Solutions for Anatomy & Physiology 7th Edition by Marieb

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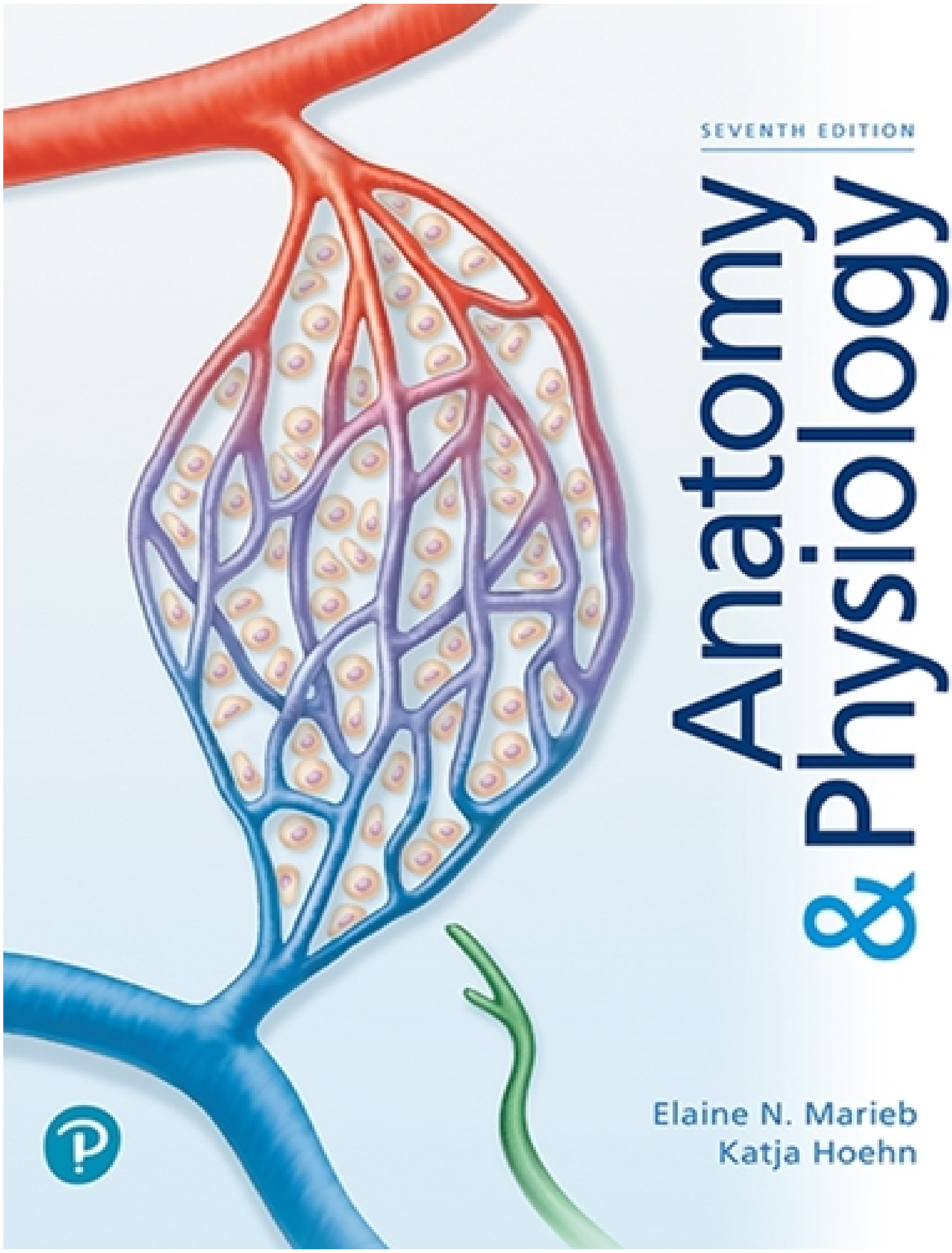


Solutions

2 EXERCISE

Organ Systems Overview

Time Allotment: 1½ hours (rat dissection—1 hour; human torso model—½ hour)

Multimedia Resources: See Appendix B for a list of multimedia resource distributors.

Homeostasis (FHS, 20 minutes, DVD, 3-year streaming webcast)
Homeostasis: The Body in Balance (HRM, IM, 26 minutes, DVD)

Advance Preparation

1. Make arrangements for appropriate storage and disposal of dissection materials. Check with the Department of Health or the Department of Environmental Protection, or their counterparts, for state regulations.
2. Designate a disposal container for organic debris, set up a dishwashing area with hot soapy water and sponges, and provide lab disinfectant such as Wavicide-01 (Carolina) for washing down the lab benches.
3. Set out safety glasses and disposable gloves for dissection of freshly killed animals (to protect students from parasites) and for dissection of preserved animals.
4. Decide on the number of students in each dissecting group (a maximum of four is suggested; two is probably best). Each dissecting group should have a dissecting pan, dissecting pins, scissors, blunt probe, forceps, twine, and a preserved or freshly killed rat.
5. Preserved rats are more convenient to use unless small mammal facilities are available. If live rats are used, they may be killed a half hour or so prior to the lab by administering an overdose of ether or chloroform. To do this, remove each rat from its cage and hold it firmly by the skin at the back of its neck. Put the rat in a container with cotton soaked in ether or chloroform. Seal the jar tightly and wait until the rat ceases to breathe.
6. Set out human torso models and a predissected rat.

