comparison of the polysaccharides starch and cellulose provides an excellent example of how structure is crucial to biological function. Namely, the structure of the glycosidic bonds linking the glucose units in cellulose and starch are very similar, yet the subtle difference in bond configuration determines whether the polymer is digestible (starch) or not (cellulose). We will spend a number of lectures on polysaccharide and general carbohydrate metabolism. The medical relevance of these topics cannot be overemphasized. For example, more than 1 in 30 Americans will become diabetic during their lifetimes and suffer consequences attributable to energy imbalance and monosaccharide-based tissue damage.

C. Nucleic acids.

Nucleic acids are composed of nucleotide monomer units. Nucleotides themselves are composed of a monosaccharide, a nitrogenous base, and one or more phosphate groups (**Fig. 1.8**). The nucleotide ATP is the major energy currency of the cell which is used to power a huge variety of energy-requiring reactions. ATP and other ribonucleotides (containing ribose) also make up the biopolymer RNA. Deoxyribonucleotides (containing deoxyribose) make up DNA. All nucleotides are held together by phosphodiester linkages where one phosphate group is attached to 2 sugar units in the backbone of the polymer (**Fig. 1.9**). Nucleotides play key roles in information transfer in all organisms (DNA $\rightarrow$ RNA $\rightarrow$ protein). RNA also can carry out structural and enzymatic functions. For example, the formation of peptide bonds during protein synthesis actually is performed by one of the RNA constituents of the ribosome. In addition the main structural component of ribosomes is RNA. Lastly, a number of nucleic acid analogs are used to inhibit DNA synthesis and are extremely important in management of cancers and virally caused diseases such as AIDS.

D. Lipids and membranes.

Lipids are a diverse collection of biomolecules that are composed mostly of carbon and hydrogen, i.e., hydrocarbons. Lipids contain relatively few polar functional groups. They typically are more soluble in organic solvents than in water. The primary building block of many lipids is a fatty acid. The most common structural lipid in cell membranes--glycerophospholipid--contains 2 fatty acids, glycerol and a polar head group (**Fig. 1.11 & 1.12**). When collected as assemblies of millions of molecules, the classical biological structure known as a membrane is formed (**Fig. 1.13**). Biological membranes usually contain proteins, and protein content and composition is highly variable and determined by membrane function. Although discussed here along with true biopolymers, membranes are actually molecular aggregates. In later chapters, we will cover the functions of membrane-bound proteins, enzymes and receptors. We'll discuss how membranes serve as the primary sites of energy production in aerobic tissues such as the brain and liver, how membrane-bound hormone receptors signal metabolic changes in cells, and how many toxins act to impair membrane protein function.

IV. The energetics of life.

Living organisms are highly complicated at the molecular level. A large amount of energy is invested in maintaining the ordered and complicated state of cells and tissues. In humans and animals, energy needed for work and biosynthesis of cellular structures is derived interactions (**Fig. 2.13**). However, van der Waals bonds often are important in the packing of amino acids inside a folded protein and in the interactions between adjacent bases stacked within the DNA double helix. They also can mediate specific interactions because they become collectively strong if the interacting molecules have precisely complementary shapes and can approach one another closely.

VII. Water is a nucleophile.

Water often is a reactant in biochemical reactions. The unshared pairs of electrons in water molecules can behave as nucleophiles which can attack an electrophilic center in another molecule. A good example where water serves as a nucleophile is in the hydrolysis of peptide bonds (**Fig. 2.14**). Although this is a favorable reaction, peptide bonds are actually quite stable due to the fact that the activation energy for this reaction is quite high. Thus the reaction is very slow at physiological temperatures and pH unless catalyzed by an enzyme.

VIII. Ionization of water.

As a prelude to our discussion of pH, we need to discuss the ionization of water, as it is through this reaction that solution pH ultimately is established. A water molecule has a slight tendency to undergo a dissociation reaction whereby a proton is lost to another water molecule. The products of this reaction are a hydronium ion (H_3O^+) and a hydroxyl ion (OH^-).

$$H_2O + H_2O \qquad H_3O^+ + OH^-$$

A hydronium ion can donate its proton to another molecule and hence is considered to be an acid (proton donor). A hydroxyl ion can accept a proton from an acid and thus is called a base (proton acceptor). The ionization reaction commonly is written as

$$H_2O \qquad H^+ + OH^-$$

Water has a finite and defined capacity to ionize, and the ionization process has a characteristic equilibrium constant at a given temperature.

$$K_{eq} = \frac{[H^+][OH^-]}{[H_2O]}$$

K_{eq} for water has been experimentally determined by measuring the electrical conductivity of pure water. (Note, electrical conductivity is proportional to the levels of ions in the water). The value for $K_{eq} = 1.8 \times 10^{-16}$ M. This K_{eq} value and the value of the concentration of water ($[H_2O] = 55.5$ M) can be substituted into the equilibrium equation to derive another equation which specifies the amounts of $[H^+]$ and $[OH^-]$ in any water sample or biochemical buffer: