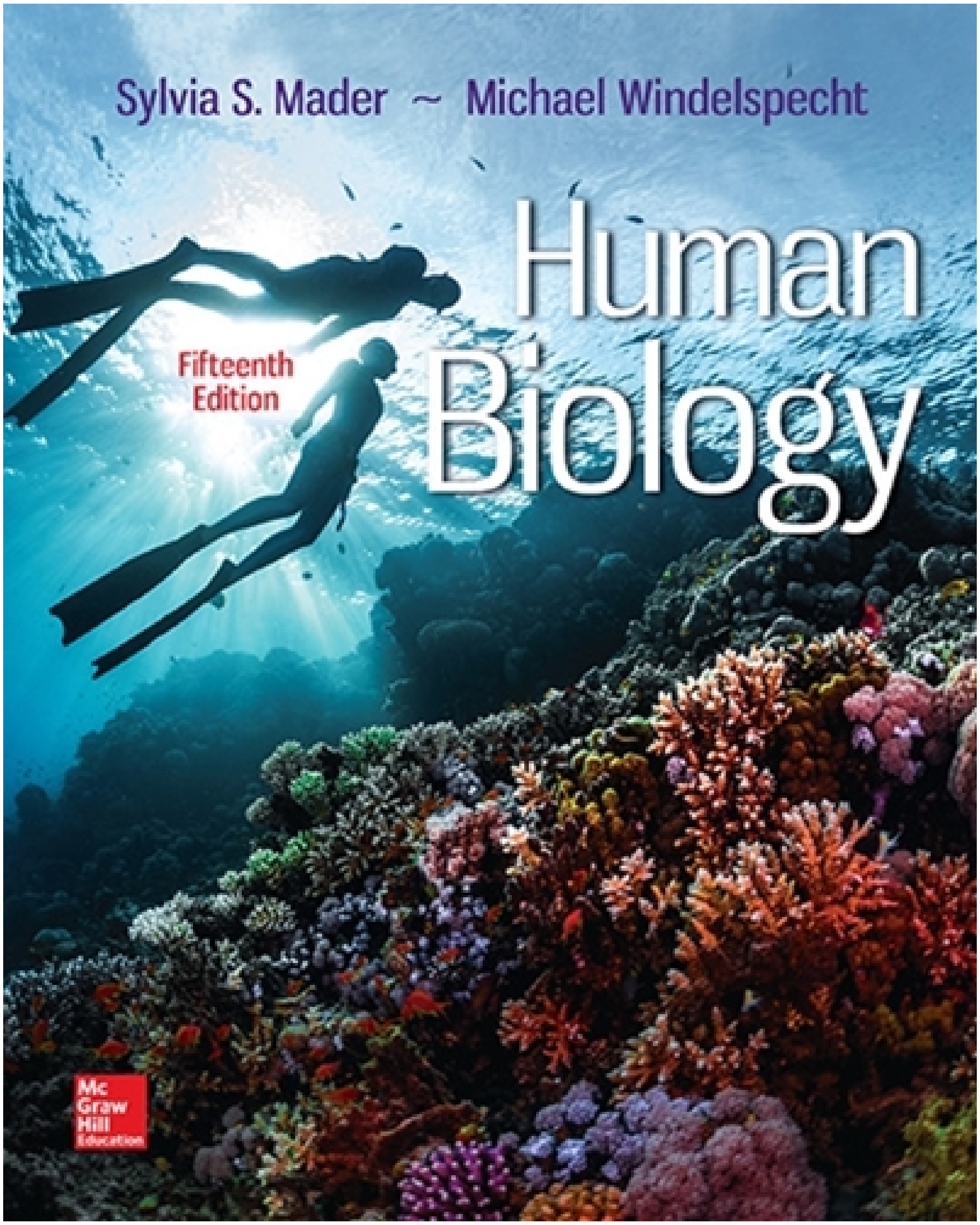
Solutions for Human Biology 15th Edition by Mader



Solutions

CHAPTER 2
CHEMISTRY OF LIFE

LEARNING OUTCOMES

2.1 From Atoms to Molecules
1. Distinguish between atoms and elements.
2. Describe the structure of an atom.
3. Define an isotope and summarize its application in both medicine and biology.
4. Distinguish between ionic and covalent bonds.

