Carbon and Biological Molecules

- Carbon plays a central role in biological molecules
- Carbon has 4 valence electrons, readily forms covalent bonds
- Carbon atoms join to form chains, branches, rings, etc.
- Carbon can form double or triple bonds with other atoms

Figure 4.3 Valences for the major elements of organic molecules

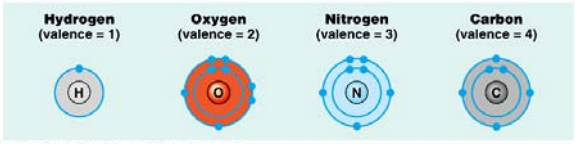
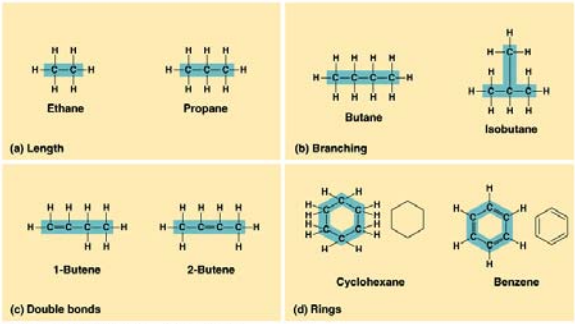


Figure 4.4 Variations in carbon skeletons



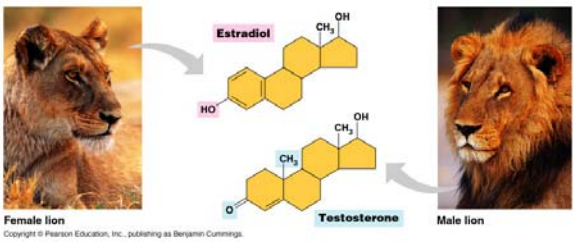
Functional Groups

- Organic compounds often contain functional groups: -OH, $-CH_3$, -COOH, $-NH_2$, $-PO_4$, etc.
- Functional groups affect chemical properties (for example, estradiol vs. testosterone)

Functional Groups

Name and Symbol	Structure	Occurs in
Hydroxyl (—OH)		Sugars, alcohols
Methyl (—CH_3)		Fats, oils, steroids, amino acids
Carboxyl (—COOH)		Amino acids, sugars, proteins
Amino (—NH_2)		Amino acids, proteins
Phosphate (–H_2PO_4)		Nucleic acids, ATP

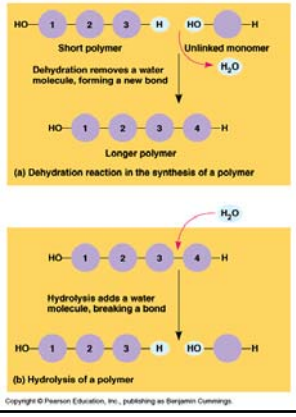
Figure 4.8 A comparison of functional groups of female (estradiol) and male (testosterone) sex hormones



Polymers

- Most large biological molecules are polymers
- Formed from repeated similar subunits
- Synthesized by dehydration
- Broken down by hydrolysis

Figure 5.2 The synthesis and breakdown of polymers



Carbohydrates

- Hydrates of carbon: $(CH_2O)_n$
- Monosaccharides (simple sugars) are monomers
- Monosaccharides join to form disaccharides, etc.
- Polysaccharides include starch, glycogen, cellulose, chitin