Comments and Pitfalls

1. Students may be overly enthusiastic when using the scalpel and cut away organs they are supposed to locate and identify. Have blunt probes available as the major dissecting tool and suggest that the scalpel be used to cut only when everyone in the group agrees that the cut is correct.
2. Be sure the lab is well ventilated, and encourage students to take fresh-air breaks if the preservative fumes are strong. If the dissection animal will be used only once, it can be rinsed to remove most of the excess preservative.
3. Organic debris may end up in the sinks, clogging the drains. Remind the students to dispose of all dissection materials in the designated container.

Answers to Activity Questions

Activity 6: Examining the Human Torso Model (pp. 15–16)

Digestive: *esophagus, liver, stomach, pancreas, small intestine, large intestine (including rectum), gallbladder*

Urinary: *kidneys, ureters, bladder*

Cardiovascular: *heart, descending aorta, inferior vena cava*

Endocrine: *thyroid gland, pancreas, adrenal gland*

Reproductive: *uterus*

Respiratory: *lungs, bronchi, trachea, diaphragm*

Lymphatic: *spleen*

Nervous: *brain, spinal cord, medulla of adrenal gland*

2 EXERCISE

REVIEW SHEET

Name ______________________

Lab Time/Date ______________________

Organ Systems Overview

1. Using the key, indicate which body system matches each of the following descriptions.

Key: cardiovascular, digestive, endocrine, integumentary, lymphatic, muscular, nervous, reproductive, respiratory, skeletal, urinary

urinary 1. rids the body of nitrogen-containing wastes

endocrine 2. is affected by removal of the adrenal gland

skeletal 3. protects and supports body organs; provides a framework for muscular action

cardiovascular 4. includes arteries and veins

endocrine 5. composed of glands that secrete hormones

integumentary 6. external body covering

lymphatic 7. houses cells involved in the body's immune response

digestive 8. breaks down ingested food into its absorbable units

respiratory 9. loads oxygen into the blood

cardiovascular/endocrine 10. uses blood as a transport vehicle

muscular 11. generates body heat and provides for locomotion of the body as a whole

nervous 12. key organs include the brain and spinal cord

reproductive and *endocrine* 13. necessary for conception and childbearing

integumentary 14. is damaged when you fall and scrape your knee

2. Using the above key, choose the *organ system* to which each of the following sets of organs or body structures belongs:

lymphatic 1. lymph nodes, spleen, lymphatic vessels

skeletal 2. bones, cartilages, ligaments

endocrine 3. thyroid, thymus, pituitary gland

respiratory 4. trachea, bronchi, alveoli

reproductive 5. uterus, ovaries, vagina

cardiovascular 6. arteries, veins, heart

3. Name the cells that are produced by the testes and ovaries. *Testes and ovaries produce gametes. The testes produce sperm and the ovaries produce eggs.*

4. List the four primary tissue types. *Epithelial, connective, muscle, and nervous*

5. Explain why an artery is an organ. *An artery is composed of multiple tissue types that perform a common function. An artery has an epithelium, connective tissue, and muscle.*

6. Name the two main organ systems that communicate within the body to maintain homeostasis. Briefly explain their different control mechanisms. *The nervous system and the endocrine systems are the key organ systems that provide for homeostasis. The nervous system uses nerve impulses and the endocrine system uses hormones to provide control.*

7. Explain the role that the skeletal system plays in facilitating cardiovascular system function. *The skeletal system provides for the production of red blood cells and protects the heart.*

8. + Untreated diabetes mellitus can lead to a condition in which the blood is more acidic than normal. Name two organ systems that play the largest role in compensating for acid-base imbalances. *The respiratory and urinary systems play the largest role in maintaining acid-base balance.*

9. + The mother of a child scheduled to receive a thymectomy (removal of the thymus gland) asks you whether there will be any side effects from the removal of the gland. Which two organ systems would you mention in your explanation? *The endocrine and lymphatic systems should be mentioned. Due to the functions of the lymphatic system, immune function can be affected.*

10. + Individuals with asplenia are missing their spleen or have a spleen that doesn't function well. It is recommended that these patients talk to their doctor about vaccines that are indicated for their health condition. Explain how this recommendation correlates to their chronic health condition. *The spleen plays a role in immune function, so individuals who are missing their spleen are at greater risk for infection. Vaccinations are recommended to reduce their susceptibility.*

CHAPTER 2

Chemistry Comes Alive

KEY CONCEPTS

PART 1 BASIC CHEMISTRY

- **2.1** Matter is the stuff of the universe and energy moves matter
- **2.2** The properties of an element depend on the structure of its atoms
- **2.3** Atoms bound together form molecules; different molecules can make mixtures
- **2.4** Three types of chemical bonds are ionic, covalent, and hydrogen
- **2.5** Chemical reactions occur when electrons are shared, gained, or lost

PART 2 BIOCHEMISTRY

- **2.6** Inorganic compounds include water, salts, and many acids and bases
- **2.7** Organic compounds are made by dehydration synthesis and broken down by hydrolysis
- **2.8** Carbohydrates provide an easily used energy source for the body
- **2.9** Lipids insulate body organs, build cell membranes, and provide stored energy
- **2.10** Proteins are the body's basic structural material and have many vital functions
- **2.11** DNA and RNA store, transmit, and help express genetic information
- **2.12** ATP transfers energy to other compounds

What's New in This Edition

- New Homeostatic Imbalance feature about a patient's pH predicting outcome of cardiopulmonary resuscitation.
- Seven higher-level Check Your Understanding questions including two new "Draw" questions and a new "What if" question.
- New summary table about chemical bonds (Table 2.2).
- Updated Figure 2.6 (formation of ionic bonds) and Figure 2.12 (dissociation of salt in water) for better teaching effectiveness.
- New figure illustrating triglyceride structure (Figure 2.16).
- New figure illustrating the difference between saturated and unsaturated fatty acids (Figure 2.17).
- New figure about phospholipids (Figure 2.18).
- New figure provides an overview of protein functions (Figure 2.20).
- New summary table about macromolecules and their monomers and polymers (Table 2.5).

