

Section 2-3

1 FOCUS

Objective

2.3.1 Describe the functions of each group of organic compounds.

Guide for Reading

Vocabulary Preview

As students read, have them make a concept map using the section's Vocabulary terms, excluding the words *monomer* and *polymer*. In the initial oval, they should write *Four Groups of Organic Compounds in Living Things*. Then, students should add Vocabulary terms to their concept map as they read the section.

Reading Strategy

Explain that the boldface sentences are the key ideas. In writing their summaries, students should use key words from the key ideas, as well as any highlighted, boldface Vocabulary terms.

2 INSTRUCT

The Chemistry of Carbon

Make Connections

Chemistry Remind students that a stable carbon atom would have eight electrons in its outermost level. Then, ask: **How many electrons would a carbon atom have to gain to fill its outermost level?** (*Four*) Point out that such a transfer is unlikely. Instead, carbon completes its outermost level by sharing electrons and forming four covalent bonds. The atoms that carbon most often forms bonds with, besides other carbon atoms, are hydrogen, oxygen, and nitrogen. Have students look for these elements in the compounds discussed in this section. (Finding a definition of organic chemistry that does not require exceptions is difficult. The definition given in the text excludes methane and compounds derived from methane, but it includes the vast majority of organic compounds.) **L2**

2-3 Carbon Compounds

Guide for Reading



Key Concept

- What are the functions of each group of organic compounds?

Vocabulary

monomer
polymer
carbohydrate
monosaccharide
polysaccharide
lipid
nucleic acid
nucleotide
ribonucleic acid (RNA)
deoxyribonucleic acid (DNA)
protein
amino acid

Reading Strategy:

Summarizing As you read, find the key ideas. Write down a few key words from each main idea. Then, use the key words in your summary. Reread your summary, keeping only the most important ideas.

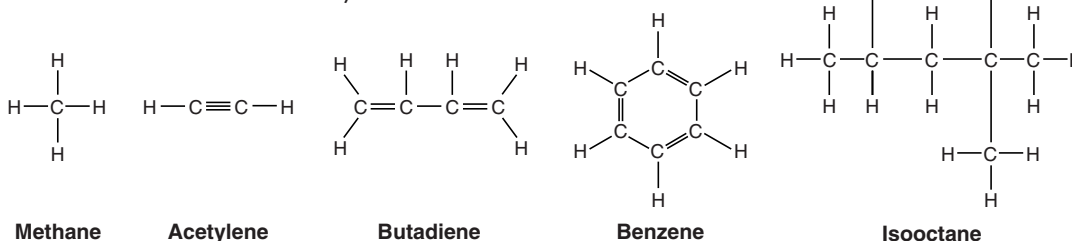
Until the early 1800s, many chemists thought that compounds created by organisms—organic compounds—were distinctly different from compounds in nonliving things. In 1828, a German chemist was able to synthesize the organic compound urea from a mineral called ammonium cyanate. Chemists soon realized that the principles governing the chemistry of nonliving things could be applied to living things. Scientists still use the term *organic chemistry*, but now it describes something a little different. Today, organic chemistry is the study of all compounds that contain bonds between carbon atoms.

The Chemistry of Carbon

Is carbon so interesting that a whole branch of chemistry should be set aside just to study carbon compounds? It is indeed, for two reasons. First, carbon atoms have four valence electrons. Each electron can join with an electron from another atom to form a strong covalent bond. Carbon can bond with many elements, including hydrogen, oxygen, phosphorus, sulfur, and nitrogen. In fact, living organisms are made up of molecules that consist of carbon and these other elements.

Even more important, a carbon atom can bond to other carbon atoms, which gives carbon the ability to form chains that are almost unlimited in length. These carbon-carbon bonds can be single, double, or triple covalent bonds. Chains of carbon atoms can even close upon themselves to form rings, as shown in **Figure 2-11**. Carbon has the ability to form millions of different large and complex structures. No other element even comes close to matching carbon's versatility.

Figure 2-11 Carbon can form single, double, or triple bonds with other carbon atoms. Each line between atoms in a molecular drawing represents one covalent bond. **Observing** How many covalent bonds are there between the carbon atoms in acetylene?



