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AP Biology

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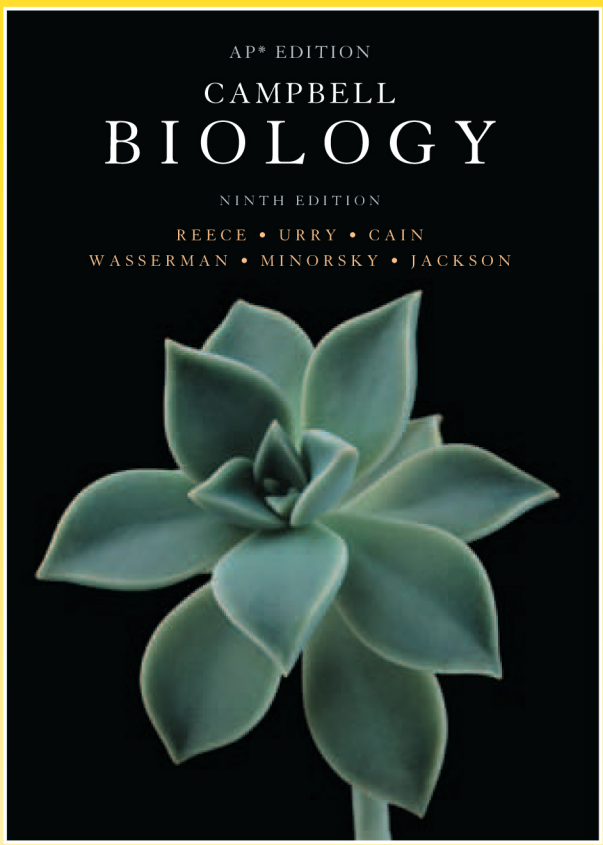

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NEW! Revised for the 2013 AP Biology Exam!

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Fred W. Holtzclaw
Theresa Knapp Holtzclaw

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by Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, and Robert B. Jackson

Campbell Biology: Concepts & Connections, Seventh Edition
by Jane B. Reece, Martha R. Taylor, Eric J. Simon, and Jean L. Dickey

Biology: Exploring Life, First Edition
By Neil A. Campbell, Brad Williamson, and Robin J. Heyden

Essential Biology with Physiology, Second Edition
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About Your Pearson AP* Guide

Pearson Education is the leading education solution provider worldwide. With operations on every continent, we make it our business to understand the changing needs of students at every level, from kindergarten to college. We think that makes us especially qualified to offer this series of AP* Test Prep workbooks, tied to some of our best-selling programs.

Our reasoning is that as you study for your course, you're preparing along the way for the AP Exam. If you can connect the material in the book directly to the exam, it makes the material that much more relevant, and enables you to focus your time most efficiently. And that's a good thing!

The AP Exam is an important milestone in your education. A high score means you're in a better position for college acceptance, and possibly puts you a step ahead with college credits. Our goal is to provide you with the tools you need to succeed.

Good luck!

Revisions to This Edition

Part I: *Introduction to the AP Biology Examination*

- The introduction is now aligned with the new Curriculum Framework (CF) that launches in the 2012–2013 school year.
- An outline of the new CF is included and its organization is explained.
- The science practices that will be tested are introduced.
- A revised topic correlation shows how concepts in *Campbell Biology* correspond to the new CF.
- The description of the exam and the testing hints are revised to reflect the changes in the course beginning with the 2013 exam.

Part II: *A Review of Topics with Sample Questions*

- You Must Know boxes have been edited to reflect the change in emphasis of the new CF.
- New boxes titled What's Important to Know? are scattered throughout the content areas to remind students of the types of questions they might be asked. These often focus on science practices, which is an emphasis of the new course.
- Content that is no longer relevant to the exam has been removed, or notes have been added to make it explicit whether material reflects illustrative examples or is required content.
- New test questions have been added to each topic to reflect changes that will be seen on the exam beginning in 2013. This includes questions that require interpretation of data or application of knowledge.

Part III: *The Laboratory*

- The 12 classic labs in the 2001 AP Biology Laboratory Manual have been modified or replaced. The College Board has released a new group of laboratory investigations, and so this section has been heavily revised to reflect these changes.
- The new CF asks students to be able to apply mathematics to a variety of topics. A sheet of formulas will be supplied to them on the exam. This is included in this revised edition, along with a number of tutorials and problems that take students through sample mathematical applications.
- New boxes titled Science Practices: Can You. . . have been added to focus students on making connections and applying science practices.

Part IV: *Sample Test*

- The format of the exam is changing beginning in 2012–2013. The sample test more accurately reflects the types of questions students may encounter. It will be very important for students to practice with these types of questions throughout the year.
- Grid-in questions are included in the sample test. Students will be expected to have a calculator for the new exam and provide numerical responses with a grid-in system.
- Free-response questions will be of varying lengths. The sample test follows this new format.

Part V: *Answers and Explanations*

- The format of this section remains similar to past editions, but some explanations focus on science practices and applications.

Part II

A Review of Topics with Sample Questions

Part II is keyed to *Campbell Biology*, Ninth Edition, by Reece et al. It gives an overview of important information and provides sample multiple-choice and free-response questions. The necessary content is included in the bulleted information, but you will need to rely on sample questions and your teacher's instruction to reinforce the science practices. Answers and explanations can be found in Part V. Use the summary of key concepts section at the end of each chapter in your textbook before attempting the practice questions. Be sure to review the answers thoroughly to prepare yourself for the range of questions you will encounter on the AP Biology Examination.

TOPIC 1

The Chemistry of Life

Chapter 2: The Chemical Context of Life

WHAT'S IMPORTANT TO KNOW?
This chapter is considered prior knowledge for the AP Biology Examination. However, you will need to know this information to proceed with the required topics, so we include what is most important in this area.

YOU MUST KNOW

- The three subatomic particles and their significance.
- The types of chemical bonds, how they form, and their relative strengths.

Concept 2.1 Matter consists of chemical elements in pure form and in combinations called compounds

- **Matter** is anything that takes up space and has mass.
- An **element** is a substance that cannot be broken down to other substances by chemical reactions. *Examples*: gold, copper, carbon, and oxygen.
- A **compound** is a substance consisting of two or more elements combined in a fixed ratio. *Examples*: water (H_2O) and table salt (NaCl).
- **C, H, O, N** make up 96% of living matter. About 25 of the 92 natural elements are known to be essential to life.
- **Trace elements** are those required by an organism in only minute quantities. *Examples*: iron and iodine.

Concept 2.2 An element's properties depend on the structure of its atoms

- **Atoms** are the smallest unit of an element that still retains the property of the element. Atoms are made up of neutrons, protons, and electrons.
- **Protons** are positively charged particles. They are found in the nucleus and determine the element.
- **Electrons** are negatively charged particles that are found in electron shells around the nucleus. They determine the chemical properties and reactivity of the element.
- **Neutrons** are particles with no charge. They are found in the nucleus. Their number can vary in the same element, resulting in isotopes.

- **Isotopes** are forms of an element with differing numbers of neutrons. Example: ^{12}C and ^{14}C are isotopes of carbon. Both have 6 protons, but ^{12}C has 6 neutrons whereas ^{14}C has 8 neutrons.
- The **atomic number** is the number of protons an element possesses. This number is unique to every element. (See Figure 1.1.)
- The **mass number** of an element is the sum of its protons and neutrons.

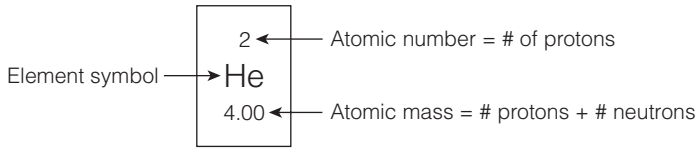


Figure 1.1 An element of the periodic table

Concept 2.3 The formation and function of molecules depend on chemical bonding between atoms

- **Chemical bonds** are defined as interactions between the valence electrons of different atoms. Atoms are held together by chemical bonds to form molecules.
- A **covalent bond** occurs when valence electrons are shared by two atoms.
  - **Nonpolar covalent bonds** occur when the electrons being shared are shared equally between the two atoms. *Examples*: O=O, H−H.
  - Atoms vary in their *electronegativity*, a tendency to attract electrons of a covalent bond. Oxygen is strongly electronegative.
  - In **polar covalent bonds**, one atom has greater electronegativity than the other, resulting in an unequal sharing of the electrons. *Example*: Refer to Figure 1.2 and note that within each molecule of H_2O the electrons are shared unequally, resulting in the region of the oxygen atom being slightly negative, whereas the regions about the hydrogen atoms are slightly positive.

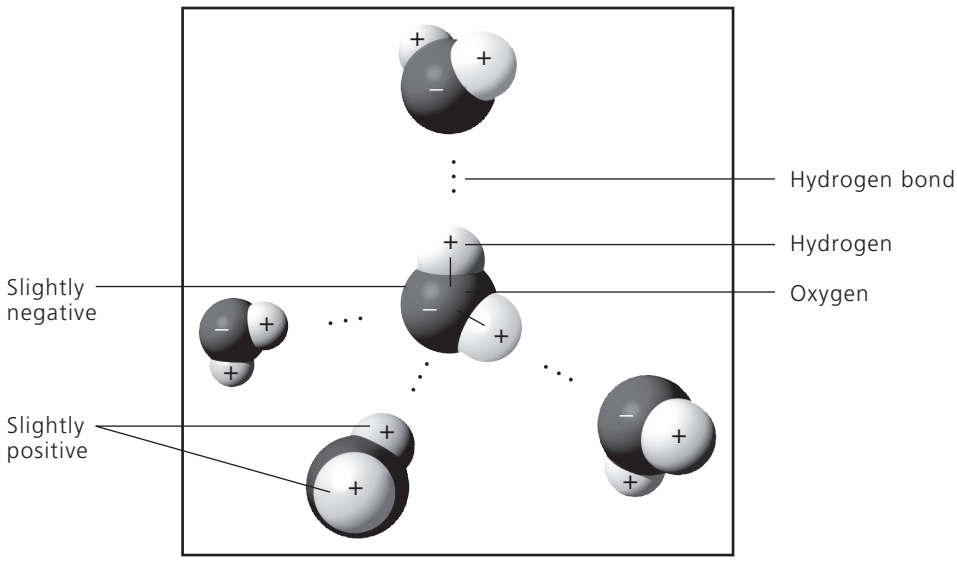


Figure 1.2 Hydrogen bonds between water molecules

- **Ionic bonds** are ones in which two atoms attract valence electrons so unequally that the more electronegative atom steals the electron away from the less electronegative atom.
  - An **ion** is the resulting charged atom or molecule.
  - **Ionic bonds** occur because these ions will be either positively or negatively charged, and will be attracted to each other by these opposite charges.
- **Hydrogen bonds** are relatively weak bonds that form between the partial positively charged hydrogen atom of one molecule and the strongly electronegative oxygen or nitrogen of *another* molecule.
- **Van der Waals interactions** are very weak, transient connections that are the result of asymmetrical distribution of electrons within a molecule. These weak interactions contribute to the three-dimensional shape of molecules.

Concept 2.4 Chemical reactions make and break chemical bonds

- A **chemical reaction** shows the **reactants**, which are the starting materials, an arrow to indicate their conversion into the **products**, the ending materials. *Example*: $6\ CO_2 + 6\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2$.
- The chemical reaction above also shows the number of molecules involved. This is the coefficient in front of each molecule. You will note that the number of atoms of each element is the same on each side of the reaction.
- Some chemical reactions are reversible, which is indicated with a double-headed arrow: $3\ H_2 + N_2 \rightleftharpoons 2\ NH_3$.
- **Chemical equilibrium** is the point at which the forward and reverse reactions offset one another exactly. Their concentrations have stabilized at a particular ratio, though they are not necessarily equal.

Chapter 3: Water and Life

YOU MUST KNOW

- The importance of hydrogen bonding to the properties of water.
- Four unique properties of water, and how each contributes to life on Earth.
- How to interpret the pH scale.
- How changes in pH can alter biological systems.
- The importance of buffers in biological systems.

Concept 3.1 Polar covalent bonds in water molecules result in hydrogen bonding

- The **structure of water** is the key to its special properties. Water is made up of one atom of oxygen and two atoms of hydrogen, bonded to form a molecule.
- Water molecules are **polar**. The oxygen region of the molecule has a partial negative charge, and each hydrogen has a partial positive charge.

