Chapter 14 &15 Polymer structures and mechanical behavior

- Hydrocarbon molecules
- Polymer molecules
- Molecular structures & configurations
- Copolymers
- Polymer crystallinity
- Polymer's mechanical behavior

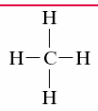
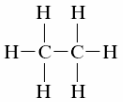
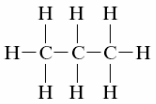
Hydrocarbon molecules

- Hydrocarbon: composed of hydrogen and carbon
- Single, double, and triple bonds
- Saturated and unsaturated: molecules that have double and triple covalent bonds are termed unsatuated
- Isomerism: same composition and different atomic arrangements

Hydrocarbon molecules

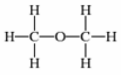
- Bonding
- Boiling T

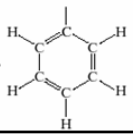
Table 15.1 Compositions and Molecular Structures for Some of the Paraffin Compounds: C_nH_{2n+2}

Name	*Composition*	*Structure*	*Boiling Point (°C)*
Methane	CH_4		−164
Ethane	C_2H_6		−88.6
Propane	C_3H_8		−42.1
Butane	C_4H_{10}	·	−0.5
Pentane	C_5H_{12}	·	36.1
Hexane	C_6H_{14}	·	69.0

Some common hydrocarbon groups

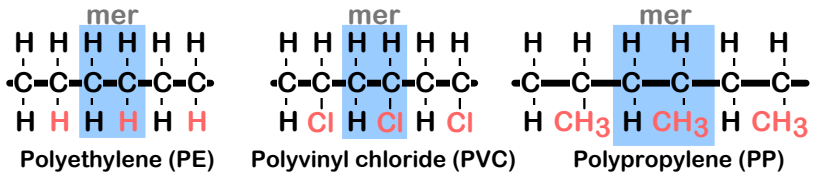
- R and R' represent organic radicals

Family	*Characteristic Unit*	*Representative Compound*	
Alcohols	R—OH		Methyl alcohol
Ethers	R—O—R'		Dimethyl ether
Acids			Acetic acid
Aldehydes			Formaldehyde
Aromatic hydrocarbons			Phenol

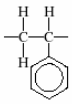
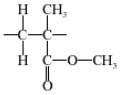
[a] The simplified structure  denotes a phenyl group, 

Polymer molecules

- Macromolecules: molecules with very large size
- mer: structural entities
- monomer: single mer
- polymer: many mers



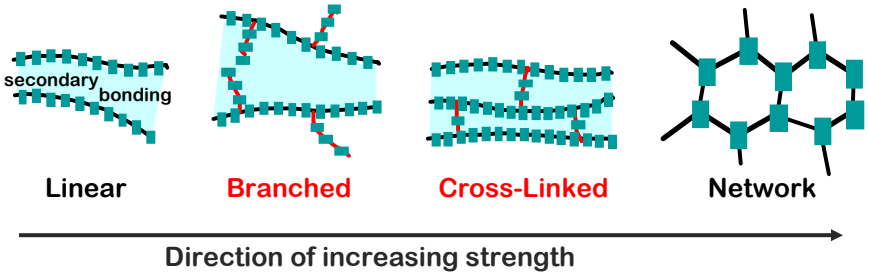
A listing of mer structure of the common polymer materials

Polymer	Repeating (Mer) Structure
Polyethylene (PE)	
Polyvinyl chloride (PVC)	
Polytetrafluoroethylene (PTFE)	
Polypropylene (PP)	
Polystyrene (PS)	
Polymethyl methacrylate (PMMA)	

Polymer structure

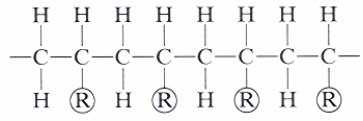
☐ Molecular structure

- **Covalent chain configurations and strength:**

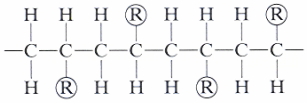


Molecular configuration

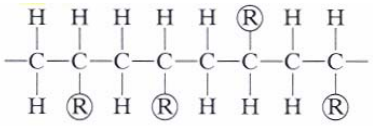
☐ Stereoisomerism: same atomic order and different spatial arrangement



isotactic



syndiotactic

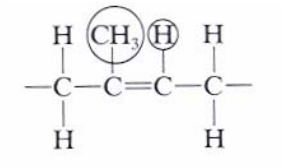


atactic

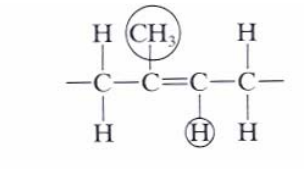
Molecule configuration (continue)