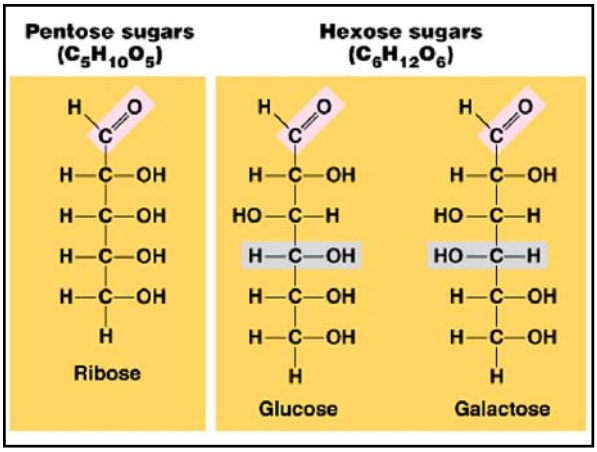


Figure 5.5 Examples of disaccharide synthesis

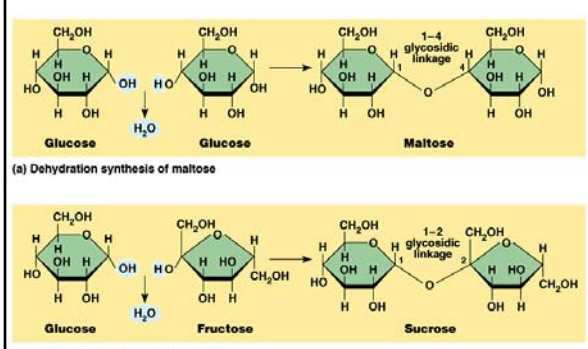
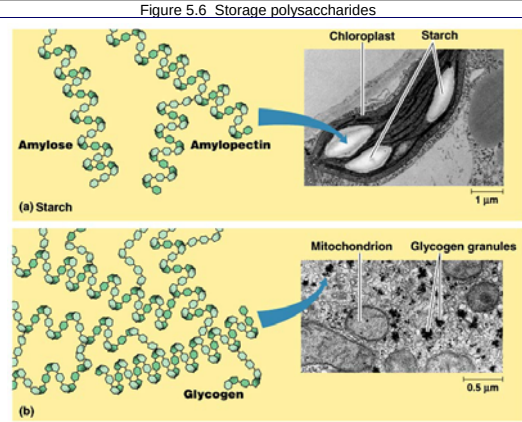


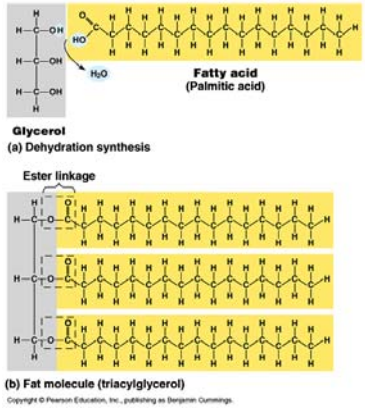
Figure 5.6 Storage polysaccharides



Lipids

- A diverse group of biological molecules
- Nonpolar, hydrophobic, not polymers
- Lipids are less oxidized than carbohydrates, can store more energy in bonds
- Examples include fatty acids, triglycerides, phospholipids, steroids

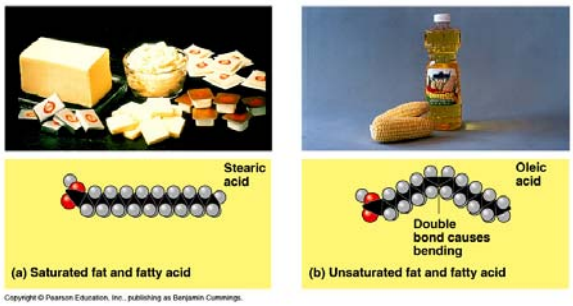
Figure 5.10 The synthesis and structure of a fat, or triacylglycerol



Saturated vs. Unsaturated Fats

- Saturated fats lack double bonds between carbon atoms of chain → saturated with hydrogen
- Unsaturated fats have double bonds between carbon atoms of chain→ not saturated with hydrogen
- Saturated fats typically solid at room temp, unsaturated fats typically liquid

Figure 5.11 Examples of saturated and unsaturated fats and fatty acids



Phospholipids

- Similar to triglycerides, but a phosphate group substitutes for one fatty acid
- Phosphate group is polar, hydrophilic
- Fatty acid tails are nonpolar, hydrophobic
- Phospholipids therefore amphipathic
- In water, phospholipids form micelles and bilayers