2.2 Water and Life
1. Describe the general process of the scientific method.
2. Explain the role of hydrogen bonds in the properties of water.
3. Summarize the structure of the pH scale and the importance of buffers to biological systems.

2.3 Molecules of Life
1. List the four classes of organic molecules that are found in cells.
2. Describe the processes by which the organic molecules are assembled and disassembled.

2.4 Carbohydrates
1. Summarize the basic chemical properties of a carbohydrate.
2. State the roles of carbohydrates in human physiology.
3. Compare the structures of simple and complex carbohydrates.
4. Explain the importance of fiber in the diet.

2.5 Lipids
1. Compare the structures of fats, phospholipids, and steroids.
2. State the function of each class of lipids.

2.6 Proteins
1. Describe the structure of an amino acid.
2. Explain how amino acids are combined to form proteins.
3. Summarize the four levels of protein structure.

2.7 Nucleic Acids
1. Explain the difference between RNA and DNA.
2. Summarize the role of ATP in cellular reactions.

EXTENDED LECTURE OUTLINE

2.1 From Atoms to Molecules
Matter refers to anything that takes up space and has mass.

Elements

All matter is composed of elements, 92 of which occur naturally. Every element has a name and symbol.

Atoms

Matter is composed of atoms that contain the subatomic particles. Positively charged protons and neutral neutrons occupy the nucleus of the atom, with negatively charged electrons in orbit about the nucleus. The atomic number is equal to the number of protons and, therefore, the number of electrons in an electrically neutral atom. The atomic weight equals the number of protons plus the number of neutrons.

The Periodic Table (Figure 2.1 on page 20 of the text)

In the periodic table of elements, the number on the top of each square is the atomic number. The letter symbols represent each element. Below the symbol is the value for atomic mass. A complete periodic table is located in Appendix A.

Isotopes

Isotopes are atoms that have the same atomic number but differ in the number of neutrons. Most isotopes are stable, but some emit radiation.

Low Levels of Radiation

A radioactive isotope behaves the same as a stable isotope of the same element. Many medical uses of radioactive isotopes that emit low levels of radiation have been found.

High Levels of Radiation

High levels of radiation can harm cells, damage DNA, and cause cancer. Accidents at nuclear power plants can have long-ranging effects.

Molecules and Compounds

Atoms bond with each other to form molecules. If the atoms come from different elements, the molecule is a compound.

Ionic Bonding

During an ionic reaction, certain atoms give up and others receive electrons to achieve a stable outer shell. The resulting oppositely charged ions (charged particles) are attracted to each other, forming an ionic bond.

Covalent Bonding

Following a covalent reaction, atoms share pairs of electrons within a covalent bond in order to achieve a stable outer shell.

Double and Triple Bonds

In addition to single bonds, double and triple bonds are also possible in some molecules.

Structural and Molecular Formulas

Covalent bonds can be represented in a number of ways, including structural and molecular formulas.

2.2 Water and Life

Life as we know it would be impossible without water, which comprises 60–70% of total body weight. Water molecules are polar: the oxygen end has a slight negative charge and the hydrogen end has a slight positive charge.

Hydrogen Bonds

Hydrogen bonds occur when a covalently bonded, slightly positively charged hydrogen atom is attracted to a negatively charged atom in the vicinity.

Properties of Water

Due to its polarity and/or hydrogen bonding, water is a liquid at room temperature, loses and gains heat slowly, has a high heat of vaporization, is less dense when frozen, fills vessels, and is the universal solvent. These properties are necessary to life.

Water Has a High Heat Capacity

Water holds onto its heat. Its temperature falls and rises more slowly than that of other liquids.

Water Has a High Heat of Evaporation

Since hydrogen bonds must be broken when water boils, our bodies can release excess body heat in a hot environment.