SECTION RESOURCES

Print:

- Laboratory Manual A**, Chapter 2 Lab
- Laboratory Manual B**, Chapter 2 Lab
- Teaching Resources**, Lesson Plan 2-3, Adapted Section Summary 2-3, Adapted Worksheets 2-3, Section Summary 2-3, Worksheets 2-3, Section Review 2-3
- Reading and Study Workbook A**, Section 2-3
- Adapted Reading and Study Workbook B**, Section 2-3


Technology:

- iText**, Section 2-3
- Transparencies Plus**, Section 2-3
- Lab Simulations CD-ROM**, Properties of Biomolecules

Macromolecules


Many of the molecules in living cells are so large that they are known as macromolecules, which means “giant molecules.” Macromolecules are made from thousands or even hundreds of thousands of smaller molecules.

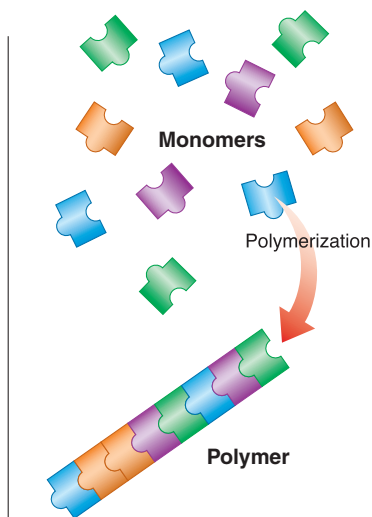
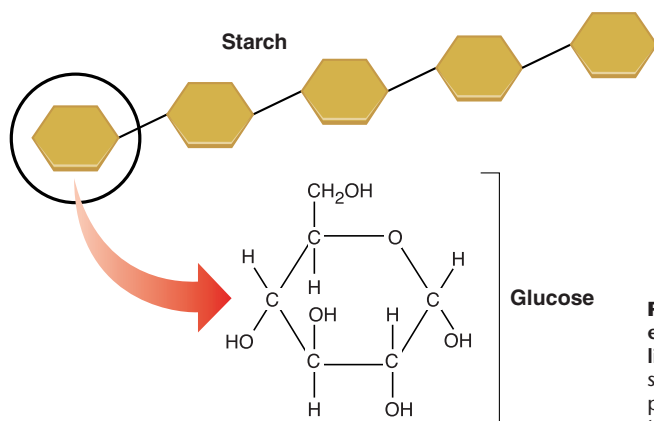
Macromolecules are formed by a process known as polymerization (pah-lih-mur-ih-ZAY-shun), in which large compounds are built by joining smaller ones together. The smaller units, or **monomers**, join together to form **polymers**. The monomers in a polymer may be identical, like the links on a metal watch band; or the monomers may be different, like the beads in a multicolored necklace. **Figure 2-12** illustrates the formation of a polymer from more than one type of monomer.

It would be difficult to study the millions of organic compounds if they were not classified into groups.  **Four groups of organic compounds found in living things are carbohydrates, lipids, nucleic acids, and proteins.** Sometimes these organic compounds are referred to as biomolecules. As you read about these molecules, compare their structures and functions.

 **CHECKPOINT** What is polymerization?


Carbohydrates

Carbohydrates are compounds made up of carbon, hydrogen, and oxygen atoms, usually in a ratio of 1 : 2 : 1.  **Living things use carbohydrates as their main source of energy. Plants and some animals also use carbohydrates for structural purposes.** The breakdown of sugars, such as glucose, supplies immediate energy for all cell activities. Living things store extra sugar as complex carbohydrates known as starches. As shown in **Figure 2-13**, the monomers in starch polymers are sugar molecules.



▲ **Figure 2-12** When small molecules called monomers join together, they form polymers, or large molecules. **Using Analogies** How are monomers similar to links in a chain?



 **Figure 2-13** Starches and sugars are examples of carbohydrates that are used by living things as a source of energy. The chef shown here is drying pasta, which is made principally of starch. Starches form when sugars join together in a long chain.

Macromolecules

Use Visuals

Figure 2-12 After you introduce the four types of macromolecules, have students revisit Figure 2-12. Ask: **Which type of macromolecule could this drawing represent?** (Students might say that the monomers represent different amino acids or nucleotides or sugars.) Explain that plant starch, glycogen, and cellulose contain only glucose monomers. The drawing cannot represent a lipid because lipids are not polymers. **L2**

Build Science Skills

Using Tables and Graphs Have students make a compare/contrast table entitled “Four Groups of Organic Compounds.” Column heads should read *Group Name*, *Chemical Composition*, *Examples*, and *Function in Living Things*. As students read the rest of the section, they should use the table to organize the information they learn about the groups of macromolecules. **L1 L2**

