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, carbonyl, carboxyl, amino, sulphydryl, and phosphate groups.

Several types of small, organic molecules—monosaccharides, fatty acids, amino acids, and nucleotides—serve as the **monomers** (building blocks) of **polymers** (larger organic molecules). These polymers (e.g., carbohydrates, 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, including 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 phosphate, a nitrogen-containing base, and a pentose sugar. 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 four classes of organic molecules in cells are carbohydrates, lipids, proteins, and nucleic acids.
- The characteristics of organic compounds depend on the chemistry of carbon.
- Variations in carbon skeletons and the attached functional groups account for the great diversity of organic molecules.
- Large organic molecules called polymers form when their specific monomers join together.

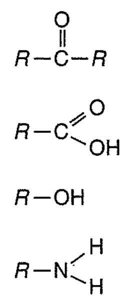
1. Indicate whether these statements about a carbon atom are true (T) or false (F):
   a. _____ There are two electrons in its outer shell.
   b. _____ It can bond to other carbon atoms.
   c. _____ It can share two pairs of electrons with another atom.
   d. _____ Chains of 50 atoms are unusual in living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

a. ____________________

b. ____________________

c. ____________________

d. ____________________



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. The term that refers to two structurally dissimilar molecules with the same molecular formula is __________.
5. Give the subunit molecule(s) for each of the larger molecules listed.

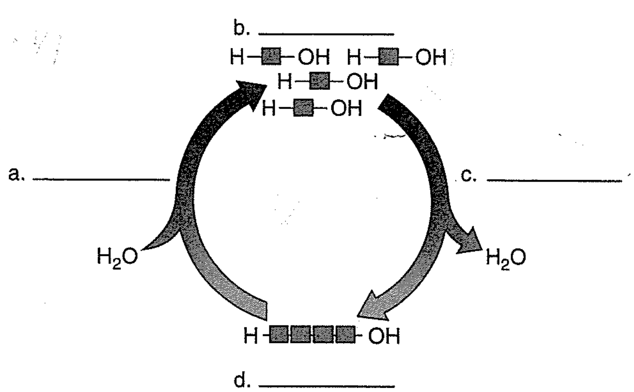
polysaccharide a. ____________________

fat b. ____________________ and c. ____________________

polypeptide d. ____________________

DNA, RNA e. ____________________

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



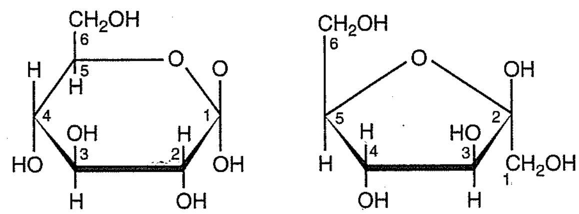
e. During a hydrolysis reaction, is water added to or taken away from the reactants? ____________________

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

3.2 Carbohydrates (pp. 38–41)

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

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



a. ______________ b. ______________

8. Complete the following table:

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

9. a. Which molecules in the first column of the table in question 8 are disaccharides? ______________

b. Which are polysaccharides? ______________

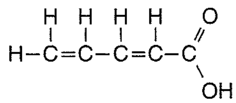
3.3 Lipids (pp. 42–45)

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

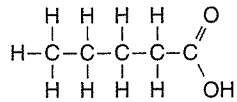
10. Complete the following table:

Lipid	Monomers	Biological Function
fats and oils (triglycerides)		
phospholipids		
waxes		

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

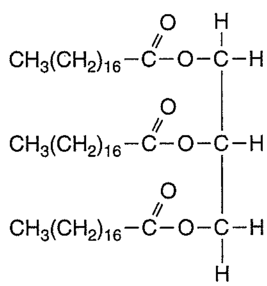


a. ______________



b. ______________

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



13. 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.

14. Examples of steroids are a. ______________, b. ______________, and c. ______________.

15. Each steroid differs from other steroids by the ______________ attached to the carbon skeleton.

3.4 Proteins (pp. 46–49)

- Proteins serve many and varied functions, such as support, enzymes, transport, defense, hormones, and motion.
- Each protein has levels of structure resulting in a particular shape. Hydrogen, ionic, and covalent bonding, plus hydrophobic interactions, all help maintain a protein's normal shape.

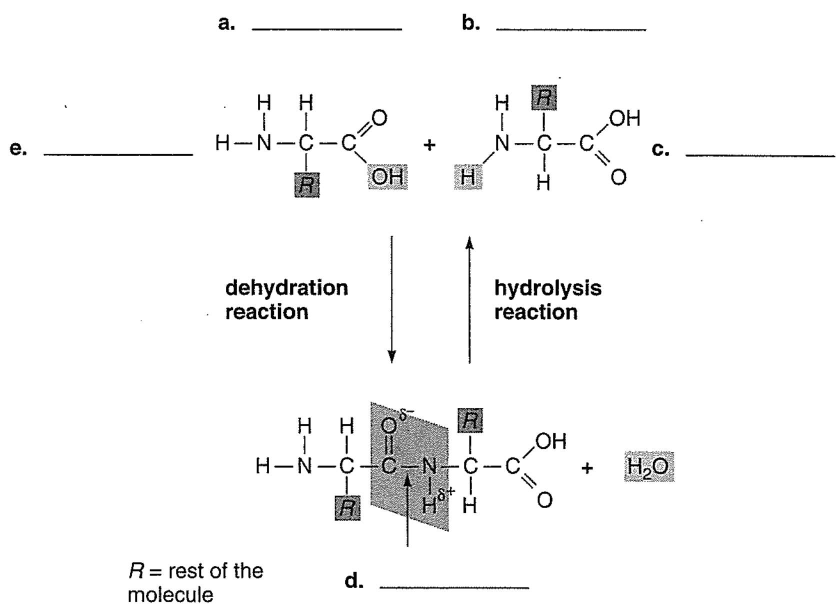
16. Complete the following table:

