

BIOLOGY 2e

Chapter 3 BIOLOGICAL MACROMOLECULES

PowerPoint Image Slide Show



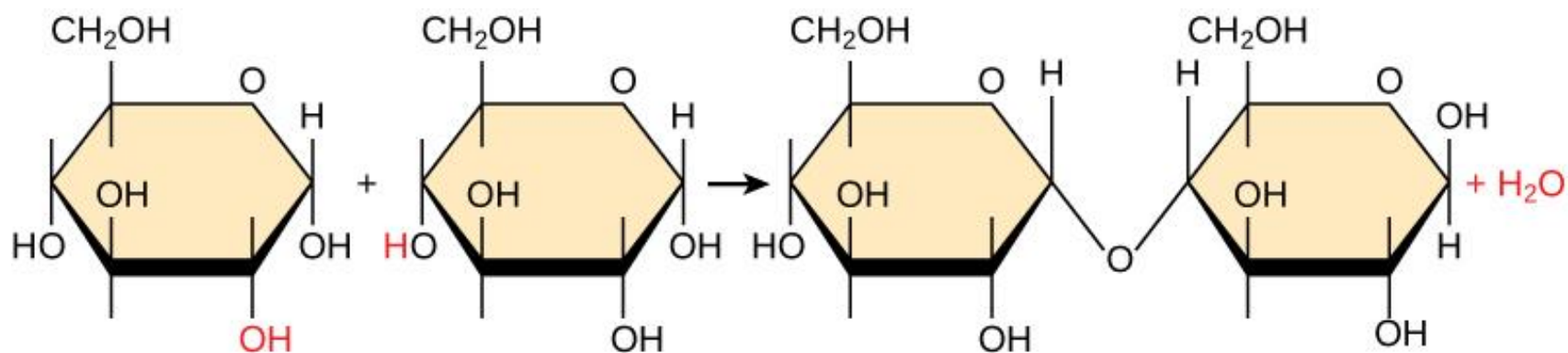
FIGURE 3.1



Foods such as bread, fruit, and cheese are rich sources of biological macromolecules.

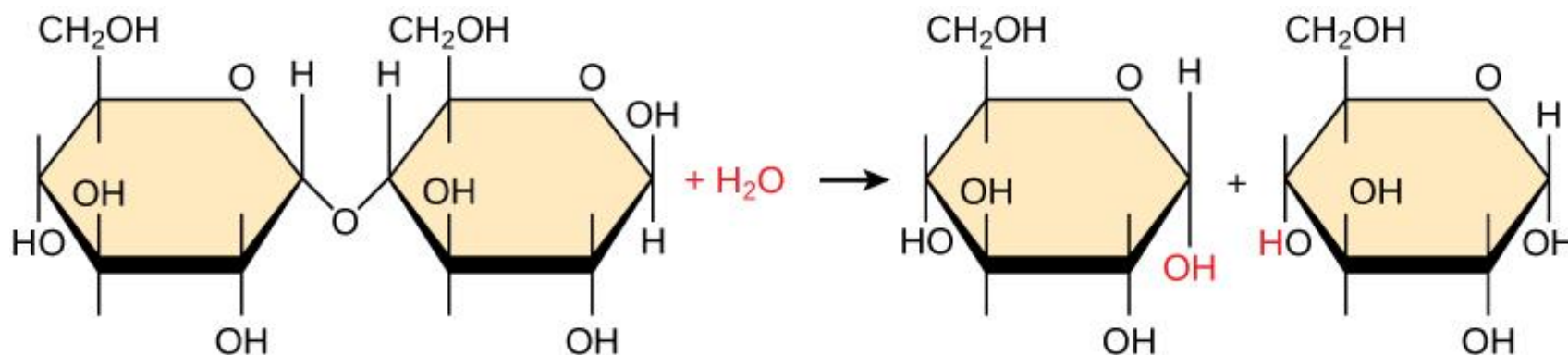
(credit: modification of work by Bengt Nyman)

FIGURE 3.2



In the dehydration synthesis reaction depicted above, two molecules of glucose are linked together to form the disaccharide maltose. In the process, a water molecule is formed.

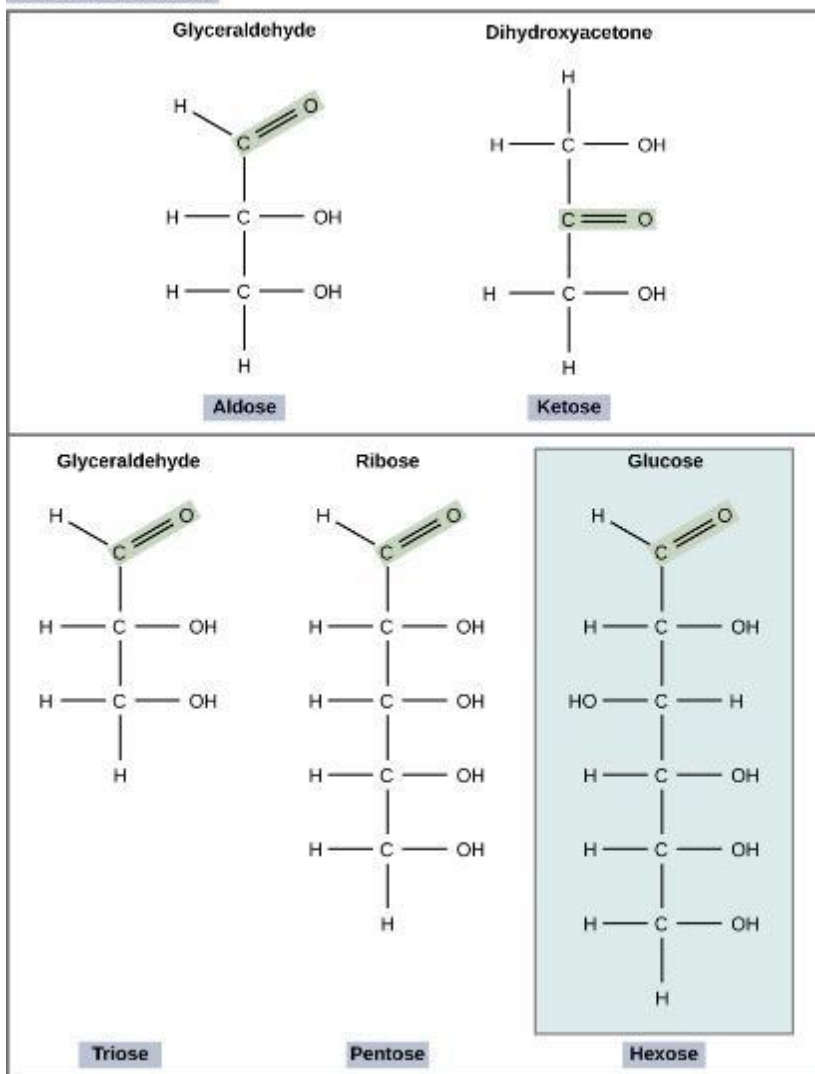
FIGURE 3.3



In the hydrolysis reaction shown here, the disaccharide maltose is broken down to form two glucose monomers with addition of water. Note that this reaction is the reverse of the synthesis reaction shown in [Figure 3.2](#).