Figure 5.12 The structure of a phospholipid

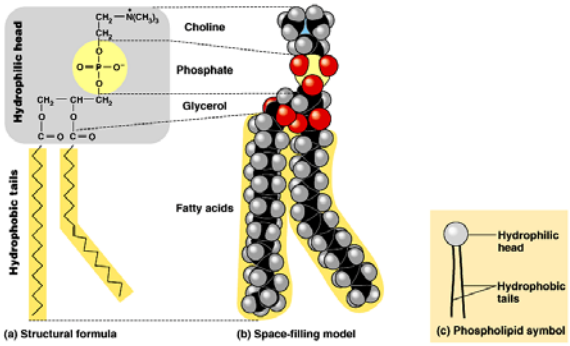
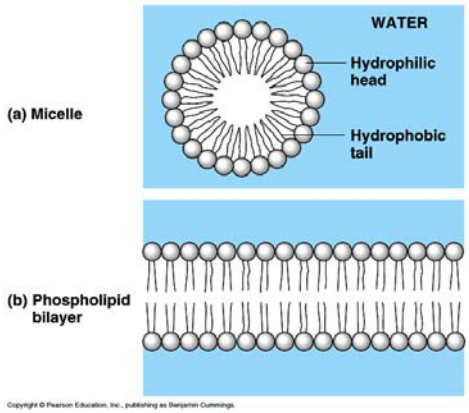


Figure 5.13 Two structures formed by self-assembly of phospholipids in aqueous



Steroids

- Steroids are lipids formed from 4 fused carbon rings
- Cholesterol is a steroid found in membranes
- Estradiol and testosterone (sex hormones) are steroids

Figure 5.14 Cholesterol, a steroid

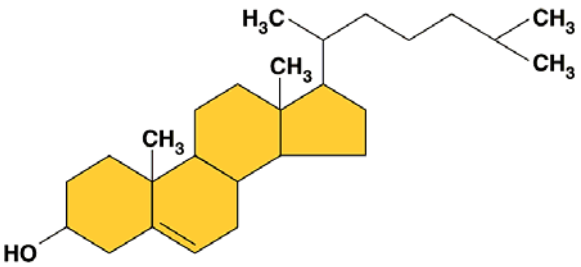
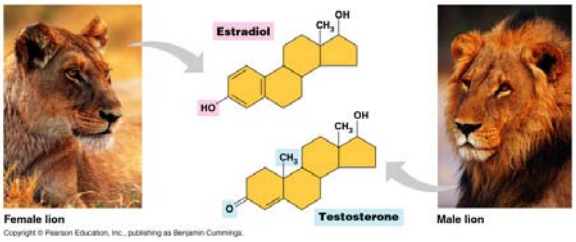


Figure 4.8 A comparison of functional groups of female (estradiol) and male (testosterone) sex hormones



Proteins

- Proteins are polymers of amino acids
- Consist of a central carbon + amine group + carboxyl group + R group (= side chain)
- Amino acids are joined by peptide bonds
- Many functions: structural, enzyme, hormone, transport, contractile

Structure of Amino Acids

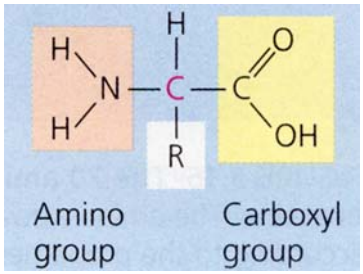


Figure 5.15 Amino acids differ in their R-groups (side chains to central carbon)

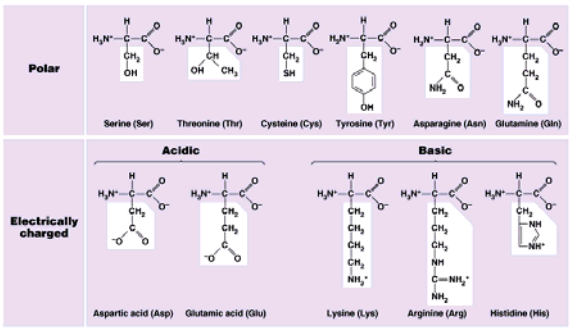


Figure 5.16 Making a polypeptide chain

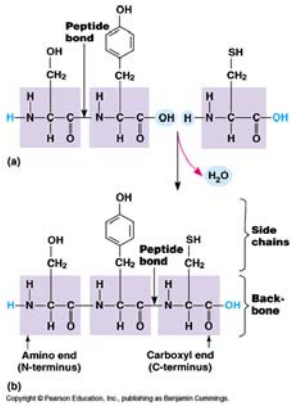
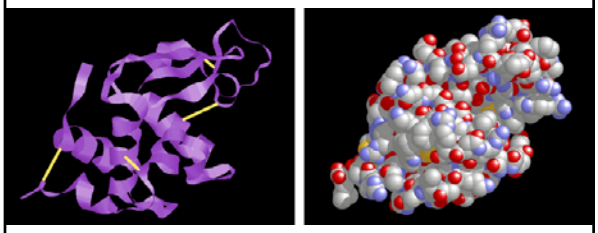


Figure 5.17 Conformation of a protein, the enzyme lysozyme



Levels of Protein Structure

Primary: unique sequence of amino acids

Secondary: localized coiling & folding of chain due to hydrogen bonds along backbone

Tertiary: 3-D folding of chain due to interactions between side chains

Quaternary: interaction of multiple polypeptide subunits

Figure 5.18 The primary structure of a protein

Figure 5.20 The secondary structure of a protein

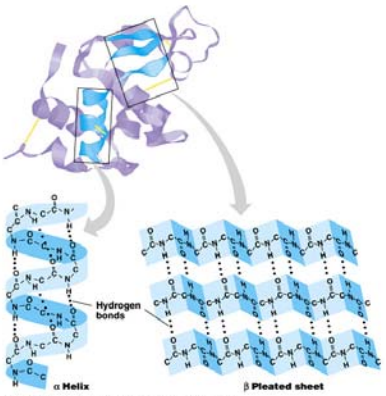


Figure 5.22 Examples of interactions contributing to the tertiary structure of a protein

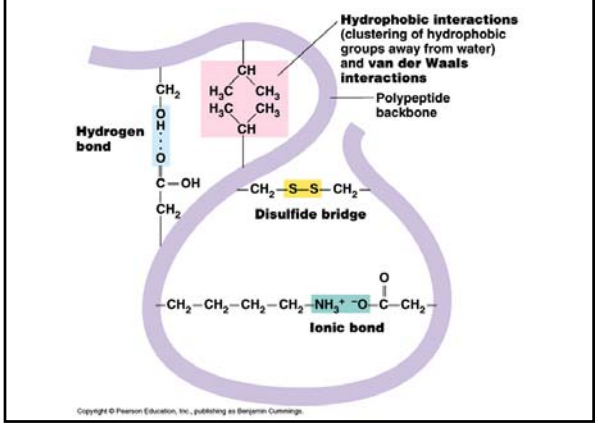


Figure 5.23 The quaternary structure of proteins

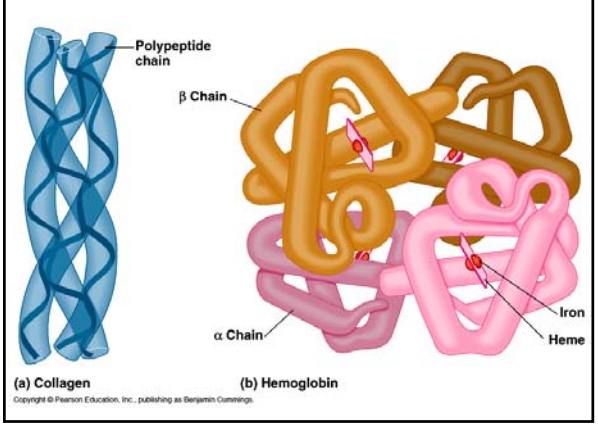
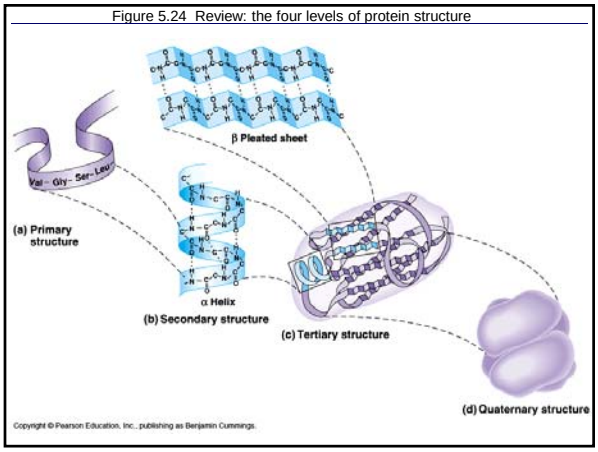


