CHAPTER 2 REVIEW QUESTIONS

1. Describe the electric charge and locations of the three major subatomic particles in an atom.
The electron has one unit of negative charge and revolves around the atomic nucleus in orbitals. The proton has one unit of positive charge and is found in the nucleus. The neutron has no charge and is also found in the nucleus.

2. Describe how an ion is formed.
Ions are formed when an atom either gains or loses one or more electrons. Atoms that gain electrons have a net negative charge and are called anions. Atoms that lose electrons have a net positive charge and are called cations.

3. Which four kinds of atoms are most abundant in the body?
hydrogen (H), oxygen (O), carbon (C), and nitrogen (N)

4. Describe the distinguishing characteristics of the three classes of essential chemical elements found in the body.
The four major elements listed above account for 99.3% of the total atoms in the body. There are seven essential mineral elements—calcium (Ca), chlorine (Cl), magnesium (Mg), phosphorus (P), potassium (K), sodium (Na), and sulfur (S). These are the most abundant substances dissolved in the body fluids. Most of the body's calcium and phosphorus atoms make up the solid matrix of bone tissue. Thirteen other elements, called essential trace elements, are present in extremely small quantities but are nevertheless essential for normal body functions, such as growth and the blood's transport of oxygen.

5. How many covalent bonds can be formed by atoms of carbon, nitrogen, oxygen, and hydrogen?
Carbon can form four, nitrogen three, oxygen two, and hydrogen one.

6. What property of molecules allows them to change their three-dimensional shape?
Molecules are not rigid structures. Atoms can rotate around their covalent bonds to form different shapes.

7. Draw the structures of an ionized carboxyl group and an ionized amino group.
Carboxyl:

```
      O
      ||
R — C — O⁻
```

Amino:

```
       H
       |
R — N⁺ — H
       |
       H
```

8. Define a free radical.
A free radical is an atom that contains a single (unpaired) electron in an orbital of its outer shell, as are molecules containing such atoms.

9. Describe the polar characteristics of a water molecule.
Water has the structure: (+) (-) (+)
H — O — H
The bonds between oxygen and each of the two hydrogen atoms are polar, meaning that oxygen, with eight times as many protons as hydrogen, draws the shared electrons closer to its nucleus. Water molecules interact with each other through hydrogen bonds.

10. What determines a molecule's solubility or lack of solubility in water?

For a molecule to dissolve in water (i.e., be hydrophilic), it must be electrically attracted to water molecules. In other words, it must have a sufficient number of polar bonds and/or ionized groups. Nonpolar molecules do not dissolve in water because their electrically neutral covalent bonds are not attracted to water molecules. Nonpolar molecules are thus hydrophobic.

11. Describe the organization of amphipathic molecules in water.
    Amphipathic molecules have two parts or domains: a polar or ionized region at one end and a nonpolar region at the other end. In water, such molecules form clusters so that their hydrophilic "heads" are oriented on the outside of the cluster and their hydrophobic "tails" are oriented toward the inside, away from the water molecules.

12. What is the molar concentration of 80 g of glucose dissolved in sufficient water to make 2 L of solution?
    Glucose has a molecular weight of 180. Eighty g of glucose is 80/180 = 0.44 mol/2 L. This is equivalent to 0.22 mol/L.

13. What distinguishes a weak acid from a strong acid?
    Molecules that release hydrogen ions in solution are called acids. A strong acid releases 100% of its hydrogen ions, while a weak acid does not ionize completely in solution.

14. What effect does increasing the pH of a solution have upon the ionization of a carboxyl group? An amino group?
    Increasing the pH of a solution decreases the concentration of free hydrogen ion in that solution, and thus will favor increasing the ionization of weak acids, such as a carboxyl group. It will decrease the ionization of weak bases, such as an amino group.

15. Name the four classes of organic molecules in the body.
    carbohydrates, lipids, proteins, and nucleic acids

16. Describe the three subclasses of carbohydrate molecules.
    The basic unit of the carbohydrates is the monosaccharide, which has the chemical formula $C_n(H_2O)_n$, *where "n" is any whole number. Two monosaccharides can join together to form a disaccharide. Polysaccharides are polymers of monosaccharides.*

17. To which subclass of carbohydrates does each of the following molecules belong: glucose, sucrose, and glycogen?
    Glucose is a monosaccharide; sucrose a disaccharide; and glycogen a polysaccharide.

18. What properties are characteristic of lipids?
    Lipids are composed primarily of carbon and hydrogen atoms, which form nonpolar covalent bonds. Thus, lipids are nonpolar and hydrophobic.