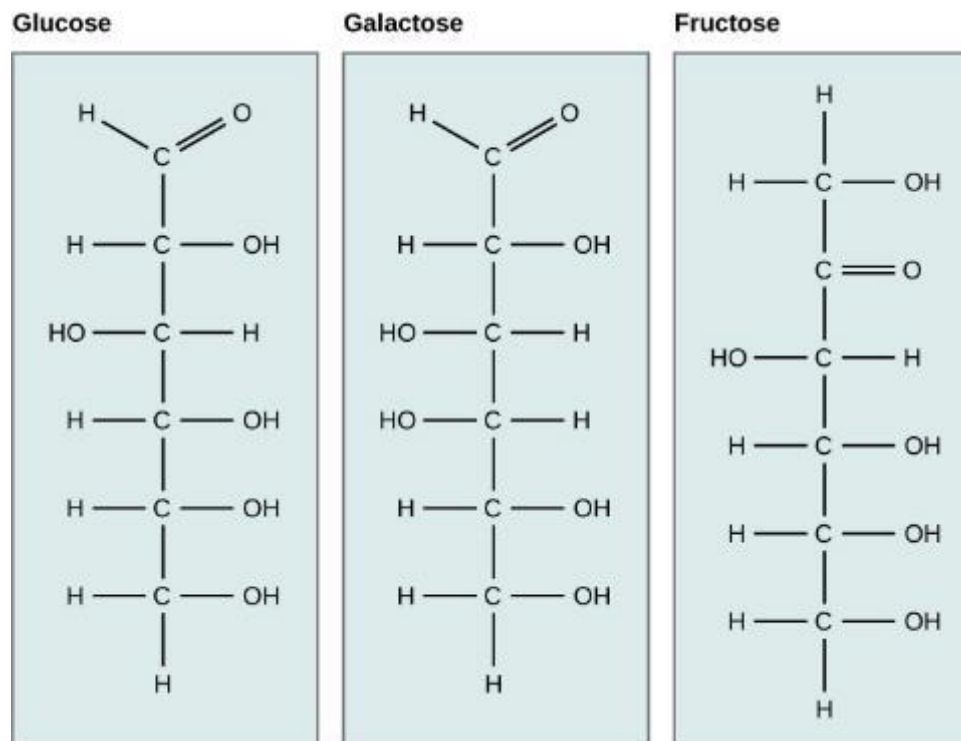
FIGURE 3.4

MONOSACCHARIDES



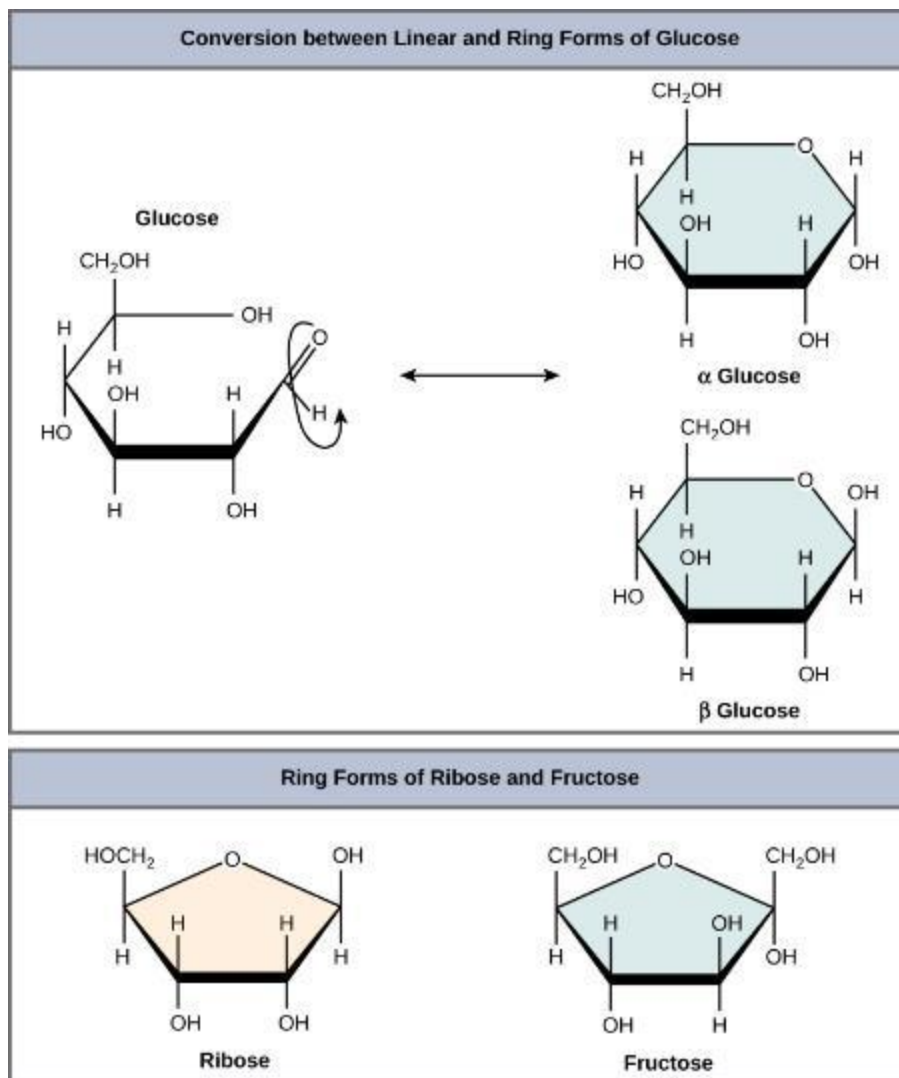
Scientists classify monosaccharides based on the position of their carbonyl group and the number of carbons in the backbone. Aldoses have a carbonyl group (indicated in green) at the end of the carbon chain, and ketoses have a carbonyl group in the middle of the carbon chain. Trioses, pentoses, and hexoses have three-, five-, and six- carbon backbones, respectively.

FIGURE 3.5



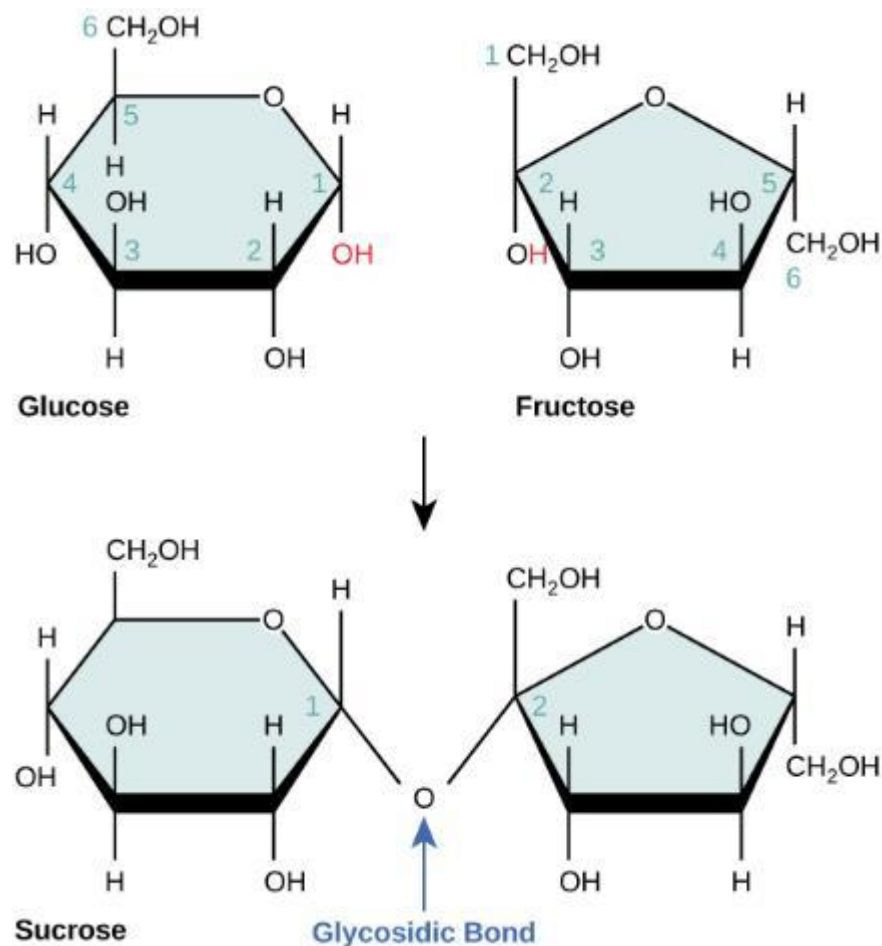
Glucose, galactose, and fructose are all hexoses. They are structural isomers, meaning they have the same chemical formula ($\text{C}_6\text{H}_{12}\text{O}_6$) but a different arrangement of atoms.

FIGURE 3.6



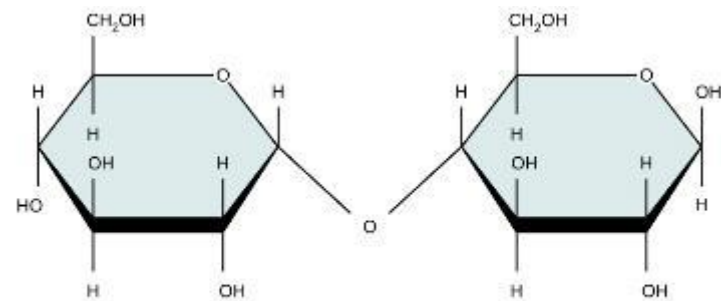
Five and six carbon monosaccharides exist in equilibrium between linear and ring forms. When the ring forms, the side chain it closes on is locked into an α or β position. Fructose and ribose also form rings, although they form five-membered rings as opposed to the six-membered ring of glucose.

FIGURE 3.7



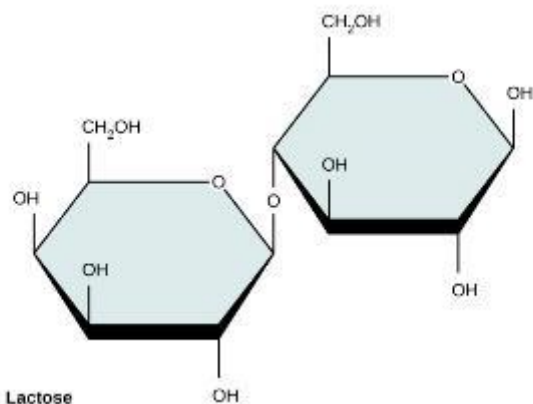
Sucrose is formed when a monomer of glucose and a monomer of fructose are joined in a dehydration reaction to form a glycosidic bond. In the process, a water molecule is lost. By convention, the carbon atoms in a monosaccharide are numbered from the terminal carbon closest to the carbonyl group. In sucrose, a glycosidic linkage is formed between carbon 1 in glucose and carbon 2 in fructose.

FIGURE 3.8

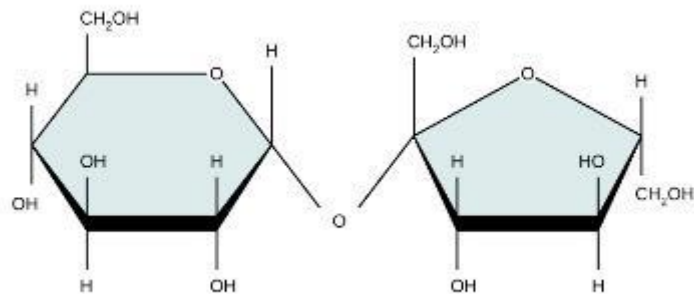


Maltose

Common disaccharides include maltose (grain sugar), lactose (milk sugar), and sucrose (table sugar).