- **Hydrogen bonds** form between water molecules. The slightly negative oxygen atom from one water molecule is attracted to the slightly positive hydrogen end of *another* water molecule.
- Each water molecule can form a maximum of four hydrogen bonds at a time.

Concept 3.2 Four emergent properties of water contribute to Earth's suitability for life

- **Hydrogen bonds** are the key to each of these properties. This is what makes water so unique.

1. **Cohesion.** Cohesion is the linking of like molecules. Think "water molecule joined to water molecule" and visualize a water strider walking on top of a pond due to the *surface tension* that is the result of this property.
    - **Adhesion** is the clinging of one substance to another. Think "water molecule attached to some other molecule" such as water droplets adhering to a glass windshield.
    - **Transpiration** is the movement of water molecules up the very thin xylem tubes and their evaporation from the stomata in plants. The water molecules cling to each other by *cohesion*, and to the walls of the xylem tubes by *adhesion*.
2. Moderation of temperature is possible because of water's high specific heat.
    - **Specific heat** is the amount of heat required to raise or lower the temperature of a substance by 1°C. Relative to most other materials, the temperature of water changes less when a given amount of heat is lost or absorbed. This high specific heat makes the temperature of Earth's oceans relatively stable and able to support vast quantities of both plant and animal life.
3. Insulation of bodies of water by floating ice.
    - Water is less dense as a solid than in its liquid state, whereas the opposite is true of most other substances. Because ice is less dense than liquid water, ice floats. This keeps large bodies of water from freezing solid and therefore moderates temperature.
4. Water is an important *solvent*. (The substance that something is dissolved in is called the *solvent*, whereas the substance being dissolved is the *solute*. Together they are called the *solution*.)
    - **Hydrophilic** substances are water-soluble. These include ionic compounds, polar molecules (e.g., sugars), and some proteins.
    - **Hydrophobic** substances such as oils are nonpolar and do not dissolve in water.

Concept 3.3 Acidic and basic conditions affect living organisms

- The **pH** scale runs between 0 and 14 and measures the relative acidity and alkalinity of aqueous solutions. (See Figure 1.3.)

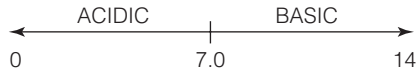


Figure 1.3 pH scale

- **Acids** have an excess of H^+ ions and a pH below 7.0. $[H^+] > [OH^-]$
- **Bases** have an excess of OH^- ions, and pH above 7.0. $[H^+] < [OH^-]$
- Pure water is neutral, which means it has a pH of 7. $[H^+] = [OH^-]$
- **Buffers** are substances that minimize changes in pH. They accept H^+ from solution when they are in excess and donate H^+ when they are depleted.
- **Carbonic acid (H_2CO_3)** is an important buffer in living systems. It moderates pH changes in blood plasma and the ocean.

Chapter 4: Carbon and the Molecular Diversity of Life

YOU MUST KNOW

- The properties of carbon that make it so important.

Concept 4.1 Organic chemistry is the study of carbon compounds

- The major elements of life are C, H, O, N, S, and P, sometimes recalled with the acronym for a person's name: ***P.S. COHN***.
- All ***organic compounds*** contain carbon, and most also contain hydrogen.
- Once thought to be made only in living cells, artificial synthesis of organic compounds is possible. A classic experiment done by Stanley Miller in 1953 showed that complex organic molecules could arise spontaneously. See the figure in your text, and note the conditions and compounds that might have been part of the early conditions on Earth.

Concept 4.2 Carbon atoms can form diverse molecules by bonding to four other atoms

- Carbon is unparalleled in its ability to form molecules that are large, complex, and diverse. Why?
  - It has 4 valence electrons.
  - It can form up to 4 covalent bonds.
  - These can be single, double, or triple covalent bonds.
  - It can form large molecules.
  - These molecules can be chains, ring-shaped, or branched.
- **Isomers** are molecules that have the same molecular formula but differ in their arrangement of these atoms. These differences can result in molecules that are very different in their biological activities. *Examples*: glucose and fructose (both have the molecular formula of $C_6H_{12}O_6$).

Concept 4.3 A few chemical groups are key to the functioning of biological molecules

- **Functional groups** attached to the carbon skeleton have diverse properties. The behavior of organic molecules is dependent on the identity of their functional groups.
- Some common functional groups are listed below:

Functional Group Name/Structure	Organic Molecules with the Functional Group and Items of Note about Functional Group
Hydroxyl, —OH	Alcohols such as ethanol, methanol; helps dissolve molecules such as sugars
Carboxyl, —COOH	Carboxylic acids such as fatty acids and sugars; acidic properties because it tends to ionize; source of H^+ ions
Carbonyl, >CO	Ketones and aldehydes such as sugars
Amino, —NH_2	Amines such as amino acids
Phosphate, PO_3	Organic phosphates, including ATP, DNA, and phospholipids
Sulfhydryl, —SH	This group is found in some amino acids; forms disulfide bridges in proteins
Methyl, —CH_3	Addition of a methyl group affects expression of genes

Chapter 5: The Structure and Function of Large Biological Molecules

YOU MUST KNOW

- The role of **dehydration reactions** in the formation of organic compounds and **hydrolysis** in the digestion of organic compounds.
- How to recognize the four biologically important organic compounds (carbohydrates, lipids, proteins, and nucleic acids) by their structural formulas.
- The cellular functions of the four groups of organic compounds.
- The four structural levels of proteins and how changes at any level can affect the activity of the protein.
- How proteins reach their final shape **(conformation)**, the **denaturing** impact that heat and pH can have on protein structure, and how these changes may affect the organism.

Concept 5.1 Macromolecules are polymers, built from monomers

- **Polymers** are long chain molecules made of repeating subunits called **monomers**. *Examples*: Starch is a polymer composed of glucose monomers. Proteins are polymers composed of amino acid monomers. (See Figure 1.4.)

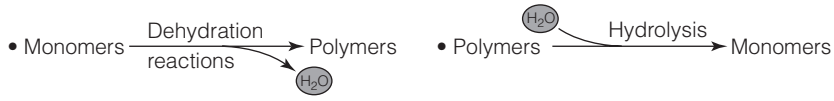


Figure 1.4 Synthesis and breakdown of polymers

- **Dehydration reactions** create polymers from monomers. Two monomers are joined by removing one molecule of water. *Example*: $C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow H_{22}O_{11} + H_2O$.
- **Hydrolysis** occurs when water is added to split large molecules. This occurs in the reverse of the above reaction.