Suggested Lecture Outline

All of the figures in the main text are available in JPEG, PPT, and labeled and unlabeled formats in the Instructor Resources section in Mastering A&P. If you need an instructor account for Mastering A&P, please contact your Pearson representative.

PART 1: BASIC CHEMISTRY

Teaching Tip: *An excellent illustration of the types of energy and their interconversion exists in a mouse trap. Discuss the low potential energy state of the unset trap, the higher potential energy state of a set trap, and the kinetic transfer of energy in a working trap. Point out that the trap transfers its energy to some other object, returning it to the original, lower-potential energy state.*

2.1 Matter is the stuff of the universe and energy moves matter (pp. 19–20)

Learning Outcomes

- Differentiate between matter and energy and between potential energy and kinetic energy.
- Describe the major energy forms.

A. Matter is anything that occupies space and has mass.

  1. The mass of an object is equal to the amount of matter in the object.

B. Matter exists in one of three states: solid, liquid, or gas.

C. Energy is the capacity to do work and exists in two forms: kinetic energy (energy of movement) and potential energy (inactive or stored energy).

  1. Energy exists in several forms:

    a. Chemical energy is stored in chemical bonds, such as the bonds in food molecules.

b. Electrical energy results from the movement of charged particles, as when ions move across cell membranes.

c. Mechanical energy is energy directly involved with moving matter; consider legs pedaling a bicycle.

d. Radiant, or electromagnetic, energy is energy that travels in waves; light, for example.

2. Energy is easily converted from one form to another, although some energy is lost to the environment in doing so.

a. Energy conversions in the body release heat.

2.2 The properties of an element depend on the structure of its atoms (pp. 20–24)

Learning Outcomes

- Define chemical element and list the four elements that form the bulk of body matter.
- Define atom. List the subatomic particles, and describe their relative masses, charges, and positions in the atom.
- Define atomic number, atomic mass, atomic weight, isotope, and radioisotope.

Figures and Table

- Figure 2.1 Two models of the structure of a helium atom. (p. 22)
- Figure 2.2 Atomic structure of the three smallest atoms. (p. 23)
- Figure 2.3 Isotopes of hydrogen. (p. 23)
- Table 2.1 Common Elements Composing the Human Body (p. 21)

A. Elements are unique substances that cannot be broken down into simpler substances

1. Four elements—carbon, hydrogen, oxygen, and nitrogen—make up roughly 96% of body weight.
2. Each element is composed of atoms: mostly identical building blocks.
3. There are 118 recognized elements; each is designated by a one- or two-letter abbreviation called the atomic symbol.
4. Each element is composed of identical particles called atoms that give each type of element its unique qualities.

B. Structure of Atoms

1. Each atom has a central nucleus made up of protons and neutrons.

a. Protons have a positive charge, whereas neutrons have no charge, giving the nucleus a net positive charge.

b. Protons and neutrons each weigh 1 atomic mass unit.

2. Electrons occupy random positions within orbitals surrounding the nucleus, have a negative charge, and are weightless, with an atomic mass of zero.

C. Identifying Elements

1. Elements are identified based on their number of protons, neutrons, and electrons.
2. The atomic number of an element is equal to the number of protons of an element; the number of electrons always equals the number of protons.
3. The mass number of an element is equal to the number of protons plus the number of neutrons.
4. Each element has isotopes, structural variations of an atom that have the same number of protons but different numbers of neutrons.
5. The atomic weight of an element is a weighted average of the mass numbers of all known isotopes of an element, based on their relative abundance in nature.
6. Radioisotopes are heavier, unstable isotopes of an element that spontaneously decompose into more stable forms, producing radioactivity.
   a. The time for a radioisotope to lose one-half of its radioactivity is called the half-life.

2.3 Atoms bound together form molecules; different molecules can make mixtures (pp. 24–26)

Learning Outcomes

- Define molecule, and distinguish between a compound and a mixture.
- Compare solutions, colloids, and suspensions.

Figure

- Figure 2.4 The three basic types of mixtures. (p. 25)

A. Molecules and Compounds

1. A combination of two or more atoms is called a molecule.
2. A combination of two or more of the same atoms is a molecule of an element; a combination of two or more different atoms is a molecule of a compound.

B. Mixtures

1. Mixtures consist of two or more substances that are physically mixed.
2. Solutions are homogeneous mixtures of compounds that may be gases, liquids, or solids.
   a. The substance present in the greatest amount (usually a liquid) is called the solvent, while substances dissolved in the solvent are called solutes.

b. Solutions may be described by their concentrations, often expressed as a percent, or molarity.

3. Colloids (emulsions) are heterogeneous mixtures that often appear milky and have larger solute particles that do not settle out of solution.

4. Suspensions are heterogeneous mixtures with large, often visible solutes that will settle out of solution.

C. Distinguishing Mixtures from Compounds

1. In mixtures, no chemical bonding occurs between molecules; they can be separated into their chemical components by physical means and may be heterogeneous.

2. In compounds, chemical bonding is possible between molecules, chemical processes are required to separate the components, and they are only homogenous.

2.4 The three types of chemical bonds are ionic, covalent, and hydrogen (pp. 26–31)

Learning Outcomes

- Explain the role of electrons in chemical bonding and in relation to the octet rule.
- Differentiate among ionic, covalent, and hydrogen bonds.
- Compare and contrast polar and nonpolar compounds.

Figures and Table

- Figure 2.5 Chemically inert and reactive elements. (p. 27)
- Figure 2.6 Formation of ionic bonds. (p. 28)
- Figure 2.7 Formation of covalent bonds. (p. 29)
- Figure 2.8 Carbon dioxide and water molecules have different shapes, as illustrated by molecular models. (p. 30)
- Figure 2.9 Ionic, polar covalent, and nonpolar covalent bonds compared along a continuum. (p. 30)
- Figure 2.10 Hydrogen bonds. (p. 31)
- Table 2.2 Summary: Major Chemical Bond Types (p. 27)

A. A chemical bond is an energy relationship between the electrons of the reacting atoms

1. The Role of Electrons in Chemical Bonding

a. Electrons occupy specific energy levels surrounding the nucleus, and energy level holds a specific number of electrons.

b. Electrons fill energy levels beginning closest to the nucleus and progressing outward.

c. The octet rule, or rule of eights, states that the maximum number of electrons available for bonding in the outer, or valence, shell is eight; except for the first energy shell

Teaching Tip: *Be sure to clarify for students that the type of bond formed will be determined by the overall electron distribution in the atom's outer energy level. Atoms with nearly empty or nearly full valence levels will form ionic bonds, while atoms with about equally full or empty valence levels will form covalent bonds.*

(stable with two electrons), atoms are stable with eight electrons in their outermost (valence) shell.

B. Ionic bonds are chemical bonds that form between two atoms that transfer one or more electrons from one atom to the other.

1. The atom that receives the electron takes on a negative charge and becomes an anion, while the atom that loses the electron acquires a positive charge, becoming a cation.

a. Most ionic compounds form salts and, when dry, form crystals that are held together by ionic bonds.

Teaching Tip: *Students often fail to grasp that a polar covalent bond does not have an actual charge. Explain that for every electron present, there is a proton, so no imbalance in charge exists in the molecule. It is because the entities shared unevenly (electrons) are charged particles that we discuss the bond in terms of relative distribution of charge.*

C. Covalent bonds occur when pairs of atoms share electrons, and atoms may share one, two, or three pairs of electrons, forming single, double, or triple bonds.

1. Covalent bonds may be either nonpolar or polar.

a. Nonpolar molecules have a balanced distribution of the shared electrons' charge across the bond.

b. In polar molecules, electrons are more attracted to one atom (an electronegative atom) than the other (an electropositive atom), resulting in the area of the bond closest to the electronegative atom assuming a partial negative charge, while the area close to the electropositive atom takes on a partial positive charge.

c. A polar molecule is often referred to as a dipole due to the two poles of charges contained in the molecule.

D. Hydrogen bonds are formed when a hydrogen that is covalently bonded to one atom (often oxygen or nitrogen) is attracted to another electronegative atom, forming a sort of "bridge."

1. Hydrogen bonding is responsible for molecular attractions between water molecules that create surface tension.

2. Hydrogen bonds are responsible for stabilizing the three dimensional shapes of large molecules.

2.5 Chemical reactions occur when electrons are shared, gained, or lost (pp. 31–33)

Learning Outcomes

- Define the three major types of chemical reactions: synthesis, decomposition, and exchange. Comment on the nature of oxidation-reduction reactions and their importance.
- Explain why chemical reactions in the body are often irreversible.
- Describe factors that affect chemical reaction rates.

Demonstration: *Use colored beads to show how reactant molecules change in each type of reaction.*

Figure

- Figure 2.11 Types of chemical reactions. (p. 32)

A. A chemical equation describes what happens in a reaction by indicating number and type of reactants, chemical composition of the products, and the relative proportion of each reactant and product (if balanced).

B. Types of Chemical Reactions

1. Synthesis (combination) reactions involve formation of chemical bonds and are the basis of anabolic, or constructive, processes in cells.
2. In a decomposition reaction, a molecule is broken down into smaller molecules by breaking chemical bonds and is a degradative, or catabolic, process.
3. Exchange (displacement) reactions involve both synthesis and decomposition reactions and involve parts of reactants "trading places," forming new products.
4. Oxidation-reduction reactions are special exchange reactions in which electrons are exchanged between reactants: the molecule losing electrons is oxidized, and the molecule receiving the electrons is reduced.
   a. Oxidation-reduction reactions are the basis for all reactions in which food is broken down to produce ATP for cellular energy.

Discussion Point: *Using commonly understood examples, ask students to tell you whether or not these things are exergonic, or endergonic. Glow sticks, melting of ice, or hot and cold packs are good examples to use.*

C. Energy Flow in Chemical Reactions

1. In exergonic reactions (often catabolic or oxidative reactions), energy is released, producing products that have lower potential energy than the reactants, while endergonic reactions (often anabolic reactions) result in products that contain more potential energy than the reactants.