Carbohydrates

Build Science Skills

Observing Divide the class in pairs, and give each pair Lugol’s solution, a dropper, test tubes, soda crackers, and several other foods, including a potato section, white bread, oatmeal, and granulated sugar. Explain that Lugol’s solution is an indicator of starch—if the solution turns dark blue or black, starch is present. Then, have pairs test the foods for the presence of starch. For example, they should place pieces of soda crackers in a test tube, add 5 drops of Lugol’s solution, and observe whether it darkens. Students should observe that all the foods listed contain starch except granulated sugar. **L2**



UNIVERSAL ACCESS

Less Proficient Readers

Have students make a concept map of the four groups of organic molecules found in living things—carbohydrates, lipids, nucleic acids, and proteins. For each group, they should attach bubbles for structure, functions, and examples. **L1 L2**

English Language Learners

Model how to divide Vocabulary words into parts—prefix, root word, and suffix. Explain that learning the parts of words will help them analyze the meanings of long and difficult terms, such as *deoxyribonucleic acid*. **L1**

Advanced Learners

Ask students to use a high-school or college chemistry text to research how chemists communicate information about compounds, including use of molecular formulas and various structural formulas. Have students collaborate on a presentation to the class about formulas. **L3**

Answers to . . .


 **CHECKPOINT** The process in which monomers are joined together to form larger molecules called polymers

Figure 2-11 Three

Figure 2-12 Like links in a chain, monomers are either identical or closely related units that connect together to form a larger structure.

2-3 (continued)

Word Origins

The term *monosaccharide* means “single sugar”; the term *polysaccharide* means “many sugars.” **L2**

Build Science Skills

Applying Concepts Display photos of various foods that contain high amounts of carbohydrates, including milk, potatoes, and fruits. Explain that milk contains the carbohydrates lactose and galactose, fruits contain fructose, and potatoes contain starch. Ask: **What is the source of these carbohydrates?** (*Energy from sunlight*) **What function do these carbohydrates serve in living things?** (*They store energy.*) **L1 L2**

Lipids

Use Visuals

Figure 2-14 After students study the structural formula of a lipid, ask: **What are the components of a lipid?** (*Glycerol and fatty acids*) **Would you describe the lipid shown in the structural formula as saturated, unsaturated, or polyunsaturated?** (*It is unsaturated because there is a single double bond in each fatty acid chain. Fatty acids with only one double bond are called mono-unsaturated.*) Then, direct students’ attention to the photo, and ask: **Which is more likely to be polyunsaturated, a solid fat or a liquid oil?** (*Oils usually contain more unsaturated fatty acids.*) **L2**

Use Community Resources

Invite a dietician to address the class about why some fats are an important part of a healthy diet and why foods with a high fat content should be avoided. Ask the speaker to explain which fats are harmful and which aren’t and which common foods have a high content of harmful fats. Make sure students ask about saturated, unsaturated, and polyunsaturated fats in foods. **L2**

Word Origins

Monomer comes from the Greek words *monos*, meaning “single,” and *meros*, meaning “part.” *Monomer* means “single part.” The prefix *poly-* comes from the Greek word *polus*, meaning “many,” so *polymer* means “many parts.” The word *saccharide* comes from the Latin word *saccharum*, meaning “sugar.” What do you think the terms *monosaccharide* and *polysaccharide* mean?

Single sugar molecules are also called **monosaccharides** (mahn-oh-SAK-uh-rydz). Besides glucose, monosaccharides include galactose, which is a component of milk, and fructose, which is found in many fruits.

The large macromolecules formed from monosaccharides are known as **polysaccharides**. Many animals store excess sugar in a polysaccharide called glycogen, or animal starch. When the level of glucose in your blood runs low, glycogen is released from your liver. The glycogen stored in your muscles supplies the energy for muscle contraction and, thus, for movement.

