Chapter 2: Chemical Basis of Life

I. Introduction

A. The study of chemistry is essential for the study of physiology because body functions depend on cellular functions that, in turn, result from chemical changes.

B. Biochemistry is the study of chemistry in living organisms.

II. Structure of Matter

A. Elements and Atoms

1. Matter is anything that has weight and takes up space.
2. All matter is composed of elements.
3. Examples of elements are iron, copper, silver, gold, aluminum, carbon, hydrogen, and oxygen.
4. Compounds are chemical combinations.
5. Elements needed by the body in large amounts are called bulk elements.
6. Six examples of bulk elements are carbon, hydrogen, oxygen, nitrogen, sulfur, and phosphorus.
7. Elements needed by the body in small amounts are called trace elements.
8. Trace elements are used by the body for parts of enzymes.
9. Ultratrace elements are elements needed by the body in very small amounts and are toxic in large amounts.
10. Elements are composed of particles called atoms.
11. Atoms that make up elements are chemically identical to one another, but they differ from the atoms that make up other elements.

B. Atomic Structure

1. The central portion of an atom is called the nucleus.
2. The nucleus contains protons and usually neutrons.
3. Electrons carry a negative charge.
4. Electrons are located around the nucleus.
5. Protons carry a positive charge.
6. Neutrons are electrically neutral.
7. The nucleus of an atom is positively charged.

8. A complete atom is electrically neutral.
9. The atoms of different elements contain different numbers of protons.
10. An atomic number is the number of protons in the atoms of a particular element.
11. Carbon has an atomic number of six.
12. One atom of carbon contains six protons.
13. The weight of an atom is primarily due to the weight of protons and neutrons.
14. The atomic weight of an atom is the number of protons plus the number of neutrons in each of an element's atoms.
15. The atomic weight of carbon is twelve.
16. One carbon atom has six protons and six neutrons.

C. Isotopes

1. Atoms of the same element can vary in atomic weights because their number of neutrons may vary.
2. An oxygen atom with an atomic weight of 17 has eight protons and nine neutrons.
3. Isotopes are atoms that have the same atomic numbers but different atomic weights.
4. The number of electrons in an atom equals the number of protons.
5. Radioactive isotopes release atomic radiation.
6. Examples of radioactive isotopes are isotopes of oxygen, iodine, iron, phosphorus, and cobalt.
7. Three common forms of atomic radiation are alpha, beta, and gamma radiation.
8. Alpha radiation consists of particles from atomic nuclei, each of which includes two protons and two neutrons.
9. Beta radiation consists of electrons.
10. The most penetrating type of atomic radiation is gamma radiation.

D. Molecules and Compounds

1. Two or more atoms may combine to form a molecule.
2. A molecular formula depicts the numbers and kinds of atoms in a molecule.

3. The subscripts in a molecular formula indicate how many atoms of each element are present.

4. When atoms of different elements combine molecules of substances called compounds form.

E. Bonding of Atoms

1. Bonds form when atoms combine.
2. Electrons of an atom are found in energy shells.
3. The first electron shell can hold two electrons.
4. The second electron shell can hold eight electrons.
5. The third electron shell of an atom with an atomic number 18 will hold eight electrons.
6. Innermost electron shells are filled first.
7. An atom will react with another atom if its outermost shell is not completely full of electrons.
8. Inert atoms are atoms that have completely full outermost electron shells.
9. Atoms with incompletely filled outer shells tend to lose, gain, or share electrons in ways that empty or fill their outer shells to become stable.
10. Ions are atoms that gain or lose electrons and become electrically charged.
11. A sodium atom loses one electron to become stable.
12. A chlorine atom gains one electron to become stable.
13. If an atom loses an electron, it becomes positively charged.
14. If an atom gains an electron, it becomes negatively charged.
15. Positively charged ions are called cations.
16. Negatively charged ions are called anions.

17. An ionic bond forms when oppositely charged ions attract.

18. A covalent bond forms when atoms share electrons.

19. When one pair of electrons is shared between atoms, a single covalent bond is formed.

20. When two pairs of electrons are shared between atoms, a double covalent bond is formed.

21. When three pairs of electrons are shared between atoms, a triple covalent bond is formed.

22. A structural formula shows how atoms bond and are arranged in a molecule.

23. When electrons are not shared equally in a covalent bond, a polar molecule forms.

24. An important example of a polar molecule is water.

25. A hydrogen bond is the weak attraction between the positive hydrogen end of a polar molecule to the negative nitrogen or oxygen end of another polar molecule.