19. Describe the subclasses of lipids.
    <u>Fatty acids</u>: Fatty acids consist of a chain of carbon and hydrogen atoms with an acidic carboxyl group at one end; therefore, they contain two oxygen atoms in addition to their complement of carbon and hydrogen atoms. Saturated fatty acids result when all the carbons are linked by single covalent bonds. Unsaturated fatty acids contain one or more double bonds between carbon atoms. If one double bond is present, the fatty acid is monounsaturated, and if there is more than one double bond, it is polyunsaturated.
    <u>Triglycerides</u>: Most of the body's lipids are triglycerides, or "fat." Each triglyceride is composed of three fatty acids linked to a three-carbon carbohydrate named glycerol.
    <u>Phospholipids</u>: A phospholipid is similar to a triglyceride except that in a phospholipid two fatty acid chains are linked to glycerol, with the sugar's third hydroxyl group attached to a phosphate group. Often a polar or ionized nitrogen-containing molecule is attached to the phosphate. Phospholipids, therefore, have a polar region as well as nonpolar ends and are thus amphipathic.
    <u>Steroids</u>: These are composed of four interconnected rings of carbon atoms bound to hydrogen atoms and each other, with a variety of chemical groups attached to different places in the rings.

20. Describe the linkages between amino acids that form polypeptide chains.
Amino acids are linked together when the carboxyl group of one reacts with the amino group of another, forming a peptide bond and releasing a molecule of water (dehydration). The carboxyl group of the second amino acid can react with the amino group of a third, and so on, forming a polymer called a polypeptide.

21. What distinguishes the terms peptide, polypeptide, and protein?
A sequence of amino acids linked by peptide bonds is known as a polypeptide. Strictly speaking, the term polypeptide refers to a structural unit and does not necessarily suggest that the molecule is functional. By convention, if the number of amino acids in a polypeptide is 50 or fewer and has a known biological function, the molecule is referred to as a peptide. When one or more polypeptides are folded into a characteristic shape forming a functional molecule, that molecule is called a protein.

22. What two factors determine the primary structure of a protein?
The primary structure of a protein is determined by the number of amino acids in the chain and the specific type of amino acid at each position along the chain.

23. Describe the types of interactions that determine the conformation of a polypeptide chain.
The conformation of a polypeptide is its three-dimensional shape. It is determined by (1) hydrogen bonds between portions of the chain or with surrounding water molecules; (2) ionic bonds between polar and ionized regions along the chain; (3) attraction between nonpolar (hydrophobic) regions; (4) covalent bonds, called disulfide bonds, between the side chains of the amino acid cysteine (not all polypeptides have disulfide bonds); and (5) van der Waals forces, which are very weak and transient electrical interactions between the orbiting electrons in the outer shells of two atoms that are in close proximity to each other.

Hydrogen bonds between the hydrogen linked to the nitrogen in one peptide bond and the oxygen in another occur at regular intervals along the chain and coil it into a helical shape (alpha helix). Hydrogen bonds between peptide bonds running parallel to each other can force a straight structure called a beta pleated sheet.

Some proteins, called multimeric proteins, consist of more than one polypeptide chain.

24. Describe the structure of DNA and RNA.
DNA and RNA are nucleic acids, deoxyribonucleic acid and ribonucleic acid, respectively. The subunits of both nucleic acids are called nucleotides, and consist of a phosphate group, a sugar (deoxyribose in DNA, ribose in RNA), and one of five possible carbon-nitrogen rings called purine or pyrimidine bases. Nucleotides are linked together by covalent bonds between the sugar and phosphate groups of adjacent subunits.

The three-dimensional structure of DNA is a double helix, with the two strands held together by hydrogen bonds between a purine base on one chain and a pyrimidine base on the other. RNA consists of a single chain of nucleotides.

25. Describe the characteristics of base pairings between nucleotide bases.
The bases in DNA are the purines adenine and guanine and the pyrimidines thymine and cytosine. Adenine binds only to thymine and guanine only to cytosine.

RNA can form base pairs with DNA, as above, except that RNA has the pyrimidine uracil instead of thymine. Uracil forms hydrogen bonds with adenine.

2: CHEMICAL COMPOSITION OF THE BODY

Although most students of human physiology have had at least some chemistry, this chapter serves very well as a review and as a glossary of chemical terms. In particular, emphasis should be given to the discussion of the properties of water and other polar molecules, and to the organic molecules of the body.

Atoms

Teaching/Learning Objectives:

Students should be able to:

- understand the relationship of atoms and elements.
- describe the three subatomic particles that constitute the atom.
- discuss the arrangement of electrons in orbitals.
- define atomic number, atomic weight, isotope, and gram atomic mass.
- describe how ions are formed.
- distinguish between anions and cations.
- become familiar with the essential chemical elements of the body.

Molecules

Teaching/Learning Objectives:

Students should be able to:

- define *molecule* and *covalent chemical bond.*
- state the number of covalent bonds formed by the four most abundant atoms in the body.
- define electronegativity.
- describe how polar covalent bonds are formed and how electrical charges are distributed in them.
- describe how nonpolar covalent bonds are formed and how electrical charges are shared in them.
- describe the differences in water solubility between polar and nonpolar molecules.
- describe how polar covalent bonds lead to the formation of hydrogen bonds.
- recognize the importance of hydrogen bonds to the structure of large molecules.
- visualize molecules as three-dimensional and realize that their shape can change under many circumstances.
- understand that ionization can occur in single atoms and also in atoms that are covalently linked in molecules.
- identify the carboxyl group and the amino group.
- state the definition of a free radical and describe how they are formed.
- discuss why free radicals are so highly reactive with other atoms and why this can be detrimental to cells.
- discuss how antioxidants can protect the body from harmful free radicals.
- identify the biologically important free radicals.

Solutions

Teaching/Learning Objectives:

Students should be able to:

- define solute, solvent, and solution.
- appreciate the importance of the polar nature of the water molecule and its ability to react with other molecules in hydrolytic reactions.
- describe the interactions of polar and ionic compounds with water molecules that allow them to dissolve.
- distinguish between *hydrophilic* and *hydrophobic* molecules.
- define *amphipathic* and describe structures formed by such molecules in solution.
- define solute concentration and the related terms *mole* and *molarity*. Determine the molarity of a solution if you are given the gram molecular weight of the solute.
- differentiate between acids and bases, and between strong and weak acids and strong and weak bases.
- define *pH* and describe the pH scale.

Classes of Organic Molecules

Teaching/Learning Objectives:

Students should be able to:

- list the four classes of organic macromolecules in the body.
- describe the structure and function of carbohydrates. Distinguish between monomers and polymers of carbohydrates.
- describe characteristics shared by all types of lipids.
- describe the structure and function of the four subclasses of lipids: fatty acids, triglycerides, phospholipids, and steroids.
- describe some of the major categories and functions of proteins.
- describe the structure of an amino acid and how they bond together to form polypeptides.
- distinguish between peptides, polypeptides, proteins, and glycoproteins.
- describe the four levels of protein structure and the types of chemical bonds important for each level.
- describe the structure and function of the nucleic acids and distinguish between DNA and RNA.
- discuss the importance of ATP as a molecule that *transfers* energy within a cell.

LECTURE OUTLINE

I. Characteristics of atoms and ions
II. Molecules
  A. Covalent chemical bonds (Fig. 2-2)
    1. Polar covalent bonds (Table 2-3)
    2. Nonpolar covalent bonds (Table 2-3)
  B. Hydrogen bonds (Fig 2-3)
  C. Ionic molecules
  D. Free radicals
III. Properties of solutions
IV. Classes of organic molecules

A. Carbohydrates—structure and function (Figs. 2-8, 2-10)
B. Lipids—characteristics common to all types of lipids
   1. Fatty acids
   2. Triglycerides (Fig. 2-12)
   3. Phospholipids
   4. Steroids (Fig. 2-13)
C. Proteins
   1. Amino acids and peptide bonds (Figs. 2-14, 2-15)
   2. Levels of protein structure (Figs. 2-16, 2-17, 2-19)
D. Nucleic acids
   1. Nucleotide structure (Fig. 2-20)
   2. Three-dimensional structure (Fig. 2-22)
   3. Base pairing (Fig. 2-23)
E. Adenosine triphosphate (ATP) (Fig. 2-24)

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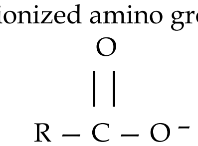
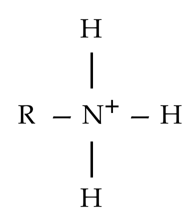


   Amino:



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21. What distinguishes the terms peptide, polypeptide, and protein?
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24. Describe the structure of DNA and RNA.
    DNA and RNA are nucleic acids, deoxyribonucleic acid and ribonucleic acid, respectively. The subunits of both nucleic acids are called nucleotides, and consist of a phosphate group, a sugar (deoxyribose in DNA, ribose in RNA), and one of five possible carbon-nitrogen rings called purine or pyrimidine bases. Nucleotides are linked together by covalent bonds between the sugar and phosphate groups of adjacent subunits.

    The three-dimensional structure of DNA is a double helix, with the two strands held together by hydrogen bonds between a purine base on one chain and a pyrimidine base on the other. RNA consists of a single chain of nucleotides.

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    The bases in DNA are the purines adenine and guanine and the pyrimidines thymine and cytosine. Adenine binds only to thymine and guanine only to cytosine.