Concept 5.2 Carbohydrates serve as fuel and building material

- **Carbohydrates** include both simple sugars (glucose, fructose, galactose, etc.) and polymers such as starch made from these and other subunits. All carbohydrates exist in a ratio of 1 carbon: 2 hydrogen: 1 oxygen or CH_2O.
- **Monosaccharides** are the monomers of carbohydrates. *Examples*: glucose ($C_6H_{12}O_6$) and ribose ($C_5H_{10}O_5$). Notice the 1:2:1 ratio discussed above.
- **Polysaccharides** are polymers of monosaccharides. *Examples*: starch, cellulose, and glycogen.
- Two functions of polysaccharides are **energy storage** and **structural support**.

1. **Energy-storage polysaccharides**
   - **Starch** is a storage polysaccharide found in plants (e.g., potatoes).
   - **Glycogen** is a storage polysaccharide found in animals, vertebrate muscle cells, and liver cells.
2. **Structural support polysaccharides**
   - **Cellulose** is a major component of plant cell walls.
   - **Chitin** is found in the exoskeleton of arthropods, such as lobsters and insects and the cell walls of fungi. It gives cockroaches their "crunch."

Concept 5.3 Lipids are a diverse group of hydrophobic molecules

- Lipids are all **hydrophobic**. They aren't polymers, as they are assembled from a variety of components. *Examples*: **waxes, oils, fats,** and **steroids**.
- **Fats** (also called triglycerides) are made up of a **glycerol** molecule and three **fatty acid** molecules.
- **Fatty acids** include hydrocarbon chains of variable lengths. These chains are nonpolar and therefore hydrophobic.
  - **Saturated fatty acids**
    - have no double bonds between carbons
    - tend to pack solidly at room temperature
    - are linked to cardiovascular disease
    - are commonly produced by animals
    - *Examples*: butter and lard
  - **Unsaturated fatty acids**
    - have some C=C (carbon double bonds); this results in kinks
    - tend to be liquid at room temperature

- are commonly produced by plants
- *Examples*: corn oil and olive oil

- **Functions of lipids**
  - *Energy storage*. Fats store twice as many calories/gram as carbohydrates!
  - *Protection* of vital organs and *insulation*. In humans and other mammals, fat is stored in **adipose cells**.
- **Phospholipids** make up cell membranes. They
  - have a glycerol backbone (head), which is hydrophilic.
  - have two fatty acid tails, which are hydrophobic.
  - are arranged in a bilayer in forming the cell membrane, with the hydrophilic heads pointing toward the watery cytosol or extracellular environment, and hydrophobic tails sandwiched in between (see Figure 1.5).

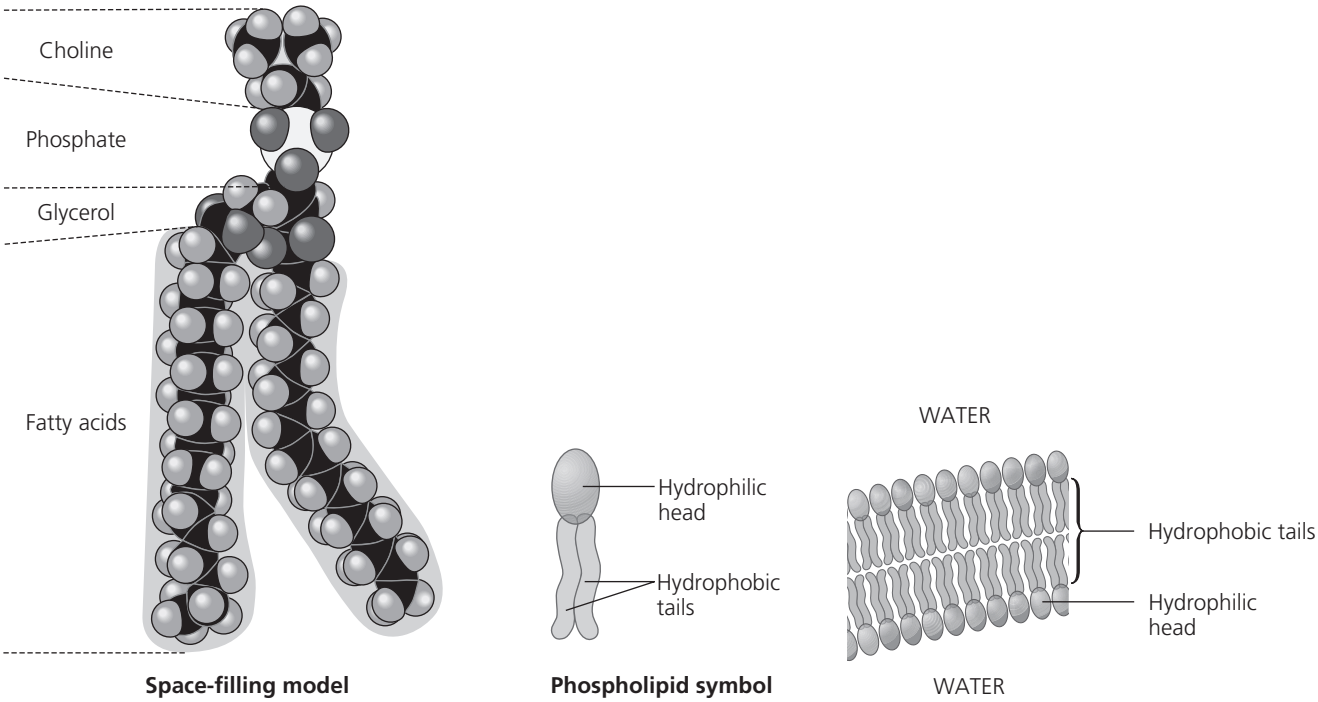


Figure 1.5 The structure of a phospholipid

- **Steroids** are made up of four rings that are fused together.
  - **Cholesterol** is a steroid. It is a common component of cell membranes.
  - **Estrogen** and **testosterone** are steroid hormones.