F. Chemical Reactions

1. Reactants of a chemical reaction are substances being changed.
2. Products of a chemical reaction are substances formed at the end of a chemical reaction.
3. A synthesis reaction occurs when two or more atoms, ions, or molecules bond to form a more complex structure.
4. A decomposition reaction occurs when the bonds of a reactant molecule break to form simpler molecules.
5. An exchange reaction occurs when parts of two different kinds of molecules trade positions.
6. In reversible reactions, products can change back to the reactant or reactants.
7. Catalysts are molecules that influence the rates of chemical reactions but are not consumed in the reactions.

G. Acids, Bases, and Salts

1. When salts are put into water, they dissolve into positive ions (cations) and negative ions (anions).

2. Substances that release ions in water are called electrolytes.
3. Acids are electrolytes that dissociate to release hydrogen ions in water.
4. Bases are substances that combine with hydrogen ions.
5. A salt is a substance formed by the reaction between an acid and a base.

H. Acid and Base Concentrations

1. Hydrogen ion concentration is typically measured in grams of ions per liter of solution.
2. The pH scale is a shorthand system used to indicate the concentration of hydrogen ions.
3. A solution with a hydrogen ion concentration of 0.1 grams per liter has a pH value of 1.0.
4. A solution with a hydrogen ion concentration of 0.001 grams per liter has a pH value of 3.0.
5. The pH scale ranges from 0 to 14.
6. Each whole number on the pH scale represents a tenfold difference in hydrogen ion concentration.
7. As the hydrogen ion concentration increases, the pH decreases.
8. A neutral pH is 7.0.
9. Acidic solutions have pH values that are less than 7.0.
10. Alkaline solutions have pH values that are more than 7.0.
11. Solutions with more hydrogen ions than hydroxide ions are acidic.
12. Solutions with more hydroxide ions than hydrogen ions are basic or alkaline.
13. Solutions with equal numbers of hydrogen ions and hydroxide ions are neutral.
14. The normal pH of blood is 7.35 – 7.45.
15. Alkalosis is a rise in blood pH.
16. Acidosis is a fall in blood pH.
17. Buffers are chemicals that resist pH change.

III. Chemical Constituents of Cells

A. Introduction

1. Chemicals that contain carbon and hydrogen are organic.

2. Chemicals that generally do not contain carbon and hydrogen are inorganic.

3. Many organic chemicals have long chains or ring structures that can be formed because of a carbon atom's ability to form four covalent bonds.

4. Inorganic chemicals usually dissociate in water.

5. Organic chemicals usually dissolve in organic liquids.

6. Nonelectrolytes are compounds that do not release ions when dissolved in water.

B. Inorganic Substances

1. Introduction

a. Four common inorganic substances in cells are water, oxygen, carbon dioxide, and inorganic salts.

2. Water

a. The most abundant compound in living material is water.

b. Most metabolic reactions occur in water because when substances dissolve in water, the polar water molecules cause molecules of the substance to separate from each other or to break up into ions. These particles are then much more likely to take part in chemical reactions.

c. In the body, water transports chemicals, waste materials, and heat.

3. Oxygen

a. Organelles use oxygen to release energy from nutrient molecules.

b. A continuing supply of oxygen is necessary for cell survival.

4. Carbon Dioxide

a. Carbon dioxide is produced when energy is released during certain metabolic processes.

b. As carbon dioxide moves into body fluids and blood, it reacts with water to forms a weak acid (carbonic acid).

5. Inorganic Salts
    a. Inorganic salts are sources of many necessary ions.
    b. Electrolyte balance is the condition of having electrolytes in correct concentrations, both inside and outside cells.