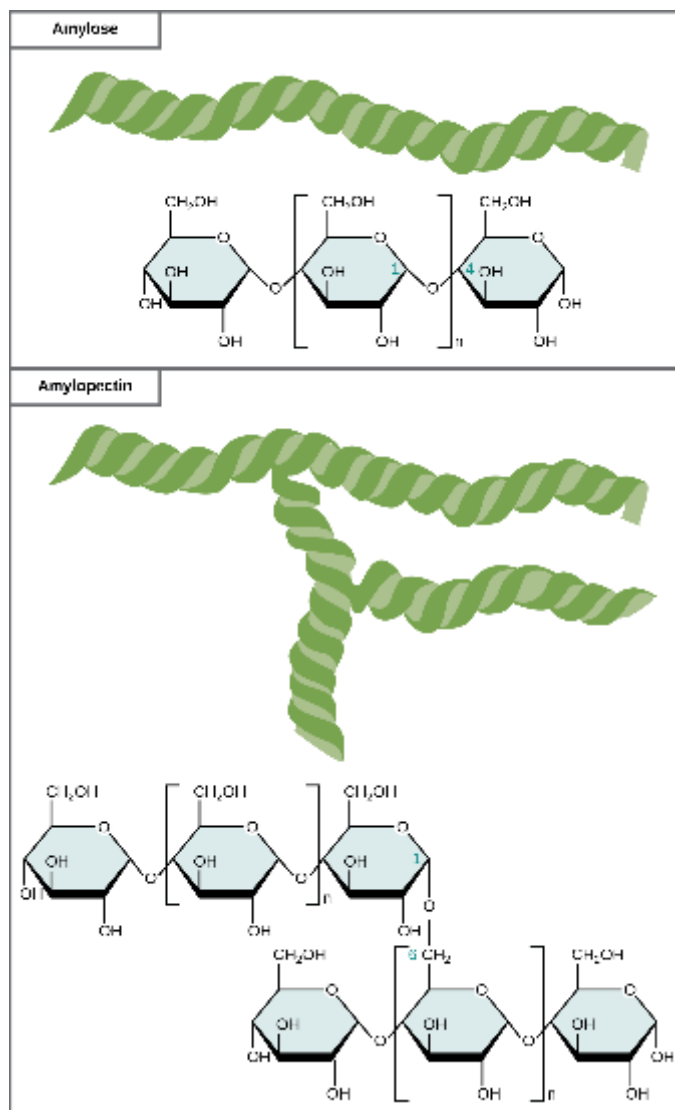


Lactose



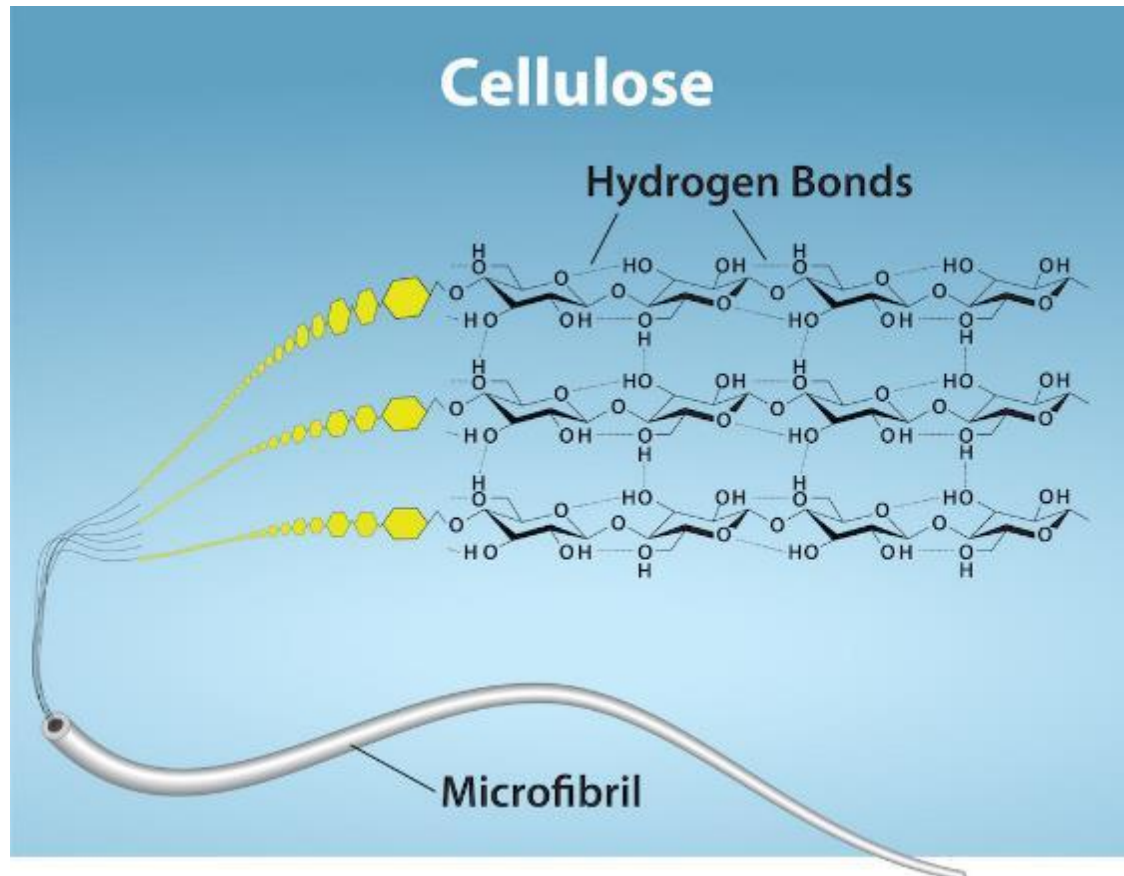
Sucrose

FIGURE 3.9



Amylose and amylopectin are two different forms of starch. Amylose is composed of unbranched chains of glucose monomers connected by α 1,4 glycosidic linkages. Amylopectin is composed of branched chains of glucose monomers connected by α 1,4 and α 1,6 glycosidic linkages. Because of the way the subunits are joined, the glucose chains have a helical structure. Glycogen (not shown) is similar in structure to amylopectin but more highly branched.

FIGURE 3.10



Cellulose is an organic compound composed of linear chains of hundreds to thousands of linked glucose molecules. The glucose monomers form hydrogen bonds, holding the chains firmly together side-by-side and form strong microfibrils. This rigidity is an important structural component of the cell walls found in plants.

(credit: Ryan, K. Rao, A. and Hawkins, A. Department of Biology, Texas A&M University)

FIGURE 3.11



Insects have a hard outer exoskeleton made of chitin, a type of polysaccharide.

(credit: Louise Docker)

FIGURE 3.12



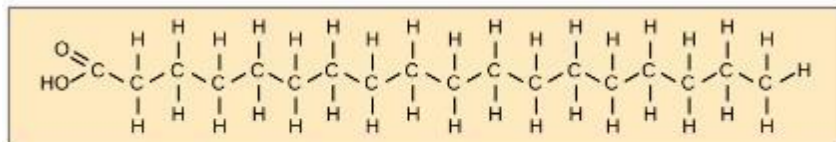
Hydrophobic lipids in the fur of aquatic mammals, such as this river otter, protect them from the elements.

(credit: Ken Bosma)

FIGURE 3.16

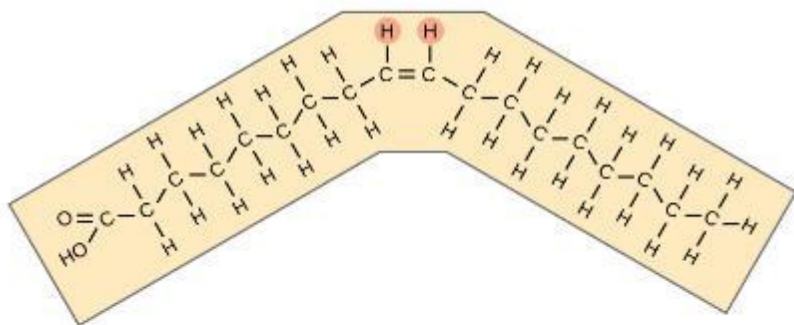
Saturated fatty acid

Stearic acid

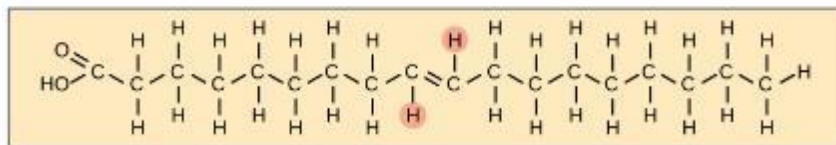


Unsaturated fatty acids

Cis oleic acid

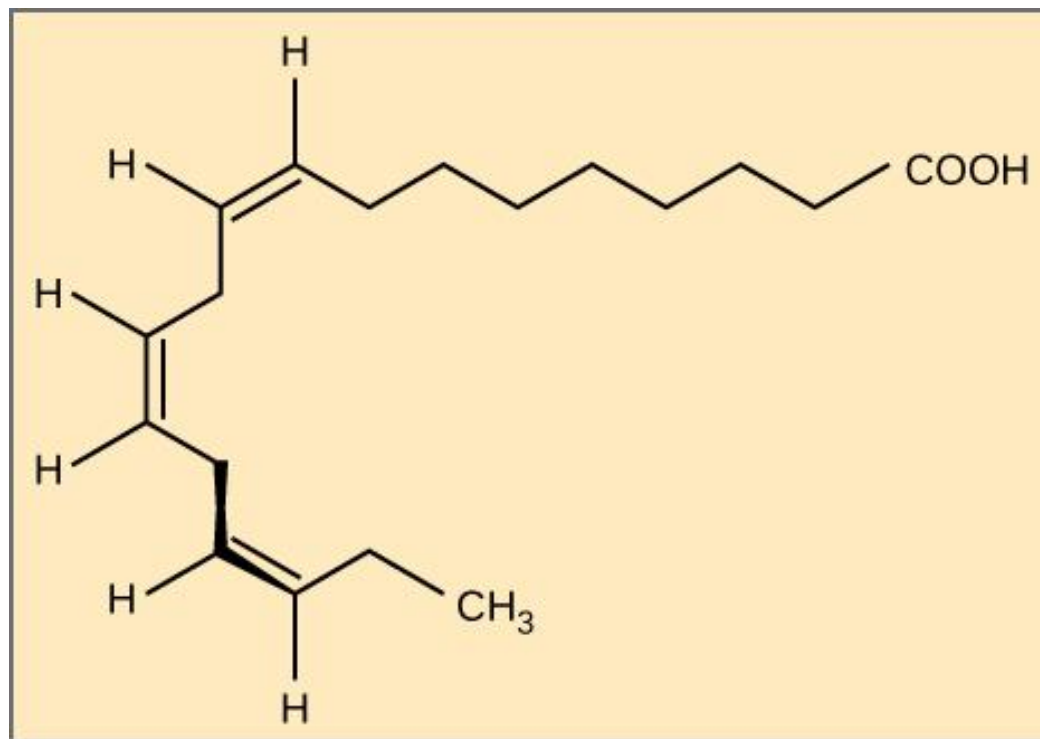


Trans oleic acid



Saturated fatty acids have hydrocarbon chains connected by single bonds only. Unsaturated fatty acids have one or more double bonds. Each double bond may be in a *cis* or *trans* configuration. In the *cis* configuration, both hydrogens are on the same side of the hydrocarbon chain. In the *trans* configuration, the hydrogens are on opposite sides. A *cis* double bond causes a kink in the chain.