Water Is a Solvent

Due to its polarity, water facilitates chemical reactions.

Water Molecules Are Cohesive and Adhesive

Cohesion refers to the ability of water molecules to cling to one another, and adhesion refers to the ability of water molecules to cling to other polar surfaces. These properties are due to hydrogen bonding.

Frozen Water Is Less Dense Than Liquid Water

As liquid water cools, the molecules come closer together. Below $4^{\circ}C$, hydrogen bonding becomes more open, meaning that water expands and is why ice floats on liquid water.

Acids and Bases

Water dissociates into an equal number of hydrogen and hydroxide ions.

Acidic Solutions (High H^+ Concentrations)

Acids release hydrogen ions. Compared to water, acidic solutions have more hydrogen ions than hydroxide ions.

Basic Solutions (Low H^+ Concentrations)

Bases take up hydrogen ions or release hydroxide ions. Compared to water, basic solutions have more hydroxide ions than hydrogen ions.

pH Scale

The pH scale is used to indicate the acidity or basicity of a solution. The scale ranges from 0 to 14 with 7 being neutral. Acids have a pH lower than 7, and bases have a pH higher than 7.

Buffers

Buffers are mechanisms that help keep pH within normal limits by taking up excess hydrogen ions or hydroxide ions. Maintaining pH within a narrow range is important to health.

2.3 Molecules of Life

Four categories of organic molecules—carbohydrates, lipids, proteins, and nucleic acids—are unique to cells. Large organic molecules (macromolecules) are polymers, which are formed when monomers join together through a dehydration reaction (synthesis). They can be broken down by a hydrolysis reaction (degradation).

2.4 Carbohydrates

Carbohydrates contain the grouping H—C—OH, in which the ratio of hydrogen atoms to oxygen atoms is approximately 2:1. Carbohydrates serve as an energy source for cells.

Simple Carbohydrates: Monosaccharides

Monosaccharides have a low number of carbon atoms; a pentose has five carbon atoms and a hexose has six carbon atoms. Glucose provides a ready source of energy for cells.

Disaccharides

Disaccharides are made by the joining of two monosaccharides in a dehydration reaction. Lactose is the disaccharide found in milk.

Complex Carbohydrates: Polysaccharides

Carbohydrate macromolecules are called polysaccharides. Polysaccharides such as starch (fewer side branches) and glycogen are polymers of glucose molecules. Cellulose, a polysaccharide found in plant cell walls, is commonly called fiber. The linkages joining glucose units cannot be digested, and, therefore, cellulose adds bulk that passes through our digestive system as fiber.

2.5 Lipids

Lipids are hydrophobic and do not dissolve in water. They function in the storage of energy.

Triglycerides: Fats and Oils

Solid fats of animal origin and liquid oils of plant origin are both composed of glycerol bonded to three fatty acids. Fats and oils are a long-term energy source for organisms. Emulsifiers cause fat droplets to disperse in water because a nonpolar end projects into a fat droplet, and a polar end projects outward to interact with water.

Saturated, Unsaturated, and Trans Fatty Acids

Saturated fatty acids have no double bonds, and unsaturated fatty acids do have double bonds between carbon atoms. Saturated fats are associated with cardiovascular disease. Even more harmful than naturally occurring saturated fats are the so-called trans fats, which are in vegetable oils that have been partially hydrogenated to make them semisolid.

Dietary Fat

The diet should contain some fat. The total recommended amount of fat in a 2,000-calorie diet is 65 grams.

Phospholipids

Phospholipids, which have a polar phosphate group instead of a third fatty acid, are the primary constituent of the plasma membrane bilayer. The nonpolar tails face one another, and the polar ends face the external environment.

Steroids

Steroid molecules have a backbone of four fused carbon rings that differ according to the functional groups attached to the rings. Cholesterol and sex hormones are steroids.

2.6 Proteins

Proteins are of primary importance in the structure and function of cells. Some of their functions include: support, enzymes, transport, defense, hormones, and motion.