Concept 5.4 Proteins include a diversity of structures, resulting in a wide range of functions

- **Proteins** are polymers made up of amino acid monomers.
- **Amino acids** contain a central carbon bonded to a carboxyl group, an amino group, a hydrogen atom, and an R group (variable group or side chain). (See Figure 1.6.)

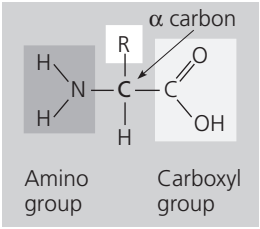


Figure 1.6 The structure of an amino acid

- **Peptide bonds** link amino acids. They are formed by dehydration synthesis.
- **There are four levels of protein structure** (see Figure 1.7):
  - **Primary structure** is the unique sequence in which amino acids are joined.
  - **Secondary structure** refers to one of two three-dimensional shapes that are the result of hydrogen bonding.
    - **Alpha (α) helix** is a coiled shape, much like a slinky.
    - **Beta (β) pleated sheet** is an accordion shape.
  - **Tertiary structure** results in a complex globular shape, due to interactions between R groups, such as hydrophobic interactions, van der Waals interactions, hydrogen bonds, and disulfide bridges.
    - Globular proteins such as enzymes are held in position by these R group interactions.
  - **Quaternary structure** refers to the association of two or more polypeptide chains into one large protein. Hemoglobin is a globular protein with quaternary structure, as it is composed of four chains.

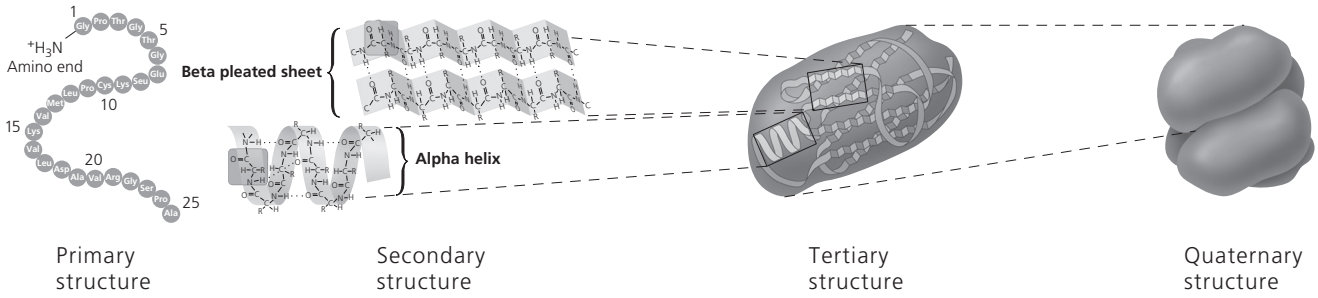


Figure 1.7 Levels of protein structure

- **Protein shape is crucial to protein function.** When a protein does not fold properly, its function is changed. This can be the result of a single amino acid substitution, such as that seen in the abnormal hemoglobin typical of sickle-cell disease.
- **Chaperonins** are protein molecules that assist in the proper folding of proteins within cells. They provide an isolating environment in which a polypeptide chain may attain final conformation.
- A protein is **denatured** when it loses its shape and ability to function due to **heat**, a **change in pH**, or some other disturbance.

Concept 5.5 Nucleic acids store, transmit, and help express hereditary information

- **DNA** (deoxyribonucleic acid) and **RNA** (ribonucleic acid) are the two nucleic acids. Their monomers are nucleotides.
- **Nucleotides** are made up of three parts (see Figure 1.8):
  - **Nitrogenous base** (adenine, thymine, cytosine, guanine, and uracil)
  - **Pentose** (5-carbon) sugar (deoxyribose in DNA or ribose in RNA)
  - **Phosphate group**

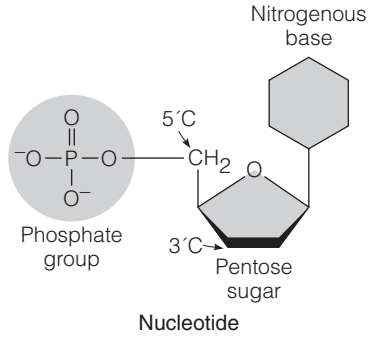


Figure 1.8 The components of nucleic acids

- **DNA** is the molecule of heredity.
  - It is double-stranded helix.
  - Its nucleotides are adenine, thymine, cytosine, and guanine.
  - Adenine nucleotides will hydrogen bond to thymine nucleotides, and cytosine to guanine.
- **RNA** is single-stranded. Its nucleotides are adenine, uracil, cytosine, and guanine. Note that it does not have thymine.

SUMMARY TABLE

Macromolecules/Polymers	Monomers/Components	Examples	Functions
Carbohydrates	Monosaccharides	Sugars, starch, glycogen, cellulose	Energy, energy storage; structural
Lipids	Fatty acids and glycerol	Fats, oils	Important energy source; insulation
Proteins	Amino acids	Hemoglobin, pepsin	Enzymes, movement
Nucleic Acids	Nucleotides (sugar, phosphate group, nitrogenous base)	DNA, RNA	Heredity; code for amino acid sequence

Level 1: Knowledge/Comprehension Questions

1. Which list of components characterizes RNA?
   (A) a PO_3 group, deoxyribose, and uracil
   (B) a PO_3 group, ribose, and uracil
   (C) a PO_3 group, ribose, and thymine
   (D) a PO_2 group, deoxyribose, and uracil
   (E) a PO_2 group, deoxyribose, and thymine

2. Which of the following molecules would contain a polar covalent bond?
   (A) Cl_2
   (B) NaCl
   (C) H_2O
   (D) CH_4
   (E) $C_6H_{12}O_6$

3. Which of the following statements regarding carbon is *false*?
   (A) Carbon has a tendency to form covalent bonds.
   (B) Carbon has the ability to bond with up to four other atoms.
   (C) Carbon has the capacity to form single and double bonds.
   (D) Carbon has the ability to bond together to form extensive, branched, or unbranched "carbon skeletons."
   (E) Carbon has the capacity to form polar bonds with hydrogen.

4. Three terms associated with the travel of water from the roots up through the vascular tissues of plants are
   (A) adhesion, cohesion, and translocation.
   (B) adhesion, cohesion, and transcription.
   (C) cohesion, hybridization, and transpiration.
   (D) cohesion, adhesion, and transpiration.
   (E) transpiration, neutralization, and adhesion.