FIGURE 3.17



Alpha-linolenic acid is an example of an omega-3 fatty acid. It has three *cis* double bonds and, as a result, a curved shape. For clarity, the carbons are not shown. Each singly bonded carbon has two hydrogens associated with it, also not shown.

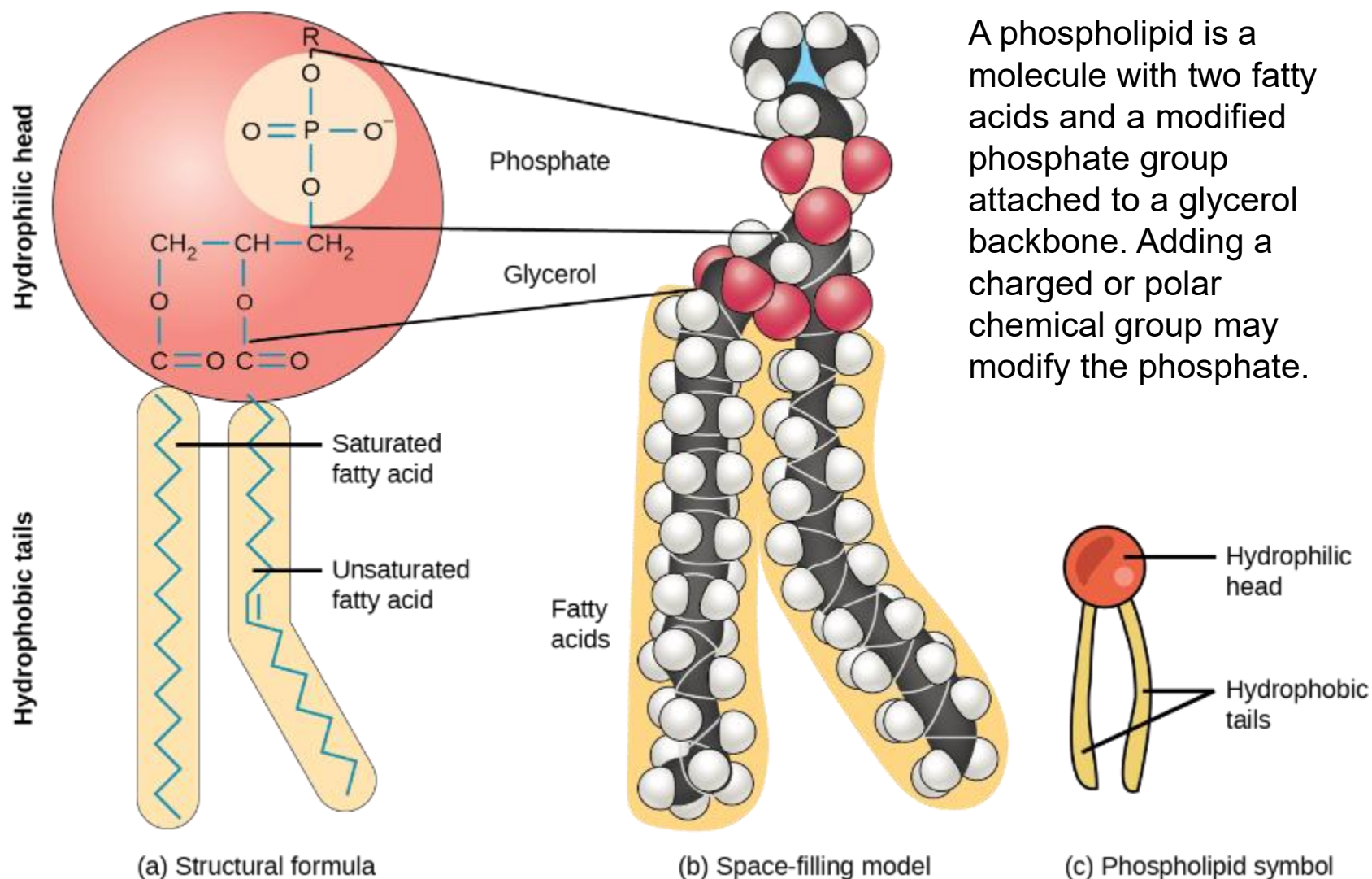
FIGURE 3.18



Lipids comprise waxy coverings on some leaves.

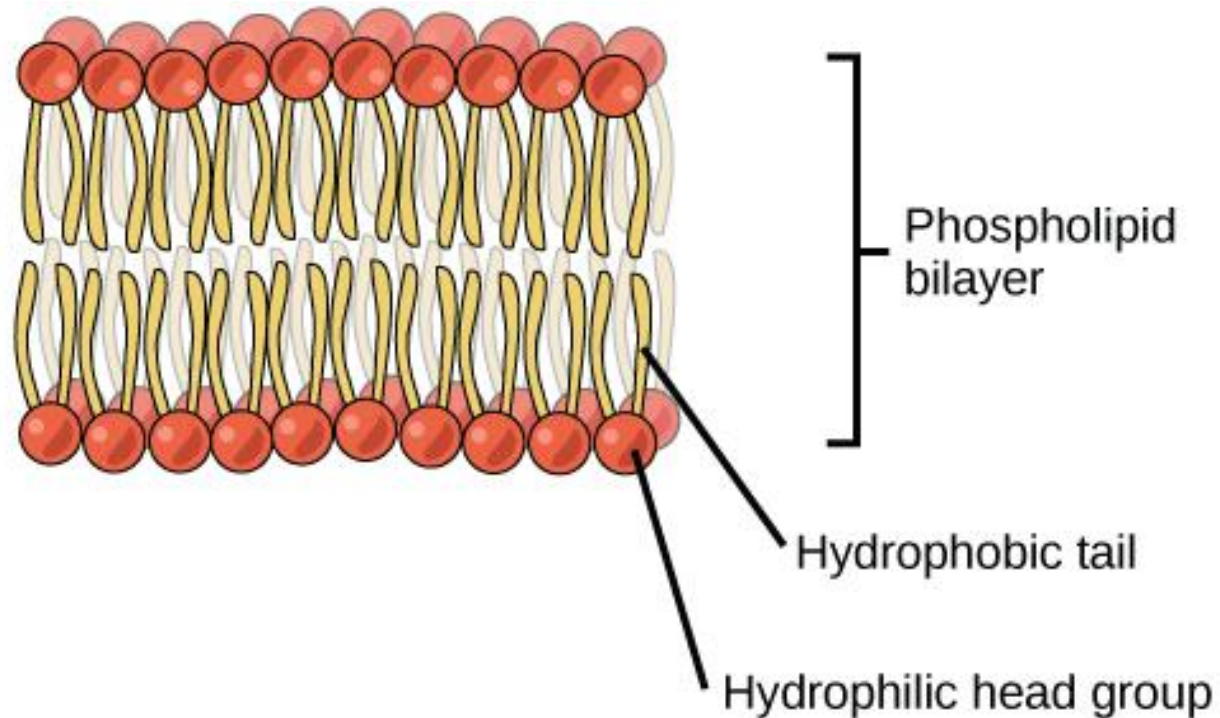
(credit: Roger Griffith)

FIGURE 3.19



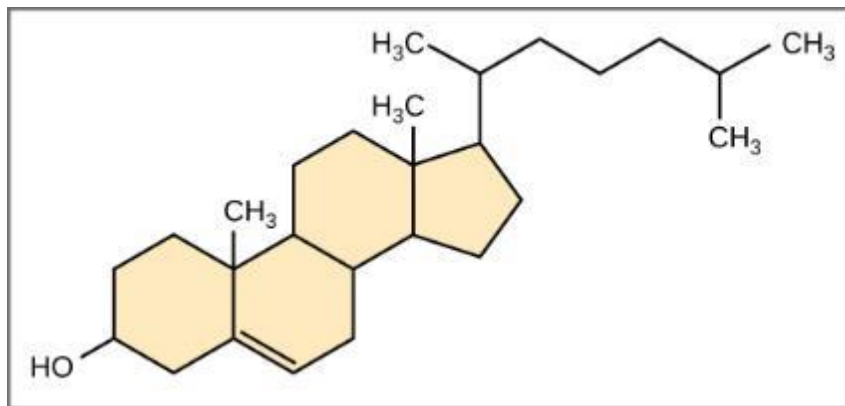
A phospholipid is a molecule with two fatty acids and a modified phosphate group attached to a glycerol backbone. Adding a charged or polar chemical group may modify the phosphate.

FIGURE 3.20

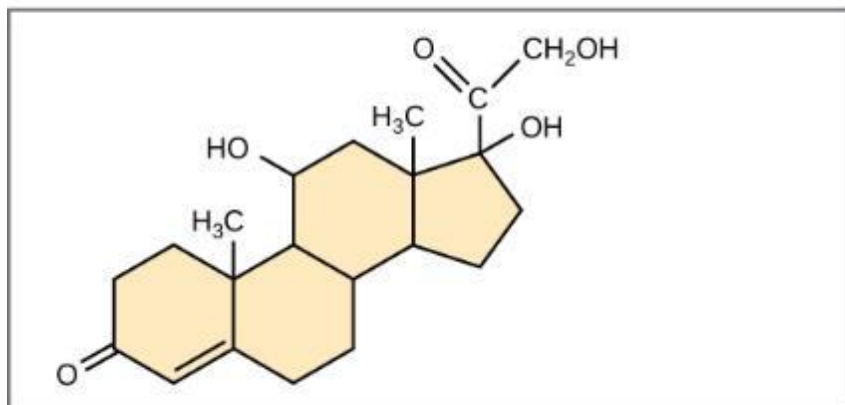


The phospholipid bilayer is the major component of all cellular membranes. The hydrophilic head groups of the phospholipids face the aqueous solution. The hydrophobic tails are sequestered in the middle of the bilayer.