- Geometrical isomerism

Cis



Trans

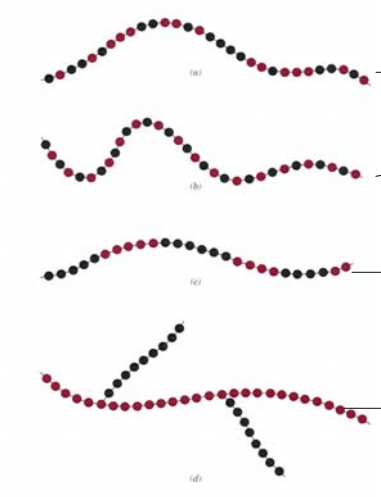


Thermoplastic and thermosetting polymers

- Thermoplastics
  - soften when heated and harden when cooled
  - little crosslink
  - ductile
  - Polyethylene, polypropylene, polycarbonate, polystyrene
- Thermosetting polymers: permanently hard when heat is applied and do not soften upon subsequent heating
  - permanently hard when heat is applied and do not soften upon heating
  - large crosslink (10 to 50% of mers)
  - hard and brittle
  - vulcanized rubber, epoxies, polyester resin, phenolic resin

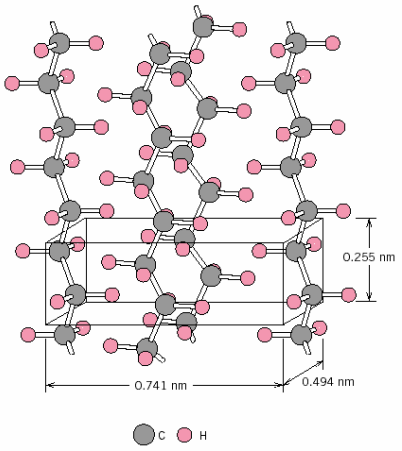
Copolymers

- Homopolymer: same type of mer units along a chain
- Copolymers: two or more different mer units
- Copolymers have four types



Polymer crystallinity

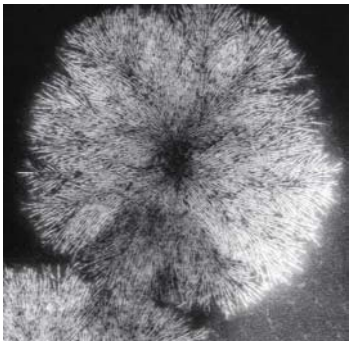
- Crystallinity: the packing of molecular chains to produce an ordered atomic array
- The effects on the degree of polymer crystallinity
  - cooling rate
  - molecule chemistry
  - chain configuration

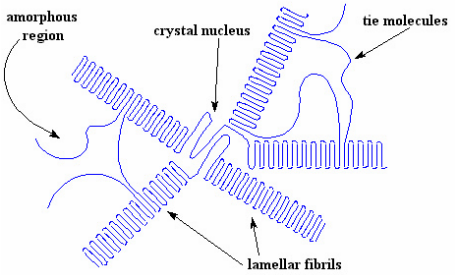


Arrangement of molecular chains in a unit cell for polyethylene

Polymer crystals

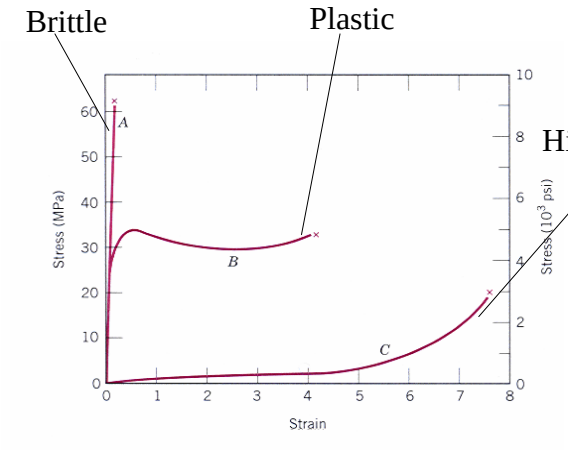
- Many semicrystalline polymers are made of spherulitic structure





a polymer crystalline spherulite

Polymer stress-strain behavior

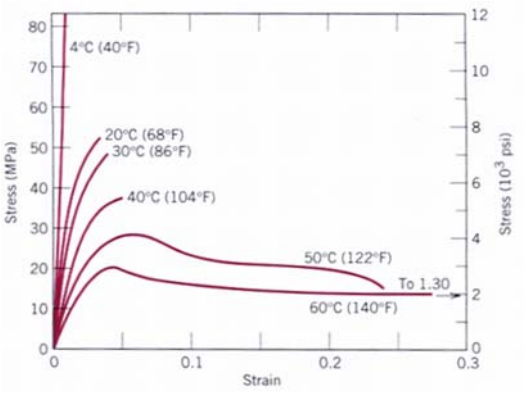


Mechanical characteristics of polymers

- Polymers
  - lower elastic modulus with a wide range (7MPa-4 GPa)
  - lower tensile strength (order of 100MPa)
  - larger plastic deformation (possibly as high as 1000%)
  - mechanical behavior are more sensitive to environmental changes
- Metals
  - Larger elastic modulus (48-410 GPa)
  - Higher tensile strength (up to 4100GPa)
  - Smaller plastic deformation(less than 100%)
  - less sensitive to environment

Effect of T and strain rate

- Decrease T
  - increase E
  - increase TS
  - decrease ductility
- Increase strain rate
  - same effect as decreasing T



Deformation of semicrystalline polymers

- Mechanism of elastic deformation
- Mechanism of plastic deformation (Figure 16.4)
- Stress-strain curve relation(Figure 16.5)