3

The Chemistry of Organic Molecules

Chapter Review

Carbon's unique properties permit the formation of many kinds of **organic molecules.** At the molecular level, this variety accounts for the diversity of living things. Many organic molecules have a carbon backbone plus functional groups. Some common functional groups are the hydroxyl, carboxyl, aldehyde, ketone, and amine groups.

Several types of small, organic molecules—sugars, fatty acids, amino acids, and nucleotides—serve as the **monomers** (building blocks) of **polymers** (larger organic molecules). These polymers (e.g., polysaccharides, lipids, proteins, nucleic acids) have important biological functions. When a **dehydration** reaction occurs, two monomers bond chemically as a water molecule is lost. Repetition of this process produces even larger molecules—the polymers—in a cell. The reverse reaction, **hydrolysis,** breaks down polymers into their chemical subunits.

Several classes of organic molecules have biological importance. One of these, the **carbohydrates,** consists of several subclasses: the monosaccharides (e.g., glucose), the disaccharides (e.g., sucrose), and the polysaccharides (e.g., starch). The monosaccharides and disaccharides—the sugars—provide an immediate energy source for organisms. Some polysaccharides store energy (i.e., starch), whereas others contribute structurally (i.e., cellulose).

Fatty acids and **glycerol** are the building blocks of fats and oils. Fatty acids may be either saturated or unsaturated. Fats and oils store energy efficiently. **Waxes** and **phospholipids** differ in some of their components compared to fats. These structural differences endow these molecules with different biological abilities. Phospholipids, for example, are a major component of plasma membrane structure and help determine a membrane's properties. **Steroids** are derived from cholesterol; their structure consists of four fused carbon rings.

Proteins have a variety of biological functions, such as support, enzymatic, transport, and hormonal regulation. The monomers of these polymers are **amino acids. Peptide bonds** join amino acids within the **polypeptides** of protein molecules. Proteins exhibit several levels of structure. The primary structure of a protein is the order of the amino acids bonded together. Several other structural levels (secondary, tertiary, quaternary) account for the molecule's three-dimensional shape and for the protein's biological properties.

DNA and **RNA** are **nucleic acids. Nucleotides,** the monomers of nucleic acids, contain a pentose sugar, phosphate, and nitrogen-containing base. DNA makes up the genes in cells. The DNA molecule is a double helix—it has the appearance of a twisted ladder. Sugar and phosphate molecules make up the sides of the ladder and hydrogen-bonded bases named adenine, guanine, cytosine, and thymine make up the rungs of the ladder. The sequence of bases in DNA stores information regarding the order in which amino acids are to be joined within a protein. RNA conveys this information from the nucleus to the cytoplasm, and therefore is an intermediary in the synthesis of proteins.

The nucleotide ATP is composed of adenosine and three phosphate groups. ATP is a high-energy molecule. Whenever cells need energy, ATP is broken down to ADP + P, and energy is released.

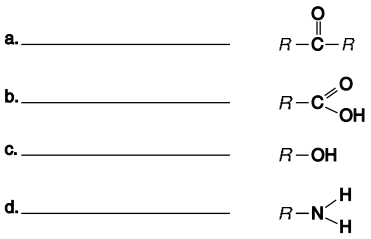
Study Exercises

Study the text section by section as you answer the questions that follow.

3.1 Organic Molecules (pp. 36–38)

- The characteristics of organic compounds depend on the chemistry of carbon.
- Variations in carbon backbones and functional groups account for the great diversity of organic molecules.
- The four classes of organic molecules in cells are carbohydrates, lipids, proteins, and nucleic acids.
- Large organic molecules called polymers form when their specific monomers join together.

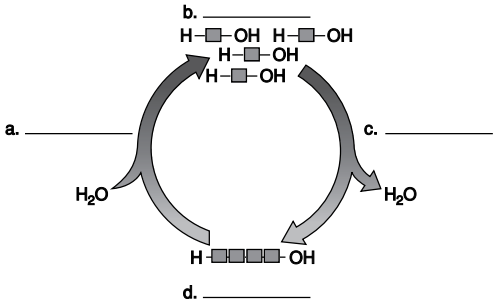
1. Indicate whether these statements about a carbon atom are true (T) or false (F):
   a. ____ There are two electrons in its outer shell.
   b. ____ It can bond to other carbon atoms.
   c. ____ It can share two pairs of electrons with another atom.
   d. ____ Chains of 50 atoms are unusual in living systems.
2. Label this diagram using the following functional group names.
   amino
   carboxyl
   hydroxyl
   carbonyl (ketone)