FIGURE 3.21



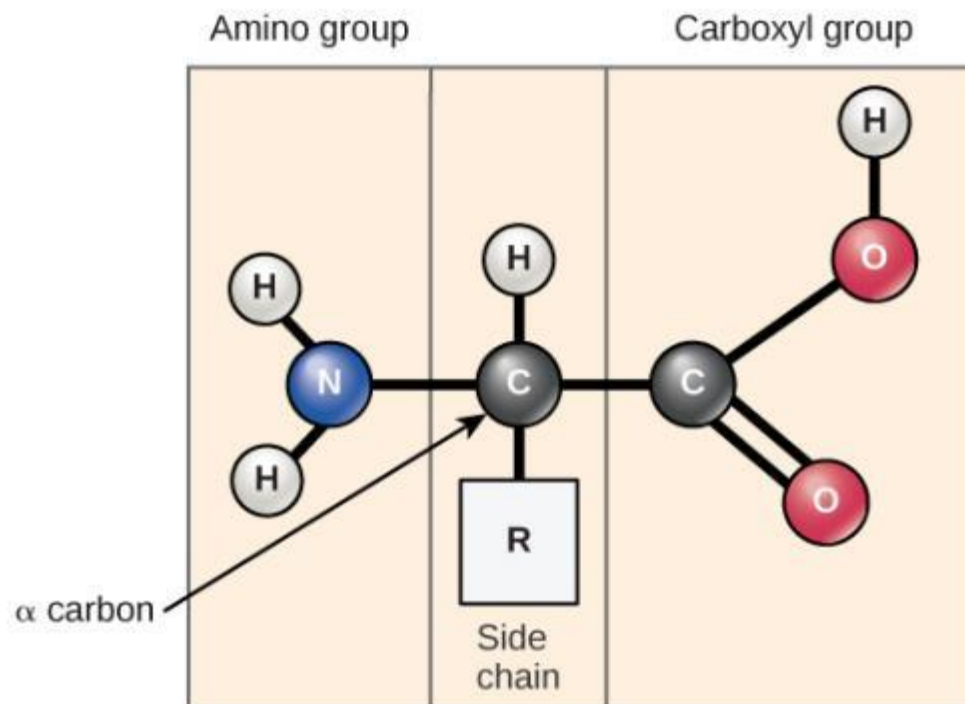
Cholesterol



Cortisol

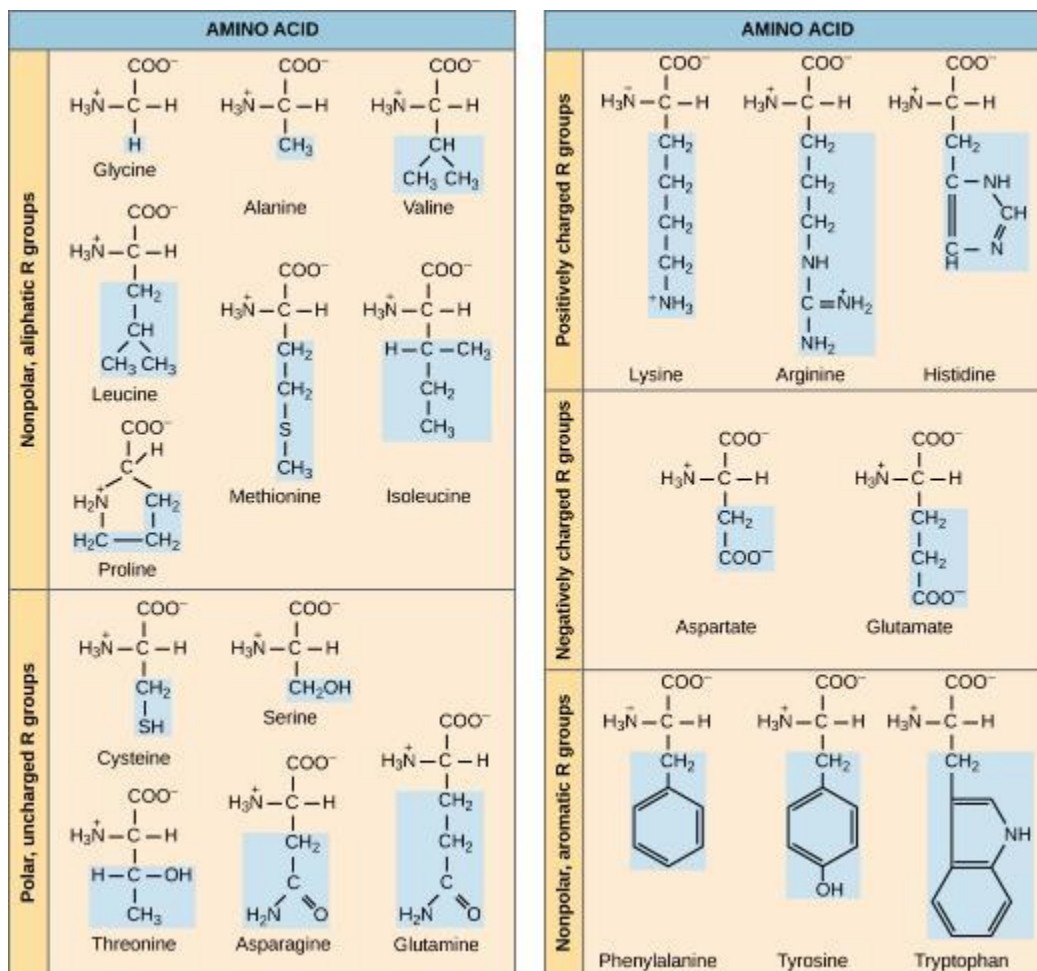
Four fused hydrocarbon rings comprise steroids such as cholesterol and cortisol.

FIGURE 3.22



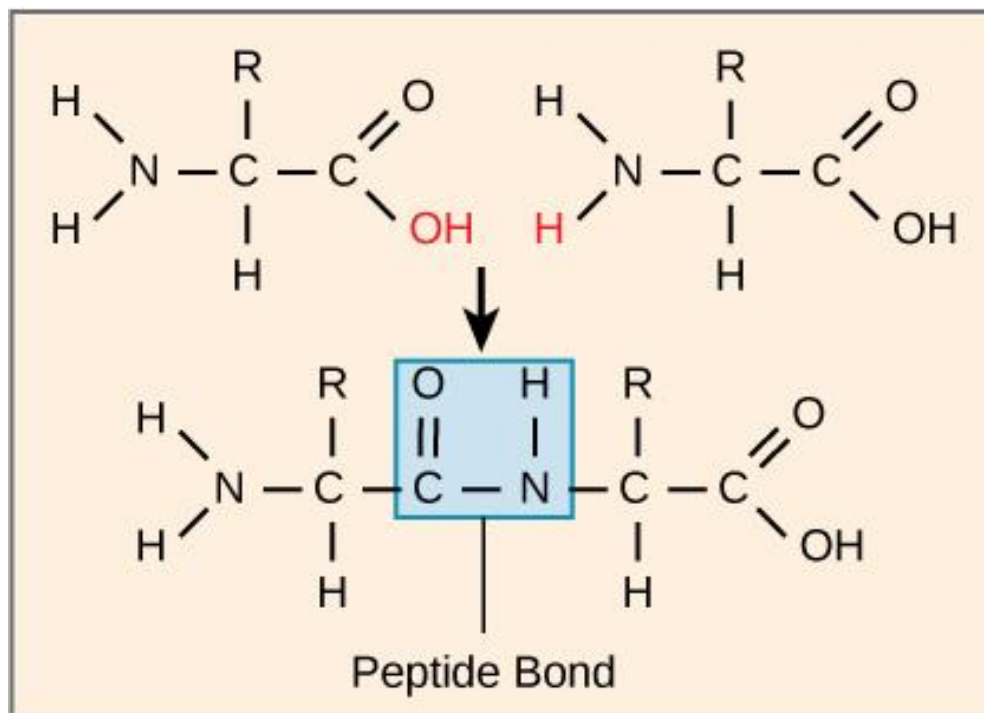
Amino acids have a central asymmetric carbon to which an amino group, a carboxyl group, a hydrogen atom, and a side chain (R group) are attached.

FIGURE 3.23



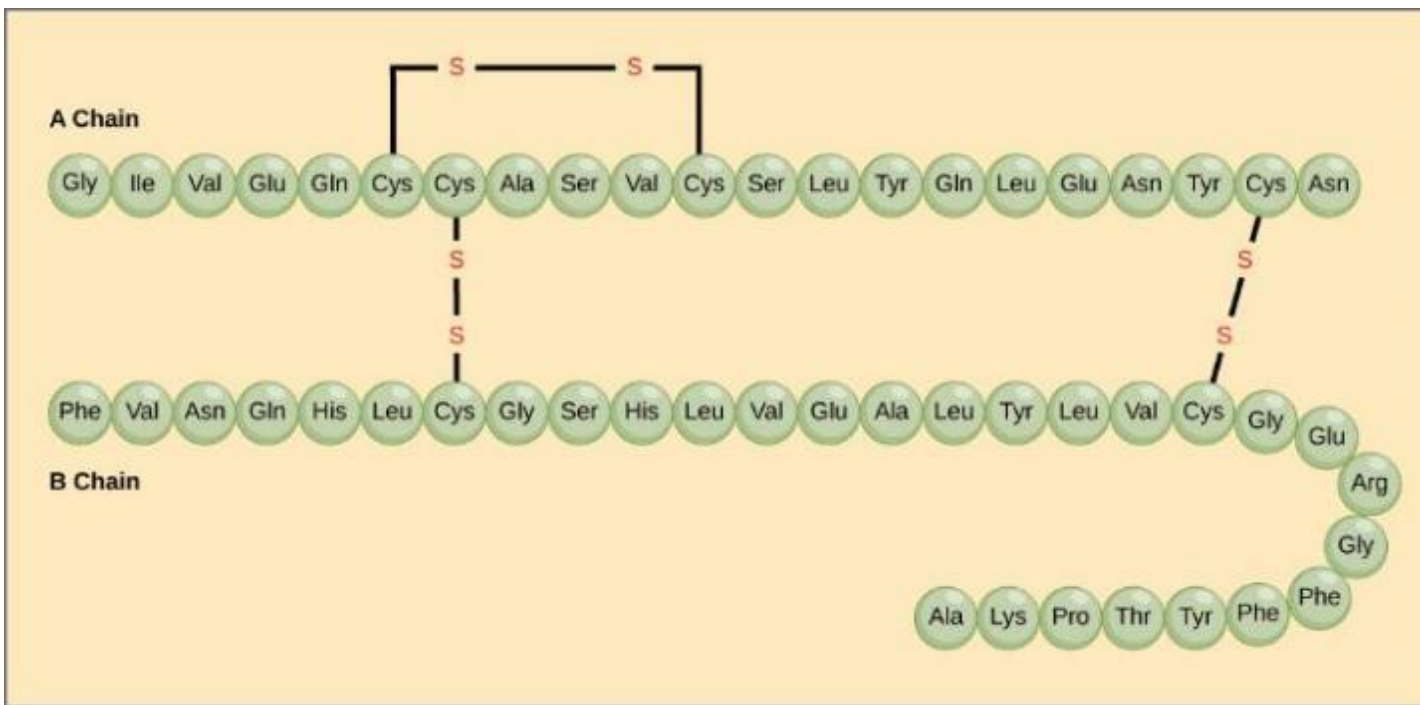
There are 20 common amino acids found in proteins, each with a different R group (variant group) that determines its chemical nature.

FIGURE 3.24







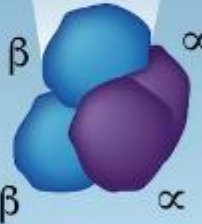
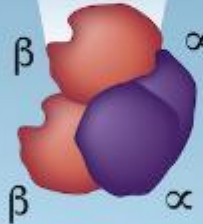
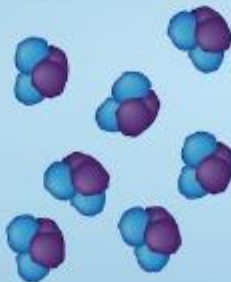
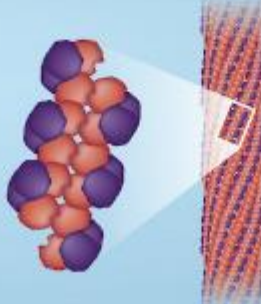
Peptide bond formation is a dehydration synthesis reaction. The carboxyl group of one amino acid is linked to the amino group of the incoming amino acid. In the process, it releases a water molecule.

FIGURE 3.25



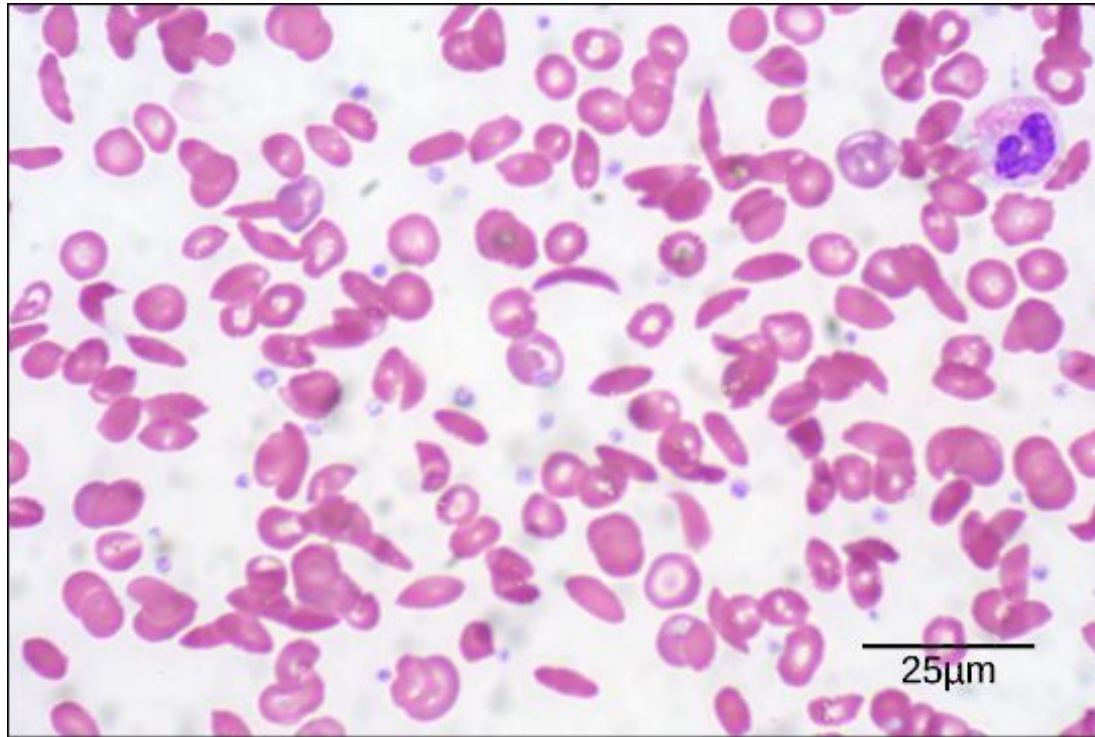
Bovine serum insulin is a protein hormone made of two peptide chains, A (21 amino acids long) and B (30 amino acids long). In each chain, primary structure is indicated by three-letter abbreviations that represent the names of the amino acids in the order they are present. The amino acid cysteine (cys) has a sulfhydryl (SH) group as a side chain. Two sulfhydryl groups can react in the presence of oxygen to form a disulfide (S-S) bond. Two disulfide bonds connect the A and B chains together, and a third helps the A chain fold into the correct shape. Note that all disulfide bonds are the same length, but are drawn different sizes for clarity.

FIGURE 3.26

| | Normal | Sickle-Cell |
|-----------------------------------|--|---|
| Primary Structure | 1 2 3 4 5 6 7 Val His Leu Thr Pro Glu Glu  | 1 2 3 4 5 6 7 Val His Leu Thr Pro Val Glu  |
| Secondary and Tertiary Structures |  Normal β Subunit |  Sickle-Cell β Subunit |
| Quaternary Structure |  Normal Hemoglobin |  Sickle-Cell Hemoglobin |
| Function |  Proteins Do Not Associate with One Another; Each Carries Oxygen |  Proteins Aggregate Into a Fiber; Capacity to Carry Oxygen is Reduced |

credit: Rao, A., Tag, A. Ryan, K. and Fletcher, S. Department of Biology, Texas A&M University

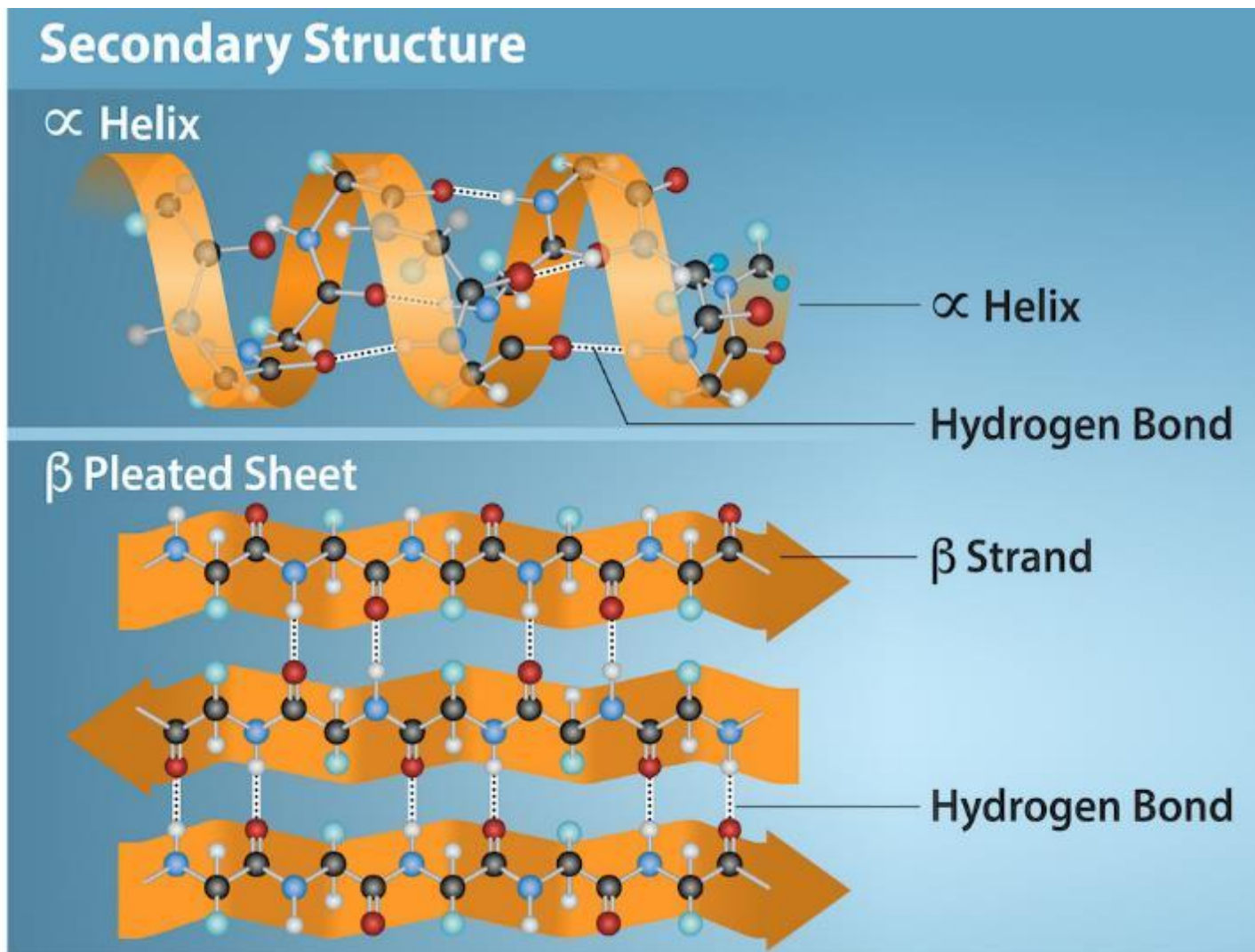
FIGURE 3.27



In this blood smear, visualized at $535\times$ magnification using bright field microscopy, sickle cells are crescent shaped, while normal cells are disc-shaped.

