Chapter 2 - Chemical Basis of Life

2.1 Introduction

A. Chemistry deals with the composition of substances and how they change.

B. A knowledge of chemistry is necessary for the understanding of physiology because of the importance of chemicals in body processes.

2.2 Structure of Matter

A. Elements and Atoms; (Table 2.1)

1. Matter is anything that takes up space.
2. All matter is composed of elements, 92 of which occur naturally.
3. Living organisms require about 20 elements, of which oxygen, carbon, hydrogen, and nitrogen are most abundant.
4. Elements are composed of atoms; atoms of different elements vary in size and in how they interact.

B. Atomic Structure (Fig. 2.1; Table 2.2)

1. An atom consists of a nucleus containing protons and neutrons, with electrons in orbit around the nucleus.
2. Protons, with a positive charge, are about equal in size to neutrons, which have no charge.
3. Electrons are much smaller and bear a negative charge.
4. An electrically neutral atom has equal numbers of protons and electrons.
5. The number of protons denotes the atomic number of an element; the number of protons plus the number of neutrons equals the atomic weight.

C. Bonding of Atoms (Figs. 2.2-2.6; Table 2.2)

1. Atoms form bonds by gaining, losing, or sharing electrons.
2. Electrons are found in shells around the nucleus.
   a. The first energy shell holds two electrons; the other energy shells each hold eight electrons when on the outside.
3. Atoms with incompletely filled outer shells tend to be reactive to form stable outer shells of 8.
4. When atoms gain or lose electrons, they become ions with a charge. Whether they gain or lose will depend on how many they have in the outer shell to start with.
5. Oppositely-charged ions attract each other and form an ionic bond.
6. Covalent bonds are formed when atoms share electrons to become stable with filled outer shells.
   a. Two pairs of electrons shared between atoms form a double covalent bond.

D. Molecules and Compounds (Figs 2.5, 2.7; Table 2.3)

1. A molecule is formed when two or more atoms combine.
2. If atoms of different elements combine, the molecule can also be called a compound.
   a. Compounds always have a definite kind and number of atoms.

E. Formulas (Figs. 2.8-2.9)

1. A molecular formula represents the numbers and types of atoms in a molecule.
2. Various representations, called structural formulas, can be used to illustrate molecules.

F. Chemical Reactions

1. A chemical reaction occurs as bonds are formed or broken between atoms,

ions, or molecules.

2. Those changed by the reaction are the reactants; those formed are the products.
3. Two or more atoms or molecules can be joined during synthesis.
4. Larger molecules can be broken into smaller ones in decomposition reactions.
5. Exchange reactions occur as parts of molecules trade places.
6. Reversible reactions are symbolized by using two arrows.
7. Catalysts influence the rates of chemical reactions.

G. Acids and Bases (Figs. 2.10-2.11)

1. Substances that release ions in water are called electrolytes.
2. Electrolytes that release hydrogen ions in water are called acids.
3. Electrolytes that release ions that combine with hydrogen ions in water are called bases.
4. The concentrations of H+ & OH- in the body are very important to physiology.
5. pH represents the concentration of hydrogen ions [H^+] in solution.
6. A pH of 7 indicates a neutral solution with equal numbers of hydrogen ions and hydroxyl (OH^-) ions.

   a. A pH of zero to less than 7 indicates the presence of more hydrogen ions, and thus the solution is more acidic; a pH greater than 7 to 14 indicates more hydroxyl ions, or a basic solution.

   b. Between each whole number of the pH scale there is a tenfold difference in hydrogen ion concentration.

2.3 Chemical Constituents of Cells

A. Compounds that contain both hydrogen and carbon are called organic, the others are inorganic

B. Inorganic Substances (Table 2.4)

1. Water
   a. Water is the most abundant compound in living things and makes up two-thirds of the weight of adults.
   b. Water is an important solvent so most metabolic reactions occur in water.
   c. Water is important in transporting materials in the body since it is a major component of blood.
   d. Water carries waste materials and can absorb and transport heat.
2. Oxygen
   a. Oxygen is needed to release energy from nutrients and is used to drive the cell's metabolism.
3. Carbon Dioxide
   a. Carbon dioxide is released as a waste product during energy-releasing metabolic reactions.
4. Salts
   a. Inorganic salts are the sources of ions of sodium, chloride, potassium, calcium, magnesium, phosphate, carbonate, bicarbonate, and sulfate.
   b. These electrolytes play important roles in many of the body's metabolic processes.

C. Organic Substances (Table 2.6)

1. Carbohydrates (Figs. 2.12-2.13)
   a. Carbohydrates provide energy for cellular activities and are

composed of carbon, hydrogen, and oxygen.

b. Carbohydrates are made from monosaccharides (simple sugars); disaccharides are two monosaccharides joined together; complex carbohydrates (polysaccharides), such as starch, are built of many sugars.

c. Humans synthesize the polysaccharide glycogen.

2. Lipids (Figs. 2.14-2.16; Table 2.5)

a. Lipids are insoluble in water but soluble in certain organic solvents: lipids include fats, phospholipids, and steroids.

b. Fats supply energy, are composed of oxygen, carbon, and hydrogen, and are built from glycerol and three fatty acids.

i. Fatty acids with hydrogen at every position along the carbon chain are saturated; those with one or more double bonds are called unsaturated fats.

c. Phospholipids contain glycerol, two fatty acids, and a phosphate group, and are important in cell structures.

d. Steroids are complex ring structures, and include cholesterol, which is used to synthesize the sex hormones.

3. Proteins (Figs. 2.17-2.19)

a. Proteins have a great variety of functions in the body---as structural materials, as energy sources, as certain hormones, as receptors on cell membranes, as antibodies, and as enzymes to catalyze metabolic reactions.

b. Proteins contain C, O, H, and nitrogen atoms; some also contain sulfur.

c. Building blocks of proteins are the amino acids, each of which has a carboxyl group, an amino group and a side chain called the R group.

d. Proteins have complex shapes held together by hydrogen bonds.

e. Protein shapes, which determine how proteins function, can be altered (denatured) by pH, temperature, radiation, or chemicals.

4. Nucleic Acids (Figs. 2.20-2.22; Table 2.6)

a. Nucleic acids form genes and take part in protein synthesis.

b. They contain carbon, hydrogen, oxygen, nitrogen, and phosphorus, which are bound into building blocks called nucleotides.

c. Nucleic acids are of two major types: DNA (with deoxyribose) and RNA (with ribose).

d. RNA (ribonucleic acid) functions in protein synthesis; DNA (deoxyribonucleic acid) stores the molecular code in genes.