3. Place a check next to the functional group(s) that can ionize (take on or give up a hydrogen ion).
   a. ____ amino
   b. ____ carboxyl
   c. ____ hydroxyl
   d. ____ carbonyl (ketone)
4. For each term on the left, write in the corresponding term; the first one is completed for you.

polymer	monomer	
polysaccharide	a. _____	
fat	b. _____	and c. _____
protein	d. _____	
nucleic acid	e. _____	

5. Label this diagram using the following alphabetized list of terms.
   dehydration reaction
   hydrolysis reaction
   monomers
   polymer

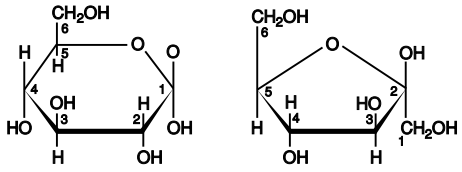


   e. During a hydrolysis reaction, is water added to or taken away from the reactants? _____
   f. During a dehydration reaction, is water added to or taken away from the reactants? _____

3.2 Carbohydrates (pp. 39–41)

- Glucose is an immediate energy source for many organisms.
- Some carbohydrates (starch and glycogen) function as stored energy sources.
- Other carbohydrates (cellulose and chitin) function as structural compounds.

6. Write the molecular formula beneath each of these structural formulas by indicating the number of carbons, hydrogens, and oxygens in each.



a. _____ b. _____

The term that refers to two structurally dissimilar molecules with the same molecular formula is c. _____.

7. Complete the following table:

Carbohydrate	Monosaccharide Composition	Biological Function
sucrose		
lactose		
maltose		
starch		
glycogen		
cellulose		
chitin		

8. a. Which molecules in the first column of the table in question 7 are disaccharides? _____

b. Which are polysaccharides? _____

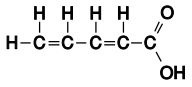
3.3 Lipids (pp. 42–45)

- Lipids vary in structure and function.
- Fats function as long-term stored energy sources.
- Cellular membranes are a bilayer of phospholipid molecules.
- Steroids are derived from cholesterol, a complex ring compound.

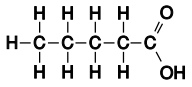
9. Complete the following table:

Lipid	Monomers	Biological Functions
fats and oils		
waxes		
phospholipids		

10. Write the word *saturated* or *unsaturated* beneath the appropriate structure.

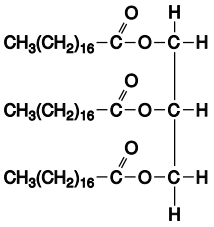


a. _____



b. _____

11. In this representation of a fat, draw a circle around the portion derived from glycerol. Draw lines under the portions derived from fatty acids.



12. When phospholipids are placed in water, the [a.] _____ face outward and the [b.] _____ face each other. This property makes phospholipids suitable molecules to form the [c.] _____ of cells.
13. Examples of steroids are [a.] _____, [b.] _____, and [c.] _____.
14. Each steroid differs from other steroids by the _____ attached to the ring.

3.4 Proteins (pp. 46–49)

- Proteins serve many and varied functions such as support, enzymatic, transport, defensive, hormonal regulation, and motion.
- Each protein has levels of structure resulting in a particular shape. Hydrogen, ionic, and covalent bonding, and hydrophobic interactions help maintain a protein's normal shape.
- Environmental conditions can cause a protein to change its shape and no longer function as it did.

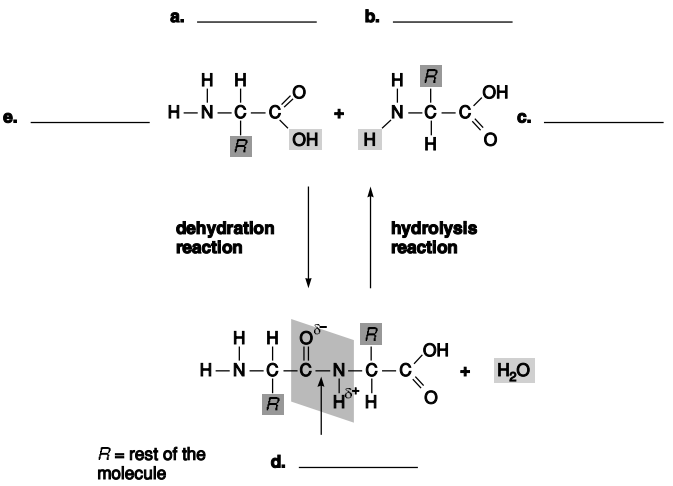
15. Complete the following table:

Protein	Biological Function
enzymes	
actin, myosin	
insulin	
hemoglobin	

Peptides (p. 46)

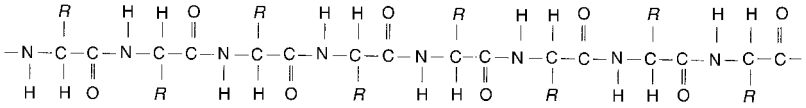
16. Label this diagram using the following alphabetized list of terms. One term is used twice.

amino acid
amino group
carboxyl (acid) group
peptide bond



Shape of Proteins (p. 49)

17. Study this representation of a polypeptide.



a. This is the _____ structure of a protein.

b. What are *R* groups? _____

_____

c. What shapes do the secondary structure of a protein normally assume? _____

d. What type of bond between amino acids is necessary to maintain secondary shape? _____

e. How does the tertiary shape of a globular protein come about? _____

_____

f. What would cause a protein to have a quaternary shape? _____

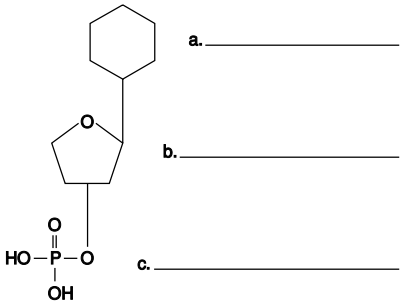
_____

_____

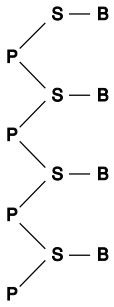
3.5 Nucleic Acids (pp. 50–52)

- Genes are composed of DNA (deoxyribonucleic acid). DNA specifies the correct ordering of amino acids in proteins, with RNA as an intermediary.
- The nucleotide ATP serves as a carrier of chemical energy in cells.

18. Both DNA and RNA are polymers of _____.
19. On this diagram, label the following components of a nucleotide.
    nitrogen-containing base
    phosphate
    sugar



20. Refer to the following diagram of a strand of nucleotides to answer questions *a–d*.
    a. What molecule is represented by S? _____
    b. What molecule is represented by B? _____
    c. How many different types of B are in DNA? _____
    d. What type of bond is represented by the lines? _____



21. a. Complete the following table to distinguish DNA from RNA:

	DNA	RNA
Sugar		
Bases		
Strands (how many?)		
Helix (yes or no)		

b. What are the functions of DNA and RNA? _____

_____

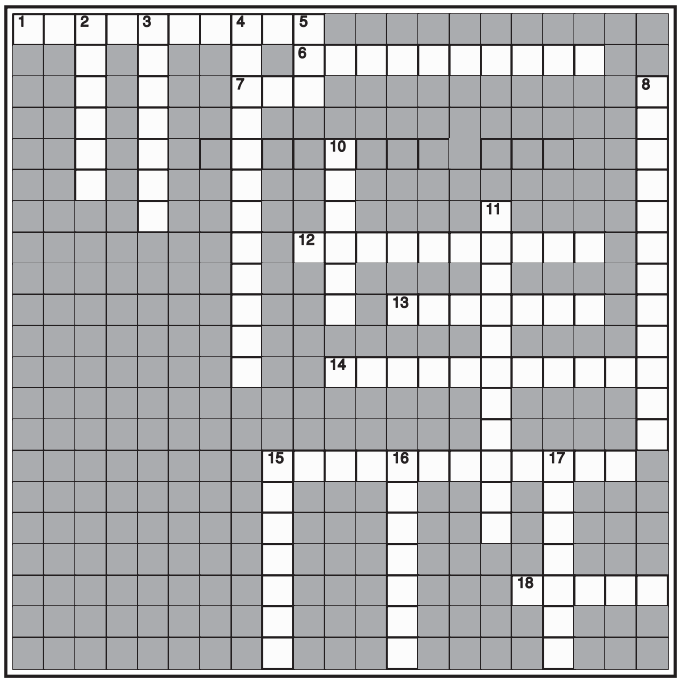
ATP (Adenosine Triphosphate) (p. 52)

22. ATP is a(n) [a.]_____; its structure consists of three [b.]_____ groups attached to the five-carbon [c.]_____ of the molecule.