D. Reversibility of Chemical Reactions

1. Reversible reactions are indicated by double arrows pointing in opposite directions.
2. A chemical equilibrium occurs when the rate of the forward reaction equals the rate of the reverse reaction, resulting in no net change in the amount of reactants or products, and is shown by the presence of arrows of equal length in the chemical equation.
3. In the body, chemical reactions are often irreversible because some of the energy released is trapped in other processes, making the necessary input of energy to reverse the reaction unlikely to occur.

E. Factors Influencing the Rate of Chemical Reactions

1. Chemicals react when they collide with enough force to overcome the repulsion by their electrons.
2. An increase in temperature increases the rate of a chemical reaction by increasing the kinetic energy of the molecules.
3. Higher concentrations of reactants result in a faster rate of reaction because the likelihood of collisions between molecules increases.
4. Higher concentrations of reactants result in a faster rate of reaction. Smaller molecules move faster and tend to collide more frequently, increasing the rate of a reaction.

5. Catalysts increase the rate of a chemical reaction without taking part in the reaction.

PART 2: BIOCHEMISTRY

2.6 Inorganic compounds include water, salts, and many acids and bases (pp. 34–37)

Learning Outcomes

- Explain the importance of water and salts to body homeostasis.
- Define acid and base, and explain the concept of pH.

Figures

- Figure 2.12 Dissociation of salt in water. (p. 34)
- Figure 2.13 The pH scale and pH values of representative substances. (p. 36)

A. Water

1. Water is the most important inorganic molecule and makes up 60–80% of the volume of most living cells.
2. Water has a high heat capacity, meaning that it absorbs and releases a great deal of heat before it changes temperature.
3. Water has a high heat of vaporization, meaning that it takes a great deal of energy (heat) to break the bonds between water molecules.
4. Water, called the universal solvent, is a polar molecule that plays a role in dissociation of ionic molecules, forms hydration layers that protect charged molecules from other charged particles, and functions as an important transport medium in the body.
5. Water is an important reactant in many chemical reactions.
6. Water forms a protective cushion around organs of the body.

B. Salts

1. Salts are ionic compounds containing cations other than H^+ and anions other than the hydroxyl (OH^-) ion that dissociate in water into their component ions when dissolved.
2. All ions are electrolytes that conduct electrical currents in solution, an important feature to body functions.

Teaching Tip: *This is a good time to point out to students that, even though discussion will often focus only on cations (such as Na^+, K^+, Ca^{++}) or anions (such as Cl^-) in the body, there are always balanced numbers of both positively charged and negatively charged atoms or molecules.*

C. Acids and Bases

1. Acids, also known as proton donors, have a sour taste and dissociate in water to yield hydrogen ions and anions.
2. Bases, also called proton acceptors, taste bitter, feel slippery, and absorb hydrogen ions.
3. The relative concentration of hydrogen ions is measured in concentration units called pH units.

a. The greater the concentration of hydrogen ions in a solution, the more acidic the solution, and the pH value is lower.
b. The greater the concentration of hydroxyl ions (lower H+ concentration), the more basic, or alkaline, the solution, resulting in a higher pH value.
c. The pH scale extends from 0 to 14. A pH of 7 is neutral; a pH below 7 is acidic; a pH above 7 is basic or alkaline.

4. Neutralization occurs when an acid and a base are mixed together, creating displacement reactions that form a salt and water.

D. Buffers are a combination of a weak acid and weak base that resists large fluctuations in pH that would be damaging to living tissues by releasing H^+ when pH rises and binding up H^+ when pH drops.

Teaching Tip: *Stress that only free hydrogen contributes to the pH of a solution. Hydrogen atoms that are a bound part of a molecule do not affect the pH of the solution. This may also help students more easily understand how a buffer affects pH.*

2.7 Organic compounds are made by dehydration synthesis and broken down by hydrolysis (pp. 37–38)

Learning Outcome

- Explain the role of dehydration synthesis and hydrolysis in forming and breaking down organic molecules.

Figure

- Figure 2.14 Dehydration synthesis and hydrolysis. (p. 38)

A. Carbohydrates, lipids, proteins, and nucleic acids are molecules unique to living systems, and all contain carbon, making them organic compounds.

B. Many biomolecules are macromolecules, large complex molecules consisting of thousands of atoms.

C. Most macromolecules are polymers, chainlike molecules made of many smaller subunits, called monomers, joined by dehydration synthesis.

1. In dehydration synthesis, a hydrogen atom is removed from one monomer and a hydroxyl group is removed from the atom to be paired with, resulting in a covalent bond forming between the monomers and the production of a water molecule from the combination of the hydrogen and hydroxyl.
2. In hydrolysis, a water molecule is used to split the covalent bond between two atoms, in reverse of dehydration synthesis.

Demonstration: *Use "molecules" constructed of colored beads to show how dehydration synthesis and hydrolysis work and to demonstrate the concepts of monomers as subunits of polymers.*

2.8 Carbohydrates provide an easily used energy source for the body (pp. 38–40)

Learning Outcome

- Describe the building blocks, general structure, and biological function of carbohydrates.

Figure and Table

- Figure 2.15 Carbohydrate molecules important to the body. (p. 39)
- Table 2.5 Summary of Monomers and Polymers of Some Organic Molecules (p. 50)

A. Carbohydrates are a group of molecules—classified as either monosaccharides, disaccharides, or polysaccharides—that contain carbon hydrogen and oxygen and include sugars and starches.

B. Monosaccharides are simple sugars, named for the number of carbons they contain, that are single-chain or single-ring structures.

C. Disaccharides are formed when two monosaccharides are joined by dehydration synthesis.

D. Polysaccharides are long chains of monosaccharides linked together by dehydration synthesis; two biologically important polysaccharides are starch and glycogen.

E. In the body, carbohydrates are primarily used as an energy source.

Discussion Point: *Ask students why molecules, such as glycogen and starch, can be made from the same substance, yet be different molecules. Also, ask how polymerization of glucose serves to store energy for the body.*

2.9 Lipids insulate body organs, build cell membranes, and provide stored energy (pp. 40–43)

Learning Outcome

- Describe the building blocks, general structure, and biological functions of lipids.

Figures and Table

- Figure 2.16 Triglycerides consist of glycerol and three fatty acids. (p. 41)
- Figure 2.17 Saturated and unsaturated fatty acids. (p. 42)
- Figure 2.18 Phospholipid structure. (p. 42)
- Figure 2.19 Steroid structure. (p. 43)
- Table 2.3 Representative Lipids Found in the Body (p. 43)

A. Lipids are insoluble in water, but dissolve readily in nonpolar solvents and include triglycerides, phospholipids, steroids, and other lipoid molecules.

B. Triglycerides consist of glycerol (a sugar alcohol) and fatty acids (linear hydrocarbon chains).

1. Triglycerides are found mainly beneath the skin and serve as insulation and mechanical protection.
2. The fatty acids may be either saturated, having only single bonds between adjacent carbons, or unsaturated, bearing at least one double bond between a pair of carbons in the chain.

C. Phospholipids are diglycerides with a phosphorus-containing group and two fatty acid chains that are primarily used to construct cell membranes.

Teaching Tip: *This is a good time to introduce the fact that it is often simply the solubility of a molecule that determines its use and limitations in the body. Students will not, at this point, know how significant this is.*

1. The two fatty acid tails create a nonpolar, hydrophobic region of the molecule that interacts only with other nonpolar molecules.
2. The polar, hydrophilic head region interacts with polar molecules, such as water.

D. Steroids, all deriving from cholesterol, are flat molecules made up of four interlocking hydrocarbon rings and are used in the body in cell membranes and hormones.

E. Eicosanoids are derived from arachidonic acid and function in blood clotting and regulation of blood pressure, inflammation, and labor contractions.

2.10 Proteins are the body's basic structural material and have many vital functions (pp. 43–48)

Learning Outcomes

- Describe the four levels of protein structure.
- Describe enzyme action.

Figures and Table

- Figure 2.20 Examples of protein functions. (p. 44)
- Figure 2.21 Amino acids are linked together by peptide bonds. (p. 45)
- Figure 2.22 Levels of protein structure. (p. 46)
- Figure 2.23 Enzymes lower the activation energy required for a reaction. (p. 48)
- Figure 2.24 Mechanism of enzyme action. (p. 48)
- Table 2.5 Summary of Monomers and Polymers of Some Organic Molecules (p. 50)

A. Proteins are the basic structural material of the body and play vital roles in cell function.

B. Proteins are long chains of amino acids connected by peptide bonds, which join the amine of one amino acid to the acid of the next.

C. The structure of proteins has four structural levels:

1. The linear sequence of amino acids is the primary structure.
2. Proteins twist and turn on themselves to form a more complex secondary structure, either spiraled α-helices or β-pleated sheets.
3. A more complex structure is tertiary structure, resulting from protein folding upon itself to form a ball-like structure.
4. Quaternary structure results from two or more polypeptide chains grouped together to form a complex protein.

Demonstration: *Locate a picture of a ribbon model of a large protein, containing areas with both α–helices (coils) and β–pleating (flat arrows). Show students how a single protein will have areas with both forms and how they transition from one form to another along the strand. Stress the function (either structural strength or flexibility) that each form serves.*

D. Fibrous and Globular Proteins

1. Fibrous proteins are extended, strandlike, insoluble molecules that provide mechanical support and tensile strength to tissues.
2. Globular proteins are compact, spherical, water-soluble, and chemically active molecules that oversee most cellular functions.

Teaching Tip: *Stress that denaturation of a protein is not always destructive. Slight denaturation is used to modulate the activity of some enzymes.*

E. Protein denaturation is a loss of the specific three-dimensional structure of a protein, leading to a potential loss of function that may occur when globular proteins experience changes in environmental factors such as temperature and pH.

F. Enzymes and Enzyme Activity

1. Enzymes are globular proteins that act as biological catalysts, enabling biological processes to happen quickly enough to support life.
2. Enzymes may be purely protein or may consist of two parts, the protein apoenzyme and nonprotein cofactor, collectively called a holoenzyme.
3. Each enzyme is chemically specific, binding only certain substrates, and possesses an active site, the location on the protein that catalyzes the reaction.
4. Enzymes work by lowering the energy required by a reaction, the activation energy.
5. There are three basic steps involved in enzyme action:
   - **a.** Substrates bind to the active site on the enzyme, forming an enzyme-substrate complex.
   - **b.** The enzyme-substrate complex undergoes internal rearrangements that form products.
   - **c.** The enzyme releases the product of the reaction.

2.11 DNA and RNA store, transmit, and help express genetic information (pp. 48–49)

Learning Outcome

- Compare and contrast DNA and RNA.