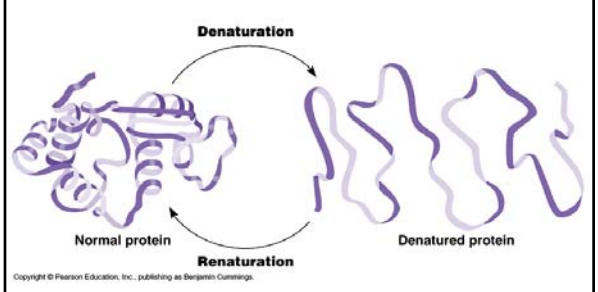
Figure 5.24 Review: the four levels of protein structure



Protein Denaturation

- Disruption of tertiary structure
- Caused by heat, change in pH, salts, dehydration, etc.
- Can be reversible or permanent

Figure 5.25 Denaturation and renaturation of a protein



Nucleotides

- Nitrogenous base (purine or pyrimidine)
- Pentose sugar (ribose or deoxyribose)
- One or more phosphate groups

Figure 5.29 The components of nucleic acids

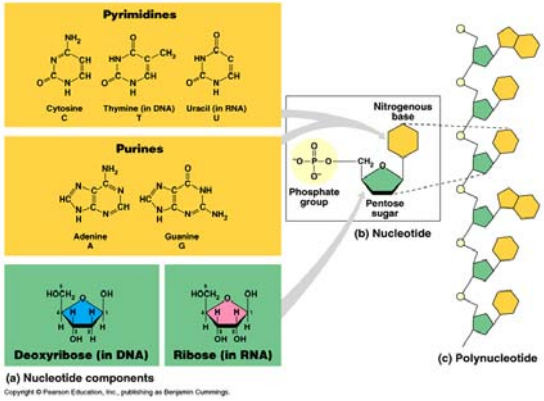
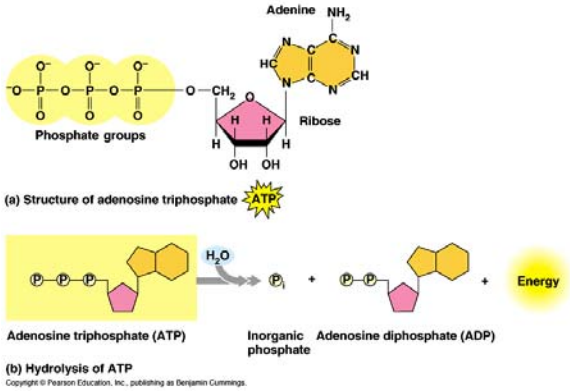


Figure 6.8 The structure and hydrolysis of ATP



Nucleic Acids

- Polymers of nucleotides: RNA & DNA
- RNA usually a single polynucleotide chain
- DNA has two polynucleotide chains that form a double helix
- DNA bases are complementary, so one strand can serve as template for other

Figure 5.30 The DNA double helix and its replication

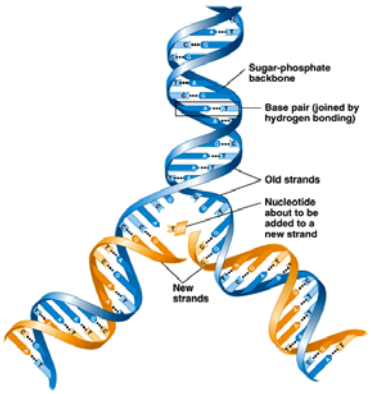


Figure 5.28 Direction of information flow in a cell