C. Organic Substances
1. Introduction
    a. Four groups of organic substances in cells are carbohydrates, lipids, proteins, and nucleic acids.
2. Carbohydrates
    a. Three things carbohydrates supply to cells are energy, materials to build certain cell structures, and a reserve energy supply.
    b. Three elements always found in carbohydrates are carbon, hydrogen, and oxygen.
    c. The ratio of hydrogen to oxygen in carbohydrates is close to 2:1.
    d. Two types of simple sugars are monosaccharides and disaccharides.
    e. Monosaccharides have 3-7 carbons.
    f. Disaccharides have 12 carbons.
    g. Three examples of monosaccharides are glucose, fructose, and galactose.
    h. Two examples of disaccharides are sucrose and lactose.
    i. Complex carbohydrates are polysaccharides.
    j. Polysaccharides are built from simple carbohydrates.
    k. Three examples of polysaccharides are cellulose, starch, and glycogen.
3. Lipids
    a. Lipids are soluble in organic solvents.
    b. Three examples of lipids are fats, phospholipids, and steroids.
    c. Three elements found in fat molecules are carbon, hydrogen, and oxygen.
    d. Fats have a smaller proportion of oxygen than carbohydrates.

e. The building blocks of fat molecules are fatty acids and glycerol.

f. All fatty acid molecules include a carboxyl group at the end of a chain of carbon atoms.

g. Two ways fatty acid molecules differ are in the lengths of their carbon atom chains and the way the carbon atoms join together.

h. A saturated fatty acid is one in which the carbon atoms are linked by single carbon-carbon bonds.

i. Fatty acids with one double carbon-carbon bond is monounsaturated.

j. Fatty acids with more than one double carbon-carbon bond is polyunsaturated.

k. A single fat molecule is called a triglyceride.

l. One triglyceride contains one glycerol molecule and three fatty acid molecules.

m. Saturated fats contain only saturated fatty acids.

n. Unsaturated fats contain at least one unsaturated fatty acid.

o. The number of fatty acid chains in a phospholipid molecule is two.

p. The part of a phospholipid molecule that is soluble in water is the phosphate containing portion.

q. The part of a phospholipid molecule that is insoluble in water is the fatty acid portion.

r. Phospholipids are important in cellular structures.

s. Steroids contain connected rings of carbon atoms.

t. An important steroid found in all body cells is cholesterol.

u. Cholesterol is used to synthesize other steroids, sex hormones, and hormones from the adrenal glands.

4. Proteins

a. Three important functions of proteins are to serve as structural materials, energy sources, and chemical messengers. Proteins also function as receptors, antibodies, and enzymes.

b. Enzymes are catalysts in living systems.

c. Four elements always found in proteins are carbon, hydrogen, oxygen, and nitrogen.

d. One element sometimes found in proteins is sulfur.

e. The building blocks of proteins are amino acids.

f. Amino acids have an amino group at one end and a carboxyl group at the other end.

g. The twenty amino acids differ in their side chains or R groups.

h. Peptide bonds are bonds between amino acids.

i. A polypeptide is a chain of amino acids.

j. The four levels of protein structure are primary, secondary, tertiary, and quaternary.

k. The primary structure of a protein is the amino acid sequence of the polypeptide chain.

l. In secondary structure, a polypeptide chain forms an alpha helix or a beta-pleated sheet.

m. Hydrogen bonding determines secondary structure.

n. The folding of secondary structure is called tertiary structure.

o. Protein function is determined by its distinct conformation created by its primary, secondary, and tertiary structures.

p. When a protein denatures, it loses its tertiary or secondary structure.

q. Four things that cause a protein to denature are heat, radiation, pH changes, and certain chemicals.

r. The quaternary structure of a protein forms when several polypeptide chains connect to form a very large protein.

5. Nucleic Acids

a. Nucleic acids carry the instructions that control a cell's activities by encoding the amino acid sequences of proteins in its building blocks.

b. The five elements found in nucleic acids are carbon, hydrogen, oxygen, nitrogen, and phosphorus.

c. The building blocks of nucleic acids are nucleotides.

d. The three parts of a nucleotide are a 5-carbon sugar, a phosphate group, and one of several nitrogenous bases.

e. A polynucleotide is a chain of nucleotides.

f. Two major types of nucleic acids are DNA and RNA.

g. RNA contains the sugar ribose.

h. DNA contains the sugar deoxyribose.

j. RNA is a single polynucleotide chain.

j. DNA is a double polynucleotide chain.

k. The function of DNA is to store information for protein synthesis.

l. The function of RNA is to use the information stored in DNA to construct specific protein molecules.

m. DNA has the unique ability to make copies of itself.