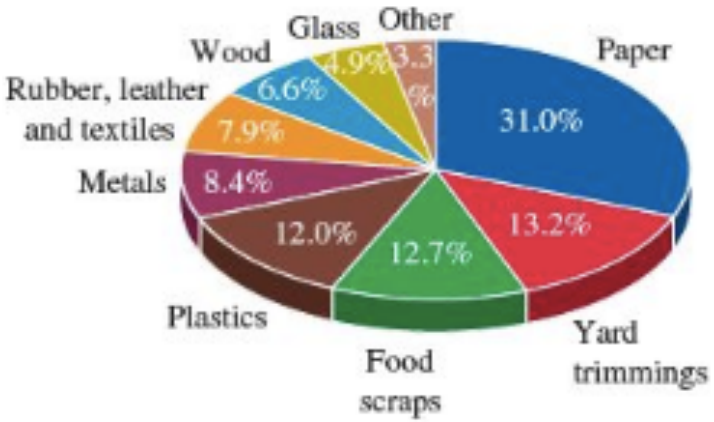


Figure 9.14

What's in your garbage? Prior to recycling, composition by weight of municipal solid waste.

Source: U.S. Environmental Protection Agency, EPA 530 F-08-018, November 2008.

- Landfill, incinerate, recycle
- Source reduction (use less) is the preferred option.
- Paper or plastic?
- Collection, transported, sorted, marketed.
- Pure polymer with little cross-linking can be melted and reused.
- Impure polymer mixtures can be used for low grade objects.
- Return polymers to monomer stock.