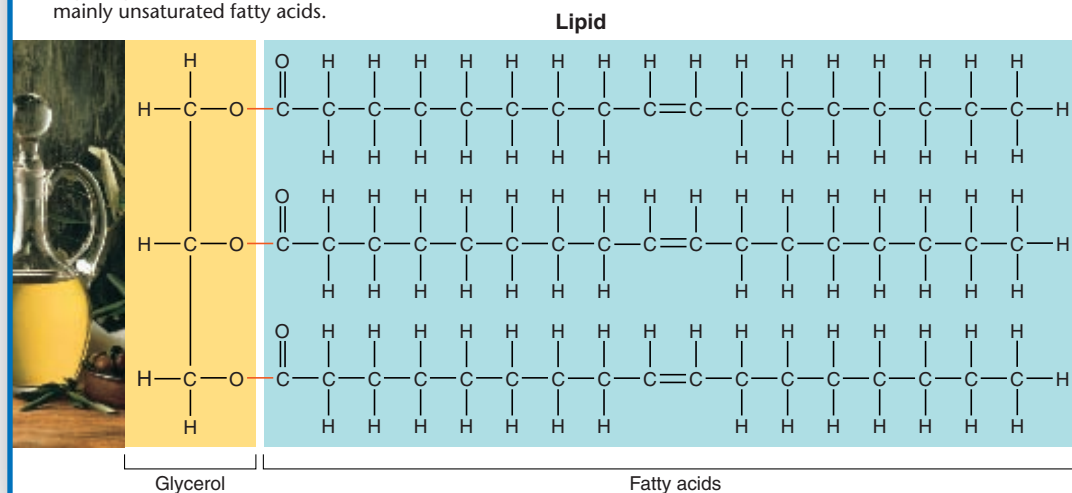
Plants use a slightly different polysaccharide, called plant starch, to store excess sugar. Plants also make another important polysaccharide called cellulose. Tough, flexible cellulose fibers give plants much of their strength and rigidity. Cellulose is the major component of both wood and paper, so you are actually looking at cellulose as you read these words!

Lipids

Lipids are a large and varied group of biological molecules that are generally not soluble in water. **Lipids** are made mostly from carbon and hydrogen atoms. The common categories of lipids are fats, oils, and waxes. **Lipids can be used to store energy. Some lipids are important parts of biological membranes and waterproof coverings.** Steroids are lipids as well. Many steroids serve as chemical messengers.

Many lipids are formed when a glycerol molecule combines with compounds called fatty acids, as shown in **Figure 2-14**. If each carbon atom in a lipid’s fatty acid chains is joined to another carbon atom by a single bond, the lipid is said to be saturated. The term *saturated* is used because the fatty acids contain the maximum possible number of hydrogen atoms.

Figure 2-14 **Lipids are used to store energy.** Lipid molecules are made up of fatty acids and glycerol. Liquid lipids, such as olive oil, contain mainly unsaturated fatty acids.



FACTS AND FIGURES

Mono-, di-, and polysaccharides


The names of carbohydrates usually end in the suffix *-ose*. This includes glucose, which is the most common monosaccharide. Its formula is $C_6H_{12}O_6$, which conforms to the general formula of all carbohydrates: $C_x(H_2O)_x$. This general formula shows the derivation of *carbohydrate*, which means “carbon hydrate.” Glucose is formed when a carbon compound, carbon dioxide, reacts with water. Monosaccharides, such as glucose, are

important nutrients for cells, as evidenced by the central role glucose has in cellular respiration. Fructose and galactose are other monosaccharides. When a covalent bond links two monosaccharides, the result is called a disaccharide. An example is lactose, a sugar in milk. Polysaccharides, which include glycogen, starch, and cellulose—the most abundant organic chemical on Earth—can contain thousands of monosaccharides linked together.

If there is at least one carbon-carbon double bond in a fatty acid, the fatty acid is said to be unsaturated. Lipids whose fatty acids contain more than one double bond are said to be polyunsaturated. If the terms *saturated* and *polyunsaturated* seem familiar, you have probably seen them on food package labels. Lipids such as olive oil, which contains unsaturated fatty acids, tend to be liquid at room temperature. Cooking oils, such as corn oil, sesame oil, canola oil, and peanut oil, contain polyunsaturated lipids.

Nucleic Acids

Nucleic acids are macromolecules containing hydrogen, oxygen, nitrogen, carbon, and phosphorus. Nucleic acids are polymers assembled from individual monomers known as nucleotides. **Nucleotides** consist of three parts: a 5-carbon sugar, a phosphate group, and a nitrogenous base, as shown in **Figure 2-15**. Individual nucleotides can be joined by covalent bonds to form a polynucleotide, or nucleic acid.