    RNA can form base pairs with DNA, as above, except that RNA has the pyrimidine uracil instead of thymine. Uracil forms hydrogen bonds with adenine.

Interactive Case Studies and the Human Body (11-20)

The Male Body

Case Study 11

Hematology

Polycythemia

Answers:

1. The disorder of this individual is polycythemia.
2. The arterial O_2 saturation and erythropoietin levels are important in confirming that the increased hematocrit is not due to hypoxemia or an abnormally elevated erythropoietin level. The O_2 saturation level would indicate if there is a physiologic stimulus for the increased erythrocyte production.
3. Phlebotomy is the letting of blood for transfusion pheresis, diagnostic testing, or experimental procedures.
4. Phlebotomy (removal of the whole blood) removes both blood cells and plasma. The plasma volume is replaced within days, whereas the erythrocytes take several weeks to be replaced.
5. Myelosuppressive therapy is therapy for the suppression of the bone marrow's production of blood cells and platelets.
6. Myelosuppressive therapy may be needed to suppress the erythrocyte production in the myeloid tissue if the hematocrit continues to rise after the phlebotomies.

Case Histories in Human Physiology
Answer Key

Third Edition

by

Donna Van Wynsberghe
University of Wisconsin-Milwaukee

Gregory M. Cooley
Radiation Oncology Associates, Mequon, Wisconsin

Contents

Neurophysiology Case Histories

Case 1 Bell's Palsy
Answers:

1. The cranial nerve involved in this individual is the facial (VII) nerve.
2. This condition is known as Bell's palsy.
3. This disorder results in blocked conduction of motor impulses along this cranial nerve, which innervates muscles of facial expression. (The conduction block may result from inflammation, hemorrhage, tumor, meningitis, or local traumatic injury around the nerve.) This motor impairment results in facial paralysis, inability to smile, and inability to close her left eye.
4. Her taste was distorted because there are also sensory fibers in this compressed cranial nerve originating from the taste buds on the anterior two-thirds of the tongue.
5. The major disorder of cranial nerve V (trigeminal) is trigeminal neuralgia (also known as tic douloureux), a painful disorder of one or more of the three major branches of the trigeminal nerve (ophthalmic, maxillary, mandibular). Trigeminal neuralgia is characterized by excruciating searing or burning pain that occurs in lightninglike jabs and lasts around one to two minutes in an area innervated by one or more branches of the trigeminal nerve.
6. Bell's palsy is a disorder of the cranial nerve VII (facial) that produces unilateral facial weakness or paralysis.
7. Trigeminal (V): mixed nerve; the "great sensory nerve"; carries sensory information from the face from the three major branches (ophthalmic, maxillary, and mandibular). Motor fibers innervate the muscles of mastication.
8. Facial (VII): mixed nerve; the "great motor nerve"; motor fibers innervate the muscles of facial expression. Sensory fibers arise from taste buds on the anterior two-thirds of the tongue.

Interactive Case Studies and the Human Body (1-10)

The Female Body

Case Study 1

Hematology

AIDS

Answers:

1. This individual has Acquired Immunodeficiency Syndrome (AIDS) caused by the Human Immunodeficiency Virus (HIV).
2. The hematocrit abnormality is caused by the dehydration.
3. Some current treatments include: AZT (Zidovudine) and ddI (Didanosine), both antiretroviral agents which slow the replication of the virus, prevent occurrence or recurrence of opportunistic infections, and boost the immune system.
4. The individual is experiencing hypokalemia prior to treatment.
5. This abnormal potassium level could cause cardiac arrhythmias due to the hyperpolarization of the resting membrane potential.

Case Study 2

Gastrointestinal

Hiatal Hernia

Answers:

1. The disorder is a hiatal hernia. This is a structural defect in which a weakened diaphragm allows a portion of the stomach to pass through the esophageal diaphragmatic opening into the chest when intra-abdominal pressure increases.
2. Adequate lower esophageal pressure at the lower esophageal sphincter normally prevents gastric reflux into the esophagus when lying down or bending over.
3. The parasympathetic division of the autonomic nervous system (cholinergic) innervates the lower esophageal sphincter (LES). Therefore, cholinergic agonists would increase LES contraction, preventing gastric reflux. Anticholinergic agents would decrease LES pressure.
4. Histamine (H2) antagonists are recommended because they reduce gastric acidity by selectively blocking the H2 receptors (which mediate gastric secretion).

5. Elevation of the head of the bed is recommended to encourage gravitational flow of the gastric contents toward the pyloric end of the stomach.
6. The normal pH of the esophagus is 6-7.
   The normal pH of the stomach is 2-5.
   The lower esophageal pH for this individual may be approximately 3-5. The stomach pH would not change (pH = 2-5).