Directions: The group of questions below consists of five lettered choices followed by a list of numbered phrases or sentences. For each numbered phrase or sentence, select the one choice that is most closely related to it. Each choice may be used once, more than once, or not at all.

Questions 5–9

(A) Lipids
(B) Peptide bonds
(C) Alpha helix
(D) Unsaturated fatty acids
(E) Cellulose

5. Contain one or more double bonds which "kink" the carbon backbone

6. The major class of biological molecules that are not polymers

7. Linkages between the monomers of proteins

8. A secondary structure of proteins

9. A structural carbohydrate found in plants

10. The process by which protein conformation is lost or broken down is
    (A) dehydration synthesis.
    (B) translation.
    (C) denaturation.
    (D) hydrolysis.
    (E) protein synthesis.

11. An organic compound that is composed of carbon, hydrogen, and oxygen in a 1:2:1 ratio is known as a
    (A) lipid.
    (B) carbohydrate.
    (C) salt.
    (D) nucleic acid.
    (E) protein.

12. If three molecules of a fatty acid that has the formula $C_{16}H_{22}O_2$ are joined to a molecule of glycerol ($C_3H_8O_3$), then the resulting molecule would have the formula
    (A) $C_{48}H_{96}O_6$.
    (B) $C_{48}H_{98}O_8$.
    (C) $C_{51}H_{68}O_6$.
    (D) $C_{51}H_{106}O_8$.
    (E) $C_{51}H_{104}O_9$.

13. Which of the macromolecules below could be structural parts of the cell, enzymes, or involved in cell movement or communication?
    (A) nucleic acids
    (B) proteins
    (C) lipids
    (D) carbohydrates
    (E) minerals

14. Which macromolecule is the main component of all cell membranes?
    (A) DNA
    (B) phospholipids
    (C) carbohydrates
    (D) steroids
    (E) glucose

15. The partial negative charge at one end of a water molecule is attracted to a partial positive charge of another water molecule. What is this type of attraction called?
    (A) a polar covalent bond
    (B) an ionic bond
    (C) a hydration shell
    (D) a hydrogen bond
    (E) a hydrophobic bond

16. Polymers of carbohydrates and proteins are all synthesized from monomers by
    (A) the joining of monosaccharides.
    (B) hydrolysis.
    (C) dehydration reactions.
    (D) ionic bonding of monomers.
    (E) cohesion.

17. If the pH of a solution is decreased from 7 to 6, it means that the
    (A) concentration of H^+ has decreased to 1/10 of what it was at pH 7.
    (B) concentration of H^+ has increased 10 times what it was at pH 7.
    (C) concentration of OH^- has increased 10 times what it was at pH 7.
    (D) concentration of OH^- has increased by 1/7 of what it was.
    (E) solution has become more basic.

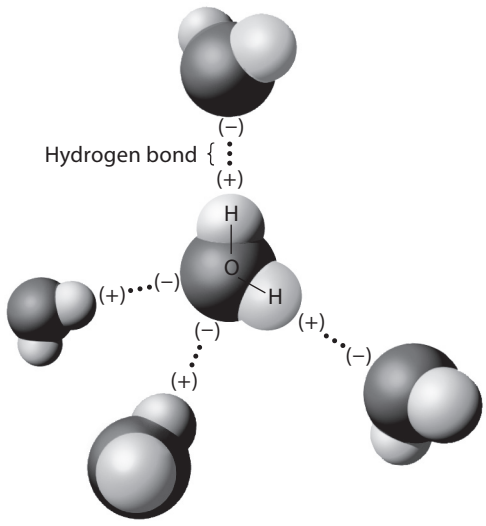
18. Which of the following is NOT considered to be an emergent property of water?
    (A) cohesion
    (B) transpiration
    (C) moderation of temperature
    (D) insulation of bodies of water by floating ice
    (E) a versatile solvent

19. Which two functional groups are always found in amino acids?
    (A) amine and sulfhydryl
    (B) carbonyl and carboxyl
    (C) carboxyl and amine
    (D) alcohol and aldehyde
    (E) ketone and amine

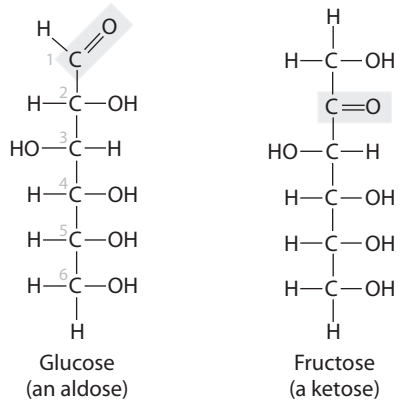
20. Hydrolysis is involved in which of the following?
    (A) formation of starch
    (B) hydrogen bond formation between nucleic acids
    (C) peptide bond formation of proteins
    (D) the hydrophilic interactions of lipids
    (E) the digestion of maltose to glucose

Level 2: Application/Analysis/Synthesis Questions

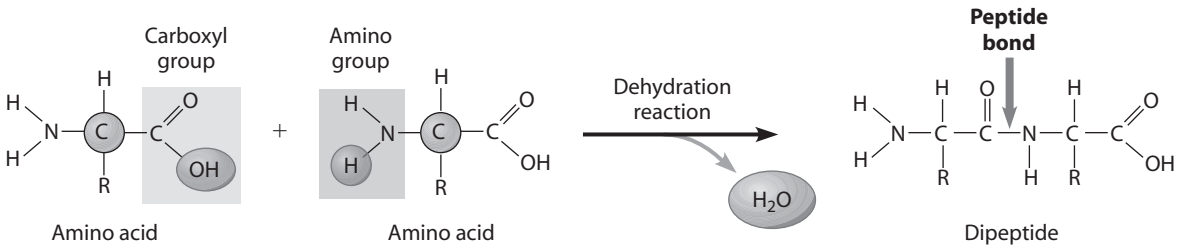
1. The hydrogen bonds shown in this figure are each
    (A) between two hydrogen atoms.
    (B) between two oxygen atoms.
    (C) between an oxygen and a hydrogen atom of the same water molecule.
    (D) between an oxygen and a hydrogen atom of different water molecules.