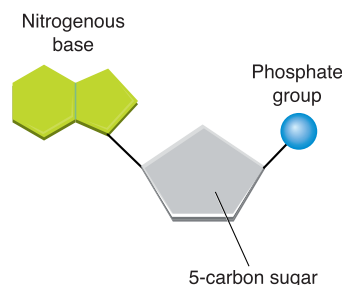
 **Nucleic acids store and transmit hereditary, or genetic, information.** There are two kinds of nucleic acids: **ribonucleic acid (RNA)** and **deoxyribonucleic acid (DNA)**. As their names indicate, RNA contains the sugar ribose and DNA contains the sugar deoxyribose.


 **CHECKPOINT** What are the three parts of a nucleotide?

Proteins

Proteins are macromolecules that contain nitrogen as well as carbon, hydrogen, and oxygen. Proteins are polymers of molecules called **amino acids**. Amino acids are compounds with an amino group ($-\text{NH}_2$) on one end and a carboxyl group ($-\text{COOH}$) on the other end.

Figure 2-16 shows one reason why proteins are among the most diverse macromolecules. More than 20 different amino acids are found in nature. All amino acids are identical in the regions where they may be joined together by covalent bonds. This uniformity allows any amino acid to be joined to any other amino acid—by bonding an amino group to a carboxyl group.



 **Figure 2-15** Nucleic acids store and transmit genetic information. The monomers that make up a nucleic acid are nucleotides. Each nucleotide has a 5-carbon sugar, a phosphate group, and a nitrogenous base.

Nucleic Acids


Build Science Skills

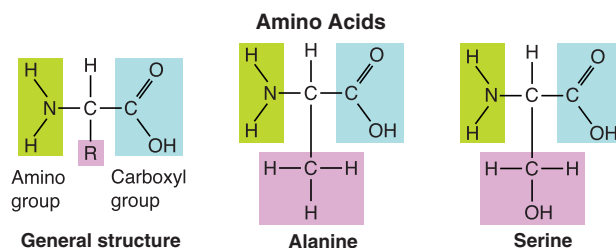
Using Analogies To help students understand nucleic acids, ask: **What are the three basic parts of a nucleotide?** (A 5-carbon sugar, a phosphate group, and a nitrogenous base) Explain that each nucleotide in DNA contains one of four nitrogenous bases—adenine, guanine, cytosine, and thymine. The sequence of the nucleotides in a DNA molecule determines the information that it contains. Point out that the English alphabet contains only 26 letters, but different combinations of letters make virtually limitless numbers of words. Likewise, different combinations of the four nucleotides make endless numbers of different DNA molecules. **L2**

Proteins

Use Visuals

Figure 2-16 Ask students: **Which parts of an amino acid are the same in every amino acid?** (The amino group, $-\text{NH}_2$, and the carboxyl group, $-\text{COOH}$) Make sure students understand what composes the R group in alanine and serine. Ask: **In what ways are R groups different?** (Some are acidic, some are basic, some are polar, and some are nonpolar.) Stress that the joining of one amino acid to another, amino group to carboxyl group, creates a product that still has an amino group on one end and a carboxyl group on the other. **L2**

 **Figure 2-16** Amino acids are the monomers of proteins. All amino acids have an amino group at one end and a carboxyl group at the other end. What distinguishes one amino acid from another is the R-group section of the molecule. **Comparing and Contrasting** How are proteins and carbohydrates similar? How are they different?



FACTS AND FIGURES

Proteins serve many functions

The word *protein* is derived from a Greek word meaning “first or primary,” and this class of molecules was so named because proteins are of “prime importance” in living things. They are so important because they have so many functions. As enzymes, they catalyze biological chemical reactions. Other proteins provide structural support, such as the protein collagen in bones and muscles. Proteins are important parts of cell

membranes, where they play a role in reaction cycles such as the citric acid cycle. Proteins such as insulin function as hormones, regulating body metabolism. Actin and myosin are the proteins responsible for muscle contraction. The antibodies that protect against foreign invaders are proteins. Some proteins function as nutrient-storage molecules. Proteins are even used as toxins by some microorganisms.

Answers to . . .


 **CHECKPOINT** A 5-carbon sugar, a phosphate group, and a nitrogenous base

Figure 2-16 Carbohydrates and proteins are both polymers. The monomers in carbohydrates are monosaccharides. The monomers in proteins are amino acids.