Amino Acids: Subunits of Proteins

An amino acid contains an amine group, an acid group, and an *R* (remainder) group that distinguishes the 20 different amino acids in cells.

Peptides
Amino acids are joined by a linkage called a peptide bond. Three or four amino acids linked together are called a polypeptide.
Shape of Proteins
The final shape of a protein is important to its function. When proteins are exposed to extremes in heat and pH, they undergo an irreversible change in shape called denaturation, which destroys the proteins' ability to function.
Levels of Protein Organization
The primary structure of a polypeptide is the sequence of amino acids. The secondary structure is an alpha helix or a pleated sheet. The tertiary, globular shape is due to interactions between the *R* groups. A quaternary structure occurs if there is more than one polypeptide.

2.7 Nucleic Acids

The two types of nucleic acids are DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). Each DNA molecule contains many genes, and genes specify the sequence of the amino acids in proteins. RNA is the intermediary that conveys DNA's instructions regarding the amino acid sequence in a protein.
How the Structures of DNA and RNA Differ
Both DNA and RNA are polymers of nucleotides.
Nucleotide Structure
A nucleotide contains phosphate, a pentose sugar, and a nitrogen-containing base. The bases in DNA are adenine, thymine, cytosine, and guanine. In RNA, uracil replaces thymine.
DNA and RNA Structure
DNA is a double helix—if unwound, its structure resembles a stepladder. Phosphate and the pentose sugar make up the sides of the ladder, and the hydrogen-bonded bases are the rungs. RNA is single-stranded and is complementary to one DNA strand.
ATP: An Energy Carrier
ATP is a nucleotide that has been modified by the addition of three phosphate groups. It functions as an energy carrier in cells.
Structure of ATP Suits Its Function
ATP is a high-energy molecule because the last two phosphate bonds are unstable and easily broken. The energy released by ATP breakdown is used by the cells for various functions.

STUDENT ACTIVITIES

pH Measurements
1. Students should research the topic of acid rain on the Internet before coming to class. They should also collect and bring in water samples from their dorm faucets, drinking fountains, rainwater, snow, or a nearby pond or stream. Have pH paper or a pH meter available in class to determine the pH of these samples. Discuss the known or potential effects of acid rain in your particular geographic location, which might include: effects on forests (including interruption of the symbiotic association between trees and their mycorrhizae), depletion of fisheries in lakes, or deterioration of car finishes and statues.
2. Bring in various types of colas and coffee. Have pH paper or a pH meter available in class to determine the pH of these beverages. How acidic are these? Discuss why you can drink such acidic beverages and not damage your stomach.

What Are You Eating?
3. Ask students to bring in one food label from a processed food they normally consume. Does it have added sugar? Where is sugar in the list of ingredients? (Ingredients are listed in order from the most abundant to the least abundant.) What other terms (such as corn syrup) could be used on the nutrition label instead of sugar?
4. Ask students to keep a food log of everything they eat for 24 hours. Using a calorie/fat counter or the nutritional label on the food, determine how many grams of fat and how many calories they consumed in one day. Convert the grams of fat into calories by multiplying by nine. What percentage of their total dietary calories was made up of fat? What is the recommended amount?

Jobs for Chemists

5. Have a chemistry professor, graduate student, technician, or chemist from your town water treatment facility talk to your students about the job opportunities available to those with a background in chemistry.

CLASSROOM DISCUSSION TOPICS

1. Ask someone who is a diabetic to come to class and describe their disease and its management. Discuss the dietary changes that are necessary to control diabetes.
2. Liken the primary structure of a protein to beads on a string. Describe how the primary structure helps determine the secondary structure. Discuss how certain diseases, such as sickle-cell anemia or cystic fibrosis, result from a change in the primary sequence of a protein. Why does one amino acid change result in so many symptoms?
3. Of the four organic molecules discussed in this section (carbohydrates, lipids, proteins, and nucleic acids), why are nucleic acids the best suited to store and transmit information? What properties of DNA allow these particular functions?
4. Ask the students to explain the difference between a period and a group using the periodic table (Figure 2.1 on page 20 of the text and Appendix A).