2. These two molecules are structural isomers and can be predicted to have different functions. What is the difference between them?
   (A) the number of carbon atoms
   (B) the number of oxygen atoms
   (C) the number of hydrogen atoms
   (D) the location of a double-bonded oxygen atom



Questions 3 and 4 refer to the following art.



3. How are these two amino acids attached together?
   (A) amino group to amino group
   (B) amino group to carboxylic acid group
   (C) carboxylic acid group to carboxylic acid group
   (D) carbon atom to carbon atom

4. If the dipeptide above were to be digested, how would it be reduced to amino acids?
   (A) by a dehydration reaction
   (B) by reduction in digestive fluid pH
   (C) through removal of functional groups
   (D) through a hydrolysis reaction

After reading the following paragraph, answer questions 5 and 6.

You're the manager of a factory that produces enzyme-washed blue jeans (the enzymes lighten the color of the denim, giving a faded appearance). When the most recent batch of fabric came out of the enzyme wash, however, the color wasn't light enough to meet your standards.

Your quality control laboratory wants to do some tests to determine why the wash enzymes didn't perform as expected.

5. Which hypothesis is most likely to be productive for their initial investigation?
   (A) The nucleotide chain of the enzymes may be incorrectly formed.
   (B) The dye in the fabric may have hydrolyzed the fatty acids in the enzymes.
   (C) The polysaccharides in the enzymes may have separated in the wash water.
   (D) The three-dimensional structure of the proteins may have been altered.

6. Based on your understanding of enzyme structure, which of the following would you recommend that they also investigate?
   (A) the temperature of the liquid in the washing vat
   (B) the pH of the liquid in the washing vat
   (C) the manufacturer of the fabric
   (D) both A and B

7. The molecular formula for glucose is $C_6H_{12}O_6$. What would be the molecular formula for a polymer made by lining ten glucose molecules together by dehydration reactions?
   (A) $C_{60}H_{120}O_{60}$
   (B) $C_6H_{12}O_6$
   (C) $C_{60}H_{102}O_{51}$
   (D) $C_{60}H_{100}O_{50}$

8. Which of the following pairs of base sequences could form a short stretch of a normal double helix of DNA?
   (A) 5′-purine-pyrimidine-purine-pyrimidine-3′ with 3′-purine-pyrimidine-purine-pyrimidine-5′
   (B) 5′-AGCT-3′ with 5′-TCGA-3′
   (C) 5′-GCGC-3′ with 5′-TATA-3′
   (D) 5′-ATGC-3′ with 5′-GCAT-3′

Free-Response Question

1. *The selectively permeable plasma membrane is composed of phospholipids and protein, which allow for its unique functions.*

(a) **Describe** the structure and properties of phospholipids and *explain* the important roles of phospholipids in the plasma membrane.

(b) **Explain** why proteins are an important component of the cell membrane, based on their structure and properties.

Part V

Answers and Explanations

Topic 1: The Chemistry of Life

ANSWERS AND EXPLANATIONS

Level 1: Knowledge/Comprehension Questions

- **1. (B) is correct.** RNA is made up of a phosphate group, a ribose sugar, and one of the following four nitrogenous bases: cytosine, guanine, uracil, and adenine. The phosphate group of RNA contains a phosphate atom and three atoms of oxygen, not two. DNA is similar to RNA in many ways but different in two important ones: It contains deoxyribose instead of ribose as its sugar and it contains the base thymine instead of uracil.
- **2. (C) is correct.** The answer is water, H_2O. Polar covalent bonds are those in which valence electrons are shared between atoms, but unequally. (The more electronegative atom will attract the electrons more strongly, and that end of the molecule will have a slightly negative charge, whereas the less electronegative atom will attract the electron less strongly and be slightly positive.) The two atoms involved in the bond must differ in electronegativity in order to form a polar covalent bond.
- **3. (E) is correct.** Use this question to review the unique properties of carbon. Since it has 4 valence electrons, carbon will form 4 covalent bonds. It does not form polar bonds.
- **4. (D) is correct.** The three terms you should keep in mind as you think of water traveling up through the xylem of a plant are transpiration (in which water evaporates from the plant's leaves); cohesion, in which the water molecules stick together due to the hydrogen bonds; and adhesion, whereby the water molecules stick to plant cell walls and resist the downward pull of gravity.
- **5. (D) is correct.** Unsaturated fatty acids contain one or more carbon-carbon double bonds, whereas saturated fatty acids contain no double bonds.
- **6. (A) is correct.** Lipids are the only one of the four major classes of biological molecules that are not polymers. They are grouped together because they are hydrophobic. Nucleic acids are polymers of nucleotide monomers, proteins are polymers of amino acid monomers, and carbohydrates are polymers of monosaccharide monomers.
- **7. (B) is correct.** The linkages between the amino acids of proteins are peptide bonds. Peptide bonds are covalent bonds formed in dehydration reactions. The carboxyl group of one amino acid is joined to the amino group of an adjacent amino acid, resulting in the loss of one molecule of water.
- **8. (C) is correct.** One common secondary structure of proteins is the alpha (α) helix; another is the beta (β) pleated sheet. The secondary structure of a protein refers to hydrogen bonding along the backbone (not the side chains) of the amino acid chain.
- **9. (E) is correct.** Cellulose is the polysaccharide that forms the strong cell walls of plant cells. It is a polymer of glucose.

- **10. (C) is correct.** Denaturation is the process by which proteins lose their overall structure, or conformation, as a result of changes in pH, temperature, or salt concentration. Denatured proteins have reduced biological activity.
- **11. (B) is correct.** The ratio of carbon, hydrogen, and oxygen atoms in carbohydrates is 1:2:1. For example, glucose is $C_6H_{12}O_6$.
- **12. (C) is correct.** To get this correct, you should first add up all the C, H, and O in three fatty acid chains plus one glycerol. This would be 51 C, 74 H, and 9 O. Then, recall that to join to molecules by dehydration synthesis, one molecule of water must be removed. Since three fatty acid chains will be attached to one glycerol, three water molecules will be removed. Subtract 6 H and 3 O to arrive at the answer.
- **13. (B) is correct.** Proteins have many functions, which encompass most of a cell's metabolic activity.
- **14. (B) is correct.** Phospholipids are unique macromolecules. Their hydrophilic heads and hydrophobic tails contribute to the semipermeability of cell membranes.
- **15. (D) is correct.** The negative charge comes from the electronegative oxygen of one water molecule attracted to the partial positive charge of hydrogen of another water molecule.
- **16. (C) is correct.** The monomers in macromolecules are joined when a molecule of water is removed during dehydration, or condensation reactions.
- **17. (B) is correct.** Since the pH scale is logarithmic, each unit change is by a factor of 10. A drop of pH means the solution is more acidic and has 10 times more H^+ ions.
- **18. (B) is correct.** Transpiration refers to the evaporation of water from pores in leaves. Transpiration is possible because of cohesion and adhesion, but it is not an emergent property of water.
- **19. (C) is correct.** An amino acid is composed of a central carbon, bonded to a hydrogen, with a variable (R) group, and with a carboxyl (the acid part) at one end, an amino group at the other end (the amino part). Aldehydes and ketones are found in sugars; the sulfhydryl group is found in one amino acid.
- **20. (E) is correct.** Recall that hydrolysis means to use water to split a molecule, so look for a large molecule reduced to its monomers. Maltose is a disaccharide; glucose is a monosaccharide.