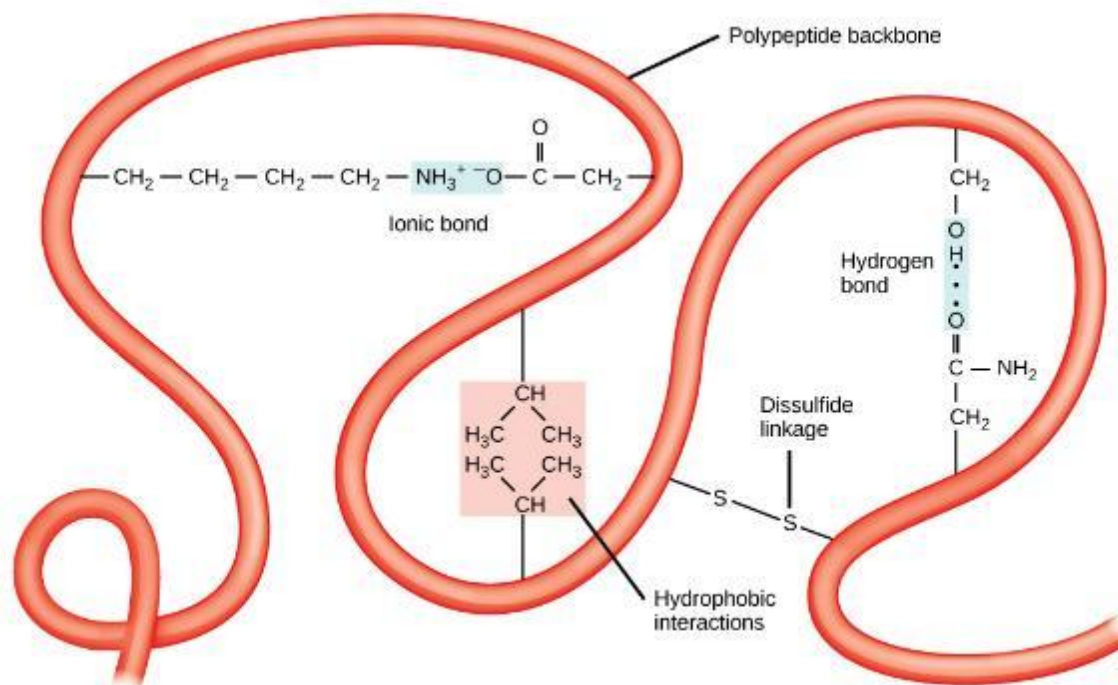
(credit: modification of work by Ed Uthman; scale-bar data from Matt Russell)

FIGURE 3.28



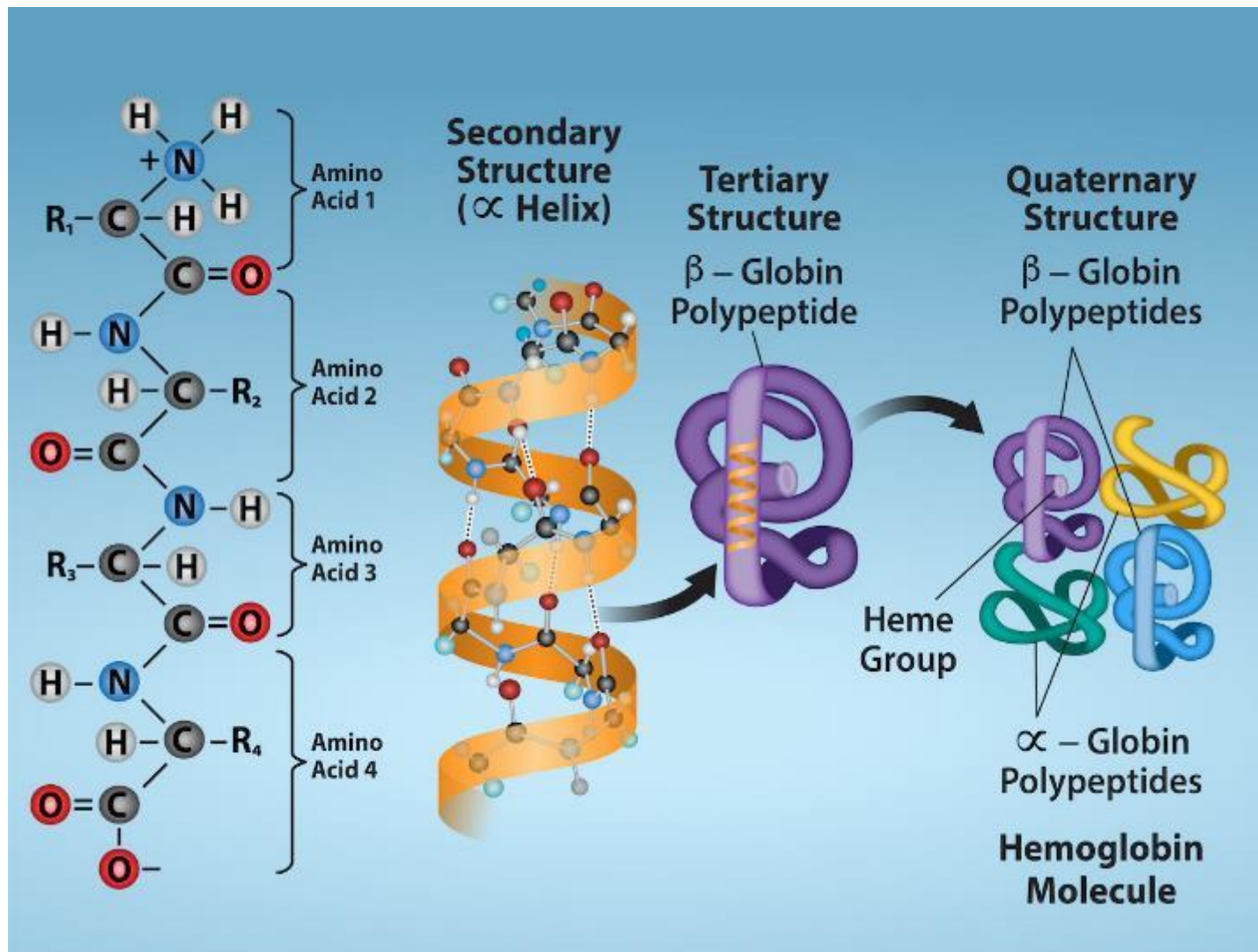
credit: Rao, A., Tag, A. Ryan, K. and Fletcher, S. Department of Biology, Texas A&M University

FIGURE 3.29



A variety of chemical interactions determine the proteins' tertiary structure. These include hydrophobic interactions, ionic bonding, hydrogen bonding, and disulfide linkages.

FIGURE 3.30



credit: Rao, A., Tag, A. Ryan, K. and Fletcher, S. Department of Biology, Texas A&M University

FIGURE 3.31

A nucleotide is made up of three components: a nitrogenous base, a pentose sugar, and one or more phosphate groups. Carbon residues in the pentose are numbered 1' through 5' (the prime distinguishes these residues from those in the base, which are numbered without using a prime notation). The base is attached to the 1' position of the ribose, and the phosphate is attached to the 5' position. When a polynucleotide is formed, the 5' phosphate of the incoming nucleotide attaches to the 3' hydroxyl group at the end of the growing chain. Two types of pentose are found in nucleotides, deoxyribose (found in DNA) and ribose (found in RNA). Deoxyribose is similar in structure to ribose, but it has an H instead of an OH at the 2' position. Bases can be divided into two categories: purines and pyrimidines. Purines have a double ring structure, and pyrimidines have a single ring.