23. Complete this reaction: ATP → ADP +Ⓟ+ [a.]_____. When cells need [b.]_____, they break down the molecule [c.]_____.

KeyWord CrossWord

Review key terms by completing this crossword puzzle, using the following alphabetized list of terms:



amino acid
carbohydrate
DNA
enzyme
hydrolysis
hydrophilic
hydrophobic
isomer
lipid
nucleic acid
nucleotide
organic
peptide
phospholipid
polymer
protein
RNA
steroid

Across

1 organic molecule that has an amino group and an acid group, and that covalently bonds to produce protein molecules (two words)
6 monomer of DNA and RNA consisting of a five-carbon sugar bonded to a nitrogen-containing base and a phosphate group
7 nucleic acid polymer produced from covalent bonding of nucleotide monomers that contain the sugar ribose; carries information for protein synthesis from DNA
12 splitting of a compound by the addition of water, with the H^+ being incorporated in one fragment and the OH^- in the other
13 type of lipid molecule having four interlocking rings; examples are cholesterol, estrogen, and testosterone
14 type of molecule that does not interact with water because it is nonpolar
15 molecule having the same structure as a fat except that a group that contains phosphate replaces one bonded fatty acid; an important component of plasma membranes
18 class of organic compounds that tend to be soluble in nonpolar solvents such as alcohol; includes fats and oils

Down

2 molecules with the same molecular formula but different structure, and therefore shape
3 type of molecule that contains carbon and hydrogen; it usually also contains oxygen
4 class of organic compounds consisting of carbon, hydrogen, and oxygen atoms; includes monosaccharides, disaccharides, and polysaccharides
5 nucleic acid polymer produced from covalent bonding of nucleotide monomers that contain the sugar deoxyribose; the genetic material of nearly all organisms
8 polymer of nucleotides; includes both DNA and RNA (two words)
10 organic catalyst, usually a protein molecule, that speeds chemical reactions in living systems
11 type of molecule that interacts with water by dissolving in water or by forming hydrogen bonds with water molecules
15 macromolecule consisting of covalently bonded monomers
16 a polymer having, as its primary structure, a sequence of amino acids united through covalent bonding
17 a series of amino acids joined by covalent bonding

Chapter Test

Objective Questions

Do not refer to the text when taking this test. For questions 1–8 match the descriptions to the following classes:

a. carbohydrates
b. fats and oils
c. proteins
d. nucleic acids

____ 1. sucrose is a member
____ 2. glycerol is a building block
____ 3. specify the sequence of amino acids in a protein
____ 4. contains the bases uracil and adenine
____ 5. insulin is a member
____ 6. triglycerides are members
____ 7. exhibit a primary, secondary, and tertiary structure
____ 8. some have enzymatic roles
____ 9. Select the functional group that can ionize.
a. amino
b. carboxyl
c. hydrogen
d. hydroxyl
____ 10. What is the relationship between glucose and fructose?
a. disaccharides
b. isomers
c. isotopes
d. polysaccharides
____ 11. The products from the hydrolysis of sucrose are
a. fructose and galactose.
b. fructose and glucose.
c. galactose and glucose.
d. galactose and lactose.
____ 12. Select the molecule with mainly a structural role.
a. cellulose
b. glycogen
c. starch
d. sucrose
____ 13. Select the false statement.
a. Fats provide short-term energy to organisms.
b. Hydroxyl groups are polar.
c. Saturated fatty acids do not have double bonds.
d. Cellulose is a chain of glucose molecules.
____ 14. Select the true statement about waxes.
a. They are hydrophobic.
b. They are liquids at room temperature.
c. They are similar in structure to steroids.
d. They consist of short-term fatty acids.
____ 15. The alpha helix refers to a protein's _____ structure.
a. primary
b. secondary
c. tertiary
d. quaternary
____ 16. Select the smallest structure.
a. amino acid
b. dipeptide
c. polypeptide
d. protein
____ 17. Which of the following is NOT a common function of some proteins?
a. energy storage
b. hormonal regulation
c. structural component
d. transport
____ 18. The opposing reaction to a dehydration reaction is
a. condensation.
b. hydrolysis.
c. monomers.
d. polymerization.
____ 19. Select the base NOT present in DNA.
a. C
b. G
c. T
d. U
____ 20. The monomers of proteins are
a. amino acids.
b. fatty acids.
c. monosaccharides.
d. nucleotides.

Critical Thinking Questions

Answer in complete sentences.