Level 2: Application/Analysis/Synthesis Questions

- **1. (D) is correct.** Hydrogen bonds occur when a slightly positive hydrogen atom of a polar covalent bond in one molecule is attracted to a slightly negative atom of a polar covalent bond in another molecule. In living systems hydrogens are often attracted to the highly electronegative elements oxygen (as in this question with water) or nitrogen.
- **2. (D) is correct.** Structural isomers have the same molecular formula, but differ in the covalent arrangement of their atoms. Answers A, B, and C would all change the molecular formula; thus, they would not be isomers. The location of the double-bonded oxygen is a change in covalent arrangement.
- **3. (B) is correct.** Peptide bonds occur between the carboxyl group of one amino acid and the amino group of another amino acid. All that is required

in this question is for you to carefully examine the information given in the diagram. Take a look at every question, even if you may think the content area is a hard one; often the answers are easier than you might expect.

- **4. (D) is correct.** Hydrolysis is a chemical process that splits molecules by the addition of water. Digestive enzymes work by hydrolysis. Water is removed to join the molecules; water is added to separate the molecules.
- **5. (D) is correct.** Recall that enzymes are proteins and proteins are made of amino acids.
- **6. (D) is correct.** Two environmental factors that affect the three-dimensional structure of enzymes are temperature and pH. As the structure of the enzyme is altered the enzyme will become less effective.
- **7. (C) is correct.** Ten glucose molecules would have a combined molecular formula of $C_{60}H_{120}O_{60}$. To form a polymer, a molecule of water would have to be removed as each glucose is added to the chain. Since ten glucose molecules are bonded together, nine H_2O must be removed, 18 hydrogen atoms and 9 oxygen atoms. This leaves a formula of $C_{60}H_{102}O_{51}$.
- **8. (D) is correct.** This conceptual question is based on your knowledge of the structure of DNA. Recall that the molecule is antiparallel, meaning one strand runs 5′ to 3′ while the opposite strand of the double helix runs 3′ to 5′. All of the answers are given with both strands running 3′ to 3′. To get the proper answer convert the second strand given in the answer to 3′ to 5′ and see which one has the proper, matching base-pair sequence.

Free-Response Questions

(a) A phospholipid molecule contains a hydrophilic "head" (containing a glycerol molecule and a phosphate group) and two hydrophobic fatty acid tails. In cell membrane surfaces, phospholipids are arranged in a bilayer, in which the hydrophilic heads are in contact with the cell's watery interior and exterior, while the tails are pointed away from water and toward each other in the interior of the membrane. The fatty acid chains of phospholipids can contain double bonds, which makes them unsaturated. Because of the kinks in the tails, phospholipids aren't packed together tightly, which contributes to the fluidity of the membrane. The fluidity of the cell membrane is very important in its function; the less fluid the membrane is, the more impermeable it is. There is an optimum permeability for the cell membrane, at which all the substances necessary for metabolism can pass into and out of the cell.

The fluidity of cell membranes enables hydrophobic molecules such as hydrocarbons, carbon dioxide, and oxygen to dissolve in the bilayer and easily cross the membrane. However, ions and polar molecules (including water, glucose, and other sugars) cannot pass through because of the hydrophobic interior. Protein channels and transport proteins allow these required substances to cross membranes.

(b) Proteins function as cell membrane transporters because they act as channels; substances that bind to them can help alter their conformation to permit the passage of molecules through them, and into the cell interior.

There are many different ways by which proteins can permit the passage of ionic and polar molecules through the lipid bilayer. Proteins associated with the membrane are either integral proteins, which actually penetrate the lipid bilayer (ones that completely go through the bilayer are called transmembrane proteins), or they are "peripheral proteins" that are associated with the outside of the membrane. Transmembrane proteins can form hydrophilic channels that permit the passage of certain hydrophilic substances that otherwise would not be able to cross the membrane. Other functions that membrane proteins serve are to attach the cell to the extracellular matrix, to stabilize it, and to function in cell-cell recognition. Membrane proteins are also important in cell-cell signaling; some have enzyme function and carry out important metabolic reactions, and they aid in joining adjacent cells.

This response shows thorough knowledge of the processes of the structure of phospholipids, cell membrane structure and components, and movement across membranes. A strong response to this item requires an understanding of topics from Units 1 and 2 of the textbook. Note that the response includes the following key terms in context, showing the writer's knowledge of their meanings and relatedness:

phospholipids
hydrophilic head
glycerol
phosphate
hydrophobic tails
lipid bilayer
double bonds
unsaturated
permeability
metabolism
protein channels
transporters
conformation
integral proteins
transmembrane proteins
extracellular matrix
cell-cell signaling

The student's response would have been strengthened by a more explicit correlation of structure and function, especially by using protein functions other than transport. Specific examples of cell-cell signaling, enzymatic function, and others listed would have demonstrated a deeper knowledge of the topic.

Topic 2: The Cell

ANSWERS AND EXPLANATIONS

Level 1: Knowledge/Comprehension Questions

1. (C) is correct. Light microscopes are good for viewing objects that are 0.2 μm or larger. With a light microscope, you can observe animal and plant cells, some bacterial cells, and some larger organelles such as nuclei mitochondria, and chloroplasts. To see the other organelles in the list of choices, you would need an electron microscope.