Protein	Biological Function
enzymes	
actin, myosin	
insulin	
hemoglobin	

Peptides (p. 46)

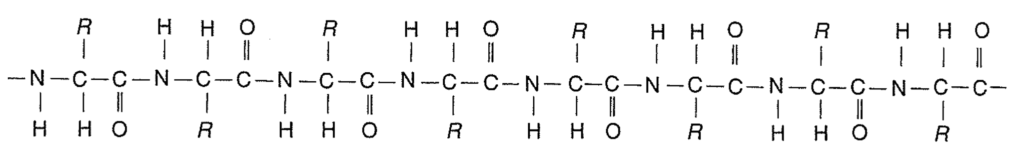
17. Label the following diagram using the alphabetized list of terms. (One term is used twice.)

acidic group
amino acid
amino group
peptide bond



Shape of Proteins (p. 48)

18. Study this representation of a polypeptide.



a. This is the ______________ structure of a protein.

b. What are *R* groups? ______________________________

____

c. What two shapes characterize the secondary structure of a protein? ______________

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? ______________________________________

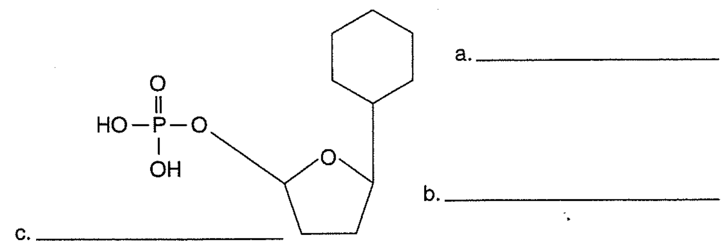
____

19. a. ____________ proteins help new proteins fold into their normal shape. In Creutzfeldt-Jakob disease, an infectious protein called a(an) b. ____________ is misfolded resulting in disease.

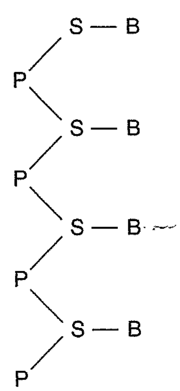
3.5 Nucleic Acids (pp. 50–52)

- 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.

20. Both DNA and RNA are polymers of ____________.
21. On the following diagram, label the components of a nucleotide.
    nitrogen-containing base
    phosphate
    pentose sugar



22. 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? ____________



23. 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? ____________________

____

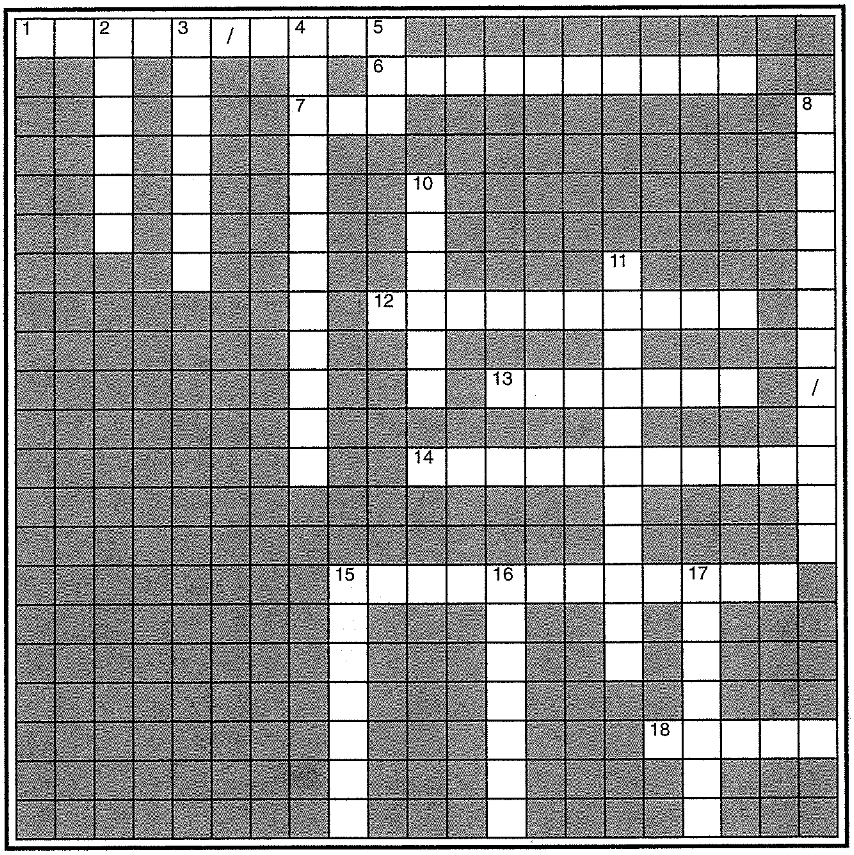
ATP (Adenosine Triphosphate) (p. 52)

24. ATP is a(n) a.__________; its structure consists of three b.__________ groups attached to c.__________, the pentose sugar.

25. 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 Molecule with the same molecular formula (as another molecule) but a 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 few amino acids joined by covalent bonding