Figure and Tables

- Figure 2.25 Structure of DNA. (p. 50)
- Table 2.4 Comparison of DNA and RNA (p. 49)
- Table 2.5 Summary of Monomers and Polymers of Some Organic Molecules (p. 50)

A. Nucleic acids have two primary classes: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

B. Roles of DNA and RNA

1. DNA is the genetic material of the cell and is found within the nucleus.

2. DNA has two primary roles: it replicates itself before cell division and provides instructions for making all of the proteins found in the body.
3. RNA is located outside the nucleus and is used to make proteins using the instructions provided by the DNA.
4. There are three major types of RNA that participate in protein synthesis: messenger RNA, ribosomal RNA, and transfer RNA, as well as several types of microRNA.

C. Structure of DNA and RNA
1. Nucleotides are the structural units of nucleic acids, and consist of three components: a nitrogen-containing base, a pentose sugar, and a phosphate group.
2. Five nitrogenous bases are used in nucleic acids: two large, double-ringed purines—adenine (A) and guanine (G)—and three smaller, single-ring pyrimidines—cytosine (C), uracil (U), and thymine (T).
3. DNA is a double-stranded polymer containing the nitrogenous bases adenine, thymine, guanine, and cytosine and the sugar deoxyribose that spiral into a double helix.
    a. Bonding of the nitrogenous bases in DNA occurs between complementary pairs: A bonds to T and G bonds to C.
4. The structure of RNA is a single-stranded polymer containing the nitrogenous bases A, G, C, and U and the sugar ribose.
    a. In RNA, complementary base pairing occurs between G and C and A and U.

Discussion Point: *Ask students what they think the importance of purine-pyrimidine base pairing is. Students rarely have a good understanding of the importance of the uniformity of the strand in managing DNA. This is an opportunity to introduce chromatin versus chromosome.*

2.12 ATP transfers energy to other compounds (pp. 49–51)

Learning Outcome

- Explain the role of ATP in cell metabolism.

Figures

- Figure 2.26 Structure of ATP (adenosine triphosphate). (p. 51)
- Figure 2.27 Three examples of cellular work driven by energy from ATP. (p. 51)

A. ATP is the primary energy transfer molecule used in the cell.
B. ATP is an adenine-containing RNA nucleotide that has two additional phosphate groups attached, connected by high-energy bonds.
C. Energy is transferred from ATP to other systems in cells by removing the terminal phosphate from ATP and binding it to other compounds, a process called phosphorylation.
D. Three examples of cellular work driven by ATP:

Discussion Point: *Ask students why we use molecules with high energy bonds, rather than just using glucose or other biomolecules for energy directly.*

1. Transport work: phosphorylation of transport proteins activates the transporter, which then moves molecules across the membrane.
2. Mechanical work: phosphorylation of contractile proteins allows interactions that result in shortening of the cell.
3. Chemical work: phosphorylation of reactants provides energy to power energy-absorbing reactions.

Cross References

Additional information on topics covered in Chapter 2 can be found in the chapters listed below.

1. Chapter 3: Phospholipids in the composition and construction of membranes; DNA replication and roles of DNA and RNA in protein synthesis; cellular ions; enzymes and proteins in cellular structure and function; hydrogen bonding
2. Chapter 9: Function of ATP in muscle contraction; role of ions in generating muscle cell contraction
3. Chapter 11: ATP, ions, and enzymes in the nervous impulse
4. Chapter 15: Steroid- and amino acid–based hormones
5. Chapter 21: Acid-base balance
6. Chapter 22: Digestive enzyme function; acid function of the digestive system; digestion of proteins, carbohydrates, and lipids
7. Chapter 23: Oxidation-reduction reaction; importance of ions (minerals) in life processes; metabolism of carbohydrates, lipids, and proteins; basic chemistry of life examples
8. Chapter 24: Renal control of electrolytes
9. Chapter 25: Acid-base balance, electrolytes, and buffers; sodium and sodium-potassium pump
10. Appendix E: Periodic Table of the Elements

Recent Discoveries

- Chemists can now create three-dimensional structures that illustrate protein folding.
  New York University. (2017, August 23). Chemists get step closer to replicating nature with assembly of new 3-D structures. *Science Daily*.
- DNA can be used as a coating to protect surfaces from UV radiation.
  Binghamton University. (2017, July 26). New DNA sunscreen gets better the longer you wear it. *Science Daily*.
- DNA robots can be constructed that move molecules from one place to another.

California Institute of Technology. (2017, September 14). Sorting molecules with DNA robots: A DNA nanorobot is programmed to pick up and sort molecules into predefined regions. *Science Daily*.

Additional Lecture Hints

1. Encourage students to spend some time looking at websites and YouTube™ videos to help explain difficult concepts. Be sure to remind students to focus on reputable sites, such as those sponsored by colleges and universities or government agencies.
2. As an alternative to presenting the chemistry in Chapter 2 as a distinct block of material, you could provide the absolute minimum coverage of the topics at this time and expand upon topics later as areas of application are discussed.

Additional Critical Thinking/Discussion Topics

1. How and why can virtually all organisms—plant, animal, and bacteria—use the exact same energy molecule, ATP?
2. Describe how weak bonds can hold large macromolecules together.
3. Why are water molecules at the surface of a drop of water closer together than those in the interior?