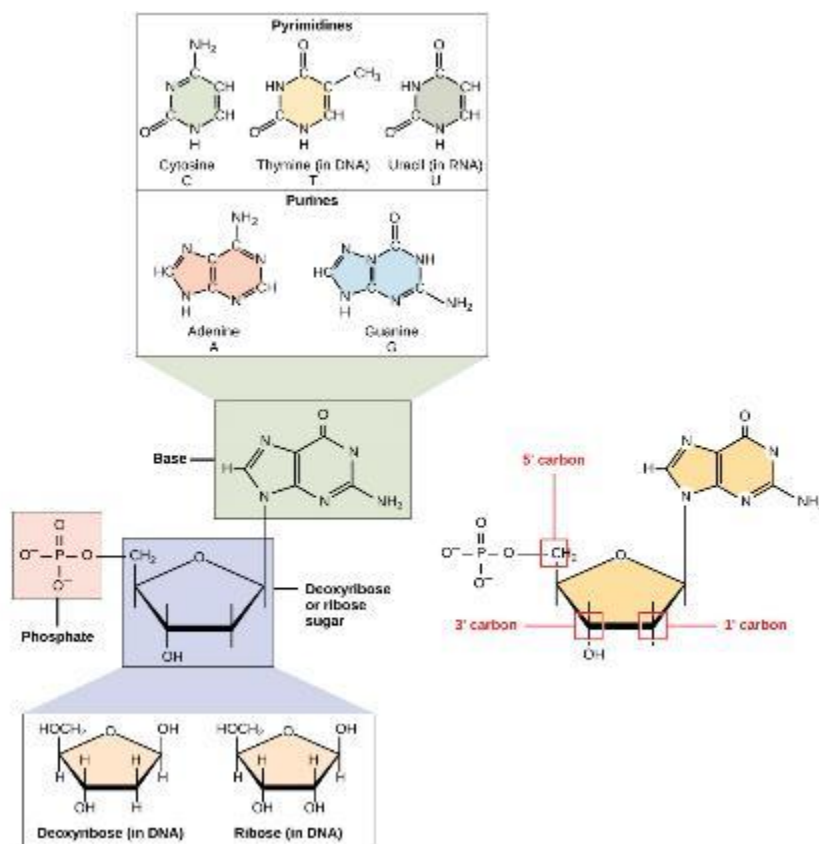
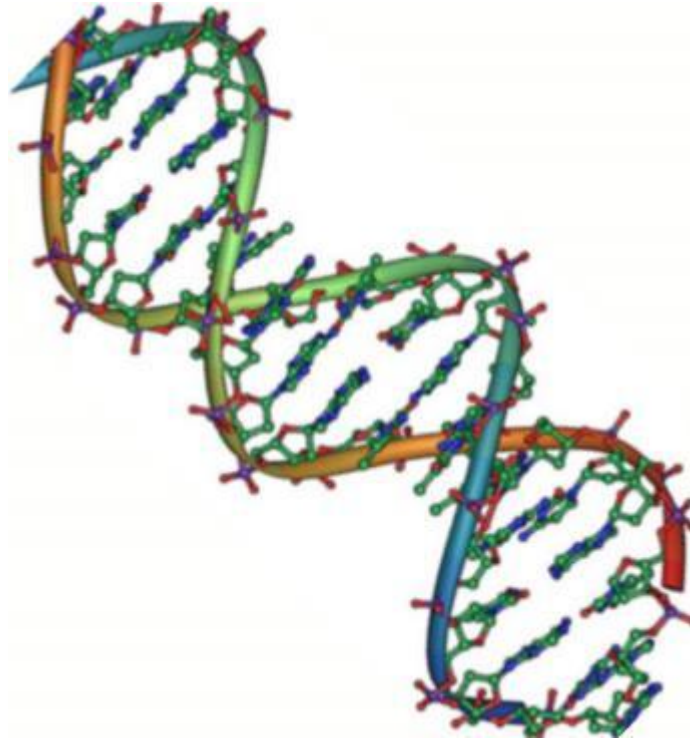


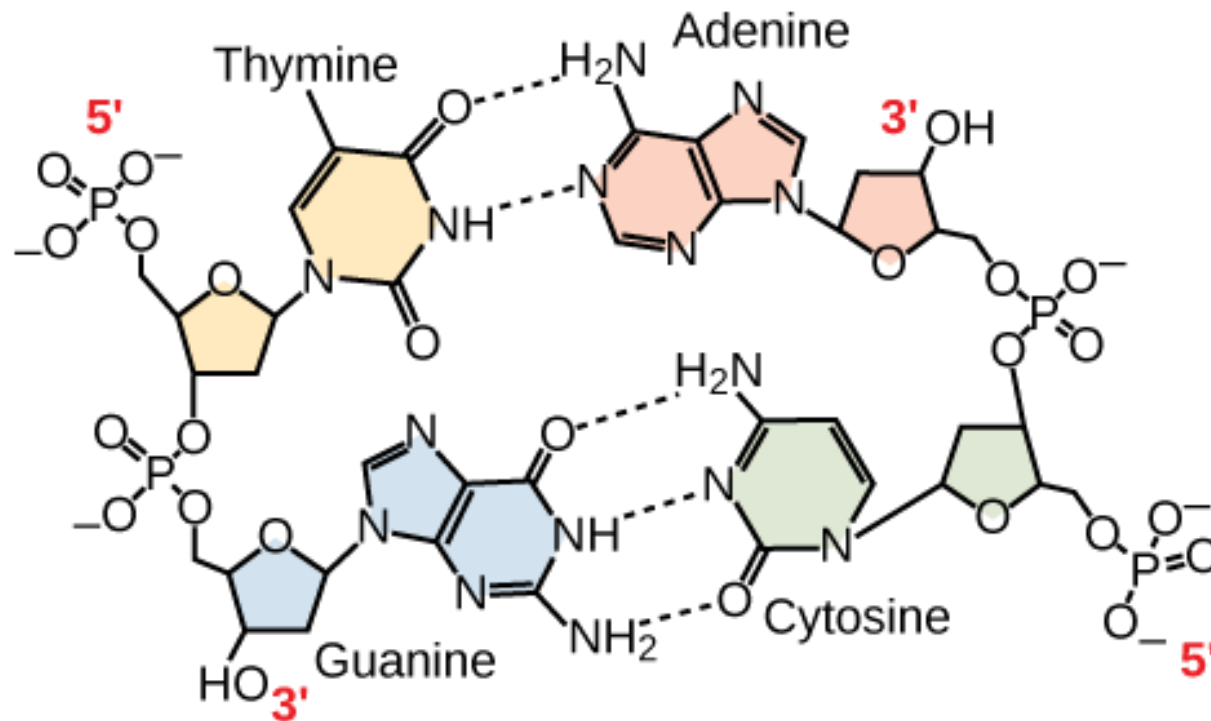
FIGURE 3.32



Native DNA is an antiparallel double helix. The phosphate backbone (indicated by the curvy lines) is on the outside, and the bases are on the inside. Each base from one strand interacts via hydrogen bonding with a base from the opposing strand.

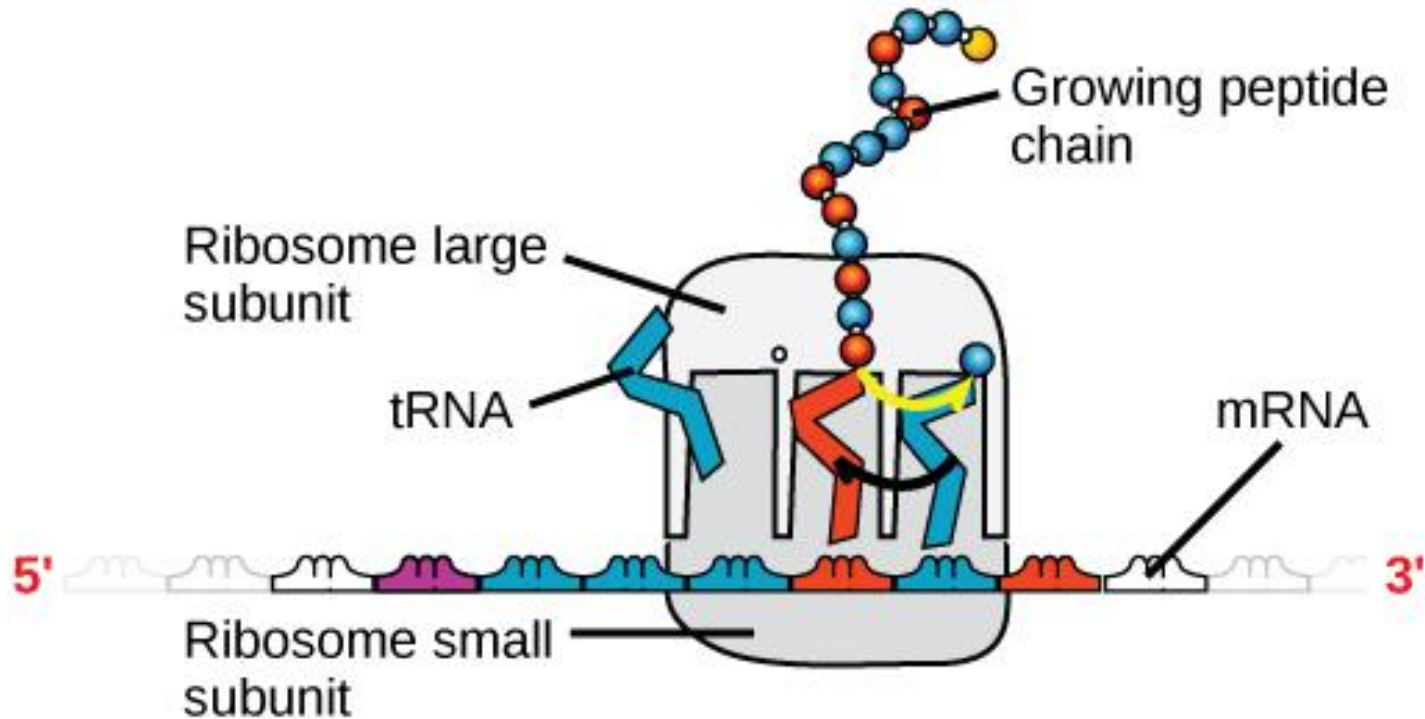
(credit: Jerome Walker/Dennis Myts)

FIGURE 3.33



In a double stranded DNA molecule, the two strands run antiparallel to one another so that one strand runs 5' to 3' and the other 3' to 5'. The phosphate backbone is located on the outside, and the bases are in the middle. Adenine forms hydrogen bonds (or base pairs) with thymine, and guanine base pairs with cytosine.

FIGURE 3.34



A ribosome has two parts: a large subunit and a small subunit. The mRNA sits in between the two subunits. A tRNA molecule recognizes a codon on the mRNA, binds to it by complementary base pairing, and adds the correct amino acid to the growing peptide chain.