21. What are the similarities and differences between glycogen and starch?

22. How does the primary structure of a polypeptide determine its secondary structure?

Test Results: _____ number correct ÷ 22 = _____ × 100 = _____ %

Exploring the Internet

The Online Learning Center at *www.mhhe.com/maderbiology8* has additional study material and practice quizzes that can help you master the content of this chapter. You can also find links to websites exploring additional topics in biology. Access to the Online Learning Center is free for those who have purchased a new textbook.

Answer Key

Study Exercises

1. a. F **b.** T **c.** T **d.** F **2. a.** carbonyl (ketone) **b.** carboxyl **c.** hydroxyl **d.** amino **3. a.** amino **b.** carboxyl **4. a.** monosaccharide **b.** fatty acid **c.** glycerol **d.** amino acid **e.** nucleotide **5. a.** hydrolysis **b.** monomers **c.** dehydration **d.** polymer **e.** added to **f.** taken away from **6. a.** $C_6H_{12}O_6$ **b.** $C_6H_{12}O_6$ **c.** isomer

7.

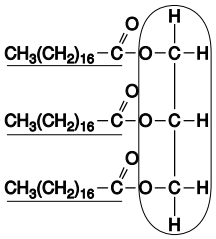
Monosaccharide Composition	Biological Function
glucose, fructose	transport sugar in plants
glucose, galactose	in milk, energy source
glucose, glucose	digestive breakdown product of starch
glucose	energy storage in plants
glucose	energy storage in animals
glucose	plant structure
glucose	exoskeleton in crabs, lobsters, insects

8. a. sucrose, lactose, maltose **b.** starch, glycogen, cellulose, chitin

9.

Monomers	Biological Functions
three fatty acids, glycerol	long-term energy storage
long-chain fatty acid and long-chain alcohol	protective cuticle to prevent water loss in plants
glycerol, two fatty acids, phosphate group	plasma membrane structure and properties

10. a. unsaturated **b.** saturated
11.



12. a. polar heads **b.** nonpolar tails **c.** plasma membrane **13. a.** cholesterol **b.** estrogen **c.** testosterone **14.** functional groups
15.

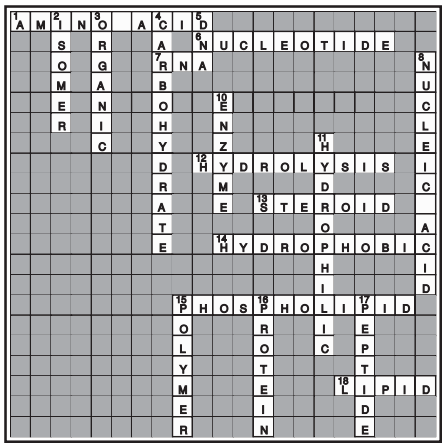
Biological Function
catalysts that speed chemical reactions
contractile proteins in muscle
hormone involved in blood sugar regulation
oxygen pigment that transports in blood

16. a. amino acid **b.** amino acid **c.** carboxyl (acid) group **d.** peptide bond **e.** amino group **17. a.** primary **b.** they represent the variable parts of the amino acids (i.e., H, CH_3, C chain, C ring) **c.** α (alpha) helix and β (beta) sheet **d.** hydrogen **e.** folding and twisting of polypeptide **f.** if it contained more than one polypeptide **18.** nucleotides **19. a.** nitrogen-containing base **b.** sugar **c.** phosphate **20. a.** sugar **b.** nitrogen-containing base **c.** 4 **d.** covalent
21. a.

DNA	RNA
deoxyribose	ribose
A, T, C, G	A, U, C, G
double stranded	single stranded
yes	no

21. b. DNA stores information regarding the order of amino acids in a polypeptide (protein); RNA carries this information as an intermediary for the process of protein synthesis. **22. a.** nucleotide **b.** phosphate **c.** sugar **23. a.** energy **b.** energy **c.** ATP

KeyWord CrossWord



Chapter Test

1. a **2.** b **3.** d **4.** d **5.** c **6.** b **7.** c **8.** c **9.** b **10.** b **11.** b **12.** a **13.** a **14.** a **15.** b **16.** a **17.** a **18.** b **19.** d **20.** a **21.** Both glycogen and starch are polysaccharides with glucose as the monomer. Both are energy-storing molecules, but starch fulfills this role in plants and glycogen does it in some animals. Glycogen exhibits more branching than starch. **22.** The secondary structure of a polypeptide depends on hydrogen bonding between the *R* groups of the amino acids making up the polypeptide. Each particular polypeptide has its own sequence of amino acids and therefore *R* groups.