Library Research Topics

1. Explore the use of radioisotopes in medicine.
2. Study the mechanisms by which DNA can repair itself.
3. Phospholipids have been used for cell membrane construction by all members of the "cellular" world. What special properties do these molecules have to explain this phenomenon?
4. What are the problems associated with trans fatty acids in the diet? How has awareness of these effects changed our food practices?
5. What advances in science have come out of the sequencing of the human genome (the Human Genome Project)?
6. How has the discovery of micro RNAs changed our understanding of what regulates functions in cells?

Answers to Level 2 and Level 3 End-of-Chapter Questions

Level 1 Remember/Understand answers appear in the Answers Appendix of the main text.

Level 2 Apply/Analyze

13. A deficiency in (a) Fe can be expected to reduce the hemoglobin content of blood. (p. 21)

14. Polar covalent bonds occur when atoms sharing a pair of electrons are of significantly different sizes. Given that chlorine is significantly larger than hydrogen, both (a) and (c) have a bond of this type. (p. 30)

15. Reaction (1) is (a) a synthesis reaction. Reaction (2) is (c) an exchange reaction. (pp. 31–32)

16. The 1:2:1 ratio of carbon, hydrogen, and oxygen indicates that this is a carbohydrate. The six-sided shape indicates that it is (a) a pentose. (p. 38)

17. The molecular mass of aspirin can be calculated as follows: C_9: (9*12 g/mol = 108 g/mol $C_9H_8O_4$) + H_8: (8* 1 g/mol = 8 g/mol $C_9H_8O_4$) + O_4: (4*16 g/mol = 64 g/mol $C_9H_8O_4$) = 180 g/mol $C_9H_8O_4$

The number of moles in 450g of aspirin can be calculated as follows: (450 g/180 g/mol) = 2.5 mol aspirin in 450 g. (p. 25)

18. (p. 33)

(a) A reversible reaction is indicated by a double arrow, each going in the opposite direction, between the reactants and products.

(b) To indicate that a reversible reaction has reached a chemical equilibrium, the double arrows are of equal length, suggesting there is no net movement in one direction over the other.

(c) A chemical equilibrium is a situation in which a reversible reaction has proceeded to the point where there is no net movement between reactants and products. Although molecules continue to move between products and reactants, the movement is equal in both directions.

Level 3 Evaluate/Synthesize

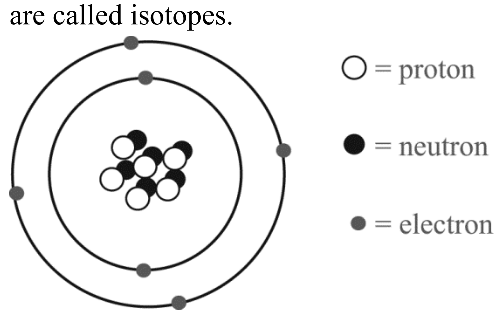
19. (pp. 22–23)

(a) Each of the atoms represented are the same substance, carbon.

(b) Each atom differs in the number of neutrons it possesses. This makes each atom an isotope of carbon. Although they are all carbon, they each possess slightly different qualities.

(c) Atoms of the same substance having different numbers of neutrons are called isotopes.

(d)



20. Hydrogen bonds are weak attractions between covalently bonded hydrogen atoms and neighboring electronegative atoms, such as oxygen or nitrogen. They are important to stabilizing the three-dimensional shape of molecules and creating the surface tension of water (p. 30).

21. Primary protein structure is the genetically determined sequence of amino acids, coded for by the nucleotide sequence of a segment of DNA (a gene).

Secondary protein structure is the specific shapes formed due to the spatial arrangement of the amino acids in the strand. Either α-helices (spirals) or β-pleated sheets (accordion-folded sheets) may be formed.

Tertiary protein structure is the three-dimensional shape formed by the arrangement of the α-helices or β-pleated sheets in a protein. (p. 46)

22. Enzymes bind and correctly orient reactant molecules on specifically shaped binding sites. Then, the active site changes shape, allowing the reactant molecule(s) to be either correctly forced together or broken apart. (p. 47)

23. Water has a high surface tension, that is, the individual molecules of water strongly hydrogen bond with the other around them. This results is a strong attraction that can hold the molecules together, even above the rim of a glass. (p. 30)

24. (p. 47)

(a) Binding to target enzymes can serve to limit the ability of these enzymes to function in the cell. Since the rate of chemical reactions is dependent on enzyme activity, one would expect the rate of activity of enzymes to change.

(b) Depending on the enzymes affected, altering enzyme activity in the bacteria can interfere with its ability to perform the reactions characteristic of the disease process. In the person taking the antibiotic, one would expect little effect, since the target enzymes are often specific to bacterial cells.

25. (p. 37)

(a) pH is a measure of the concentration of free H^+ in a solution. Normal blood pH should be between 7.35 and 7.45.

(b) Severe acidosis is a problem, since the functional proteins that are responsible for our physiological function are affected by changes in pH. The three-dimensional shape of proteins determines the exact function they can perform, and this shape is stabilized by hydrogen bonding. Changes in pH affect the strength of hydrogen bonding, leading to subtle changes in shape of functional proteins. Small changes in pH can have big effects on molecular function, to the point that these molecules do not work as they should.

26. Hyperventilation results in increased loss of CO_2 from the blood to the atmosphere, resulting in a rise in pH. (p. 37)

27. In order to build proteins from the amino acids absorbed from the protein bar, anabolic dehydration synthesis reactions must take place. (p. 32)