2–3 (continued)

Make Connections

Health Science Have students list foods that contain high amounts of protein, such as meats, fish, dairy products, and beans. Ask: **Why is it important to have an adequate amount of protein for a healthy diet?** (*Proteins perform numerous functions.*) **How can one group of compounds have so many different functions?** (*The diversity of amino acids and four levels of organization account for proteins with properties suited to a myriad of biological tasks.*) L2

3 ASSESS

Evaluate Understanding

Ask students to use their understanding of monomers, polymers, and polymerization to write an explanation of how polysaccharides, nucleic acids, and proteins are formed. They should use monosaccharides, nucleotides, and amino acids to explain polymerization.

Reteach

Ask a volunteer to explain what macromolecules are. Ask another student to list the four main groups of organic compounds found in living things. Then, call on students to explain the functions of each group of organic compounds.

Focus on the BIG Idea

Each level in a system is made up of smaller parts and is part of a larger system. For example, a nucleotide is made up of a sugar, a phosphate group, and a nitrogenous base. A nucleotide is part of a nucleic acid molecule. The nucleic acid molecule is larger and more complex than the nucleotide, which is larger and more complex than its components.

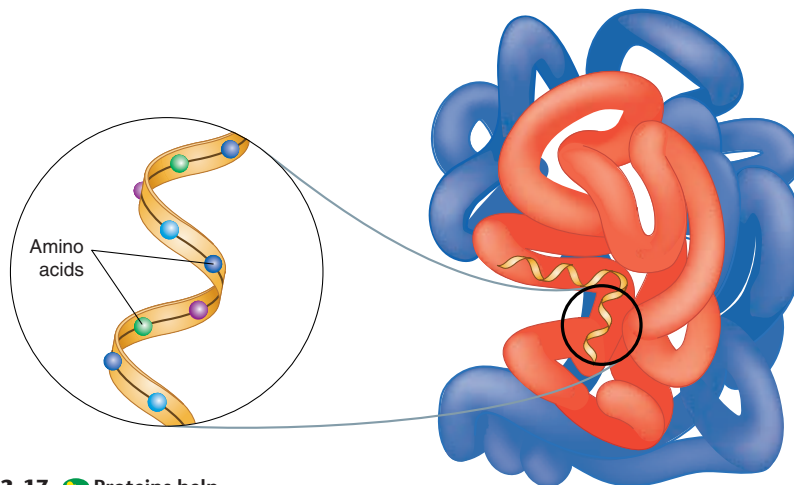


Figure 2-17 Proteins help to carry out chemical reactions, transport small molecules in and out of cells, and fight diseases. Proteins are made up of chains of amino acids folded into complex structures.

The portion of each amino acid that is different is a side chain called an R-group. Some R-groups are acidic and some are basic. Some are polar and some are nonpolar. Some contain carbon rings. The instructions for arranging amino acids into many different proteins are stored in DNA. Each protein has a specific role. **Some proteins control the rate of reactions and regulate cell processes. Some are used to form bones and muscles. Others transport substances into or out of cells or help to fight disease.**

Proteins can have up to four levels of organization. The first level is the sequence of amino acids in a protein chain. Second, the amino acids within a chain can be twisted or folded. Third, the chain itself is folded. If a protein has more than one chain, each chain has a specific arrangement in space as shown by the red and blue structures in **Figure 2-17**. Van der Waals forces and hydrogen bonds help maintain a protein's shape. In the next section, you will learn why a protein's shape is so important.

2–3 Section Assessment

Focus on the BIG Idea

Science as a Way of Knowing Use what you learned about levels of organization in Section 1–3 to discuss the levels of organization in macromolecules. Begin your discussion with the smallest structure.

- Key Concept** Name four groups of organic compounds found in living things.
- Key Concept** Describe at least one function of each group of organic compounds.
- What properties of carbon explain carbon's ability to form many different macromolecules?
- Critical Thinking Applying Concepts** Explain why proteins are considered polymers but lipids are not.
- Critical Thinking Comparing and Contrasting** Compare the structures and functions of the biomolecules lipids and starches.

2–3 Section Assessment

- Carbohydrates, lipids, nucleic acids, and proteins
- A typical response might mention that living things use carbohydrates as their main source of energy, fats can be used to store energy, nucleic acids transmit hereditary information, and proteins form tissues.
- Each carbon atom can form four covalent bonds, and carbon atoms can bond with other carbon atoms.
- Proteins are made up of amino acid monomers joined in long chains. Although fatty acid chains may be mistaken for monomers, only three fatty acids can attach to a glycerol molecule.
- Lipids are made mostly from carbon and hydrogen atoms; starch is a carbohydrate made up of carbon, hydrogen, and oxygen atoms. Both can be used to store energy.