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.

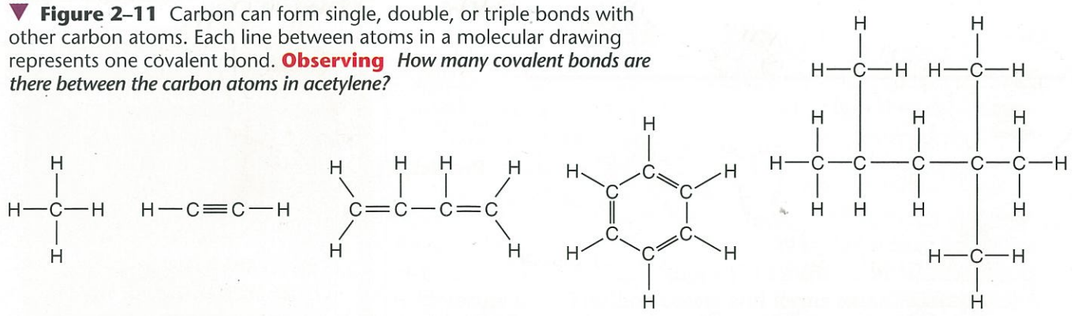
Until the early 1800s, many chemists thought that compounds created by organisms—organic compounds—were distinctly different from compounds in nonliving things. In 1828, a German chemist was able to synthesize the organic compound urea from a mineral called ammonium cyanate. Chemists soon realized that 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.

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?*



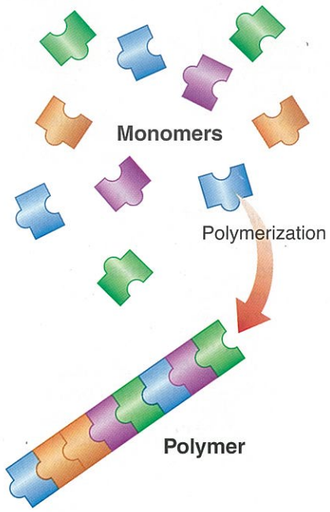
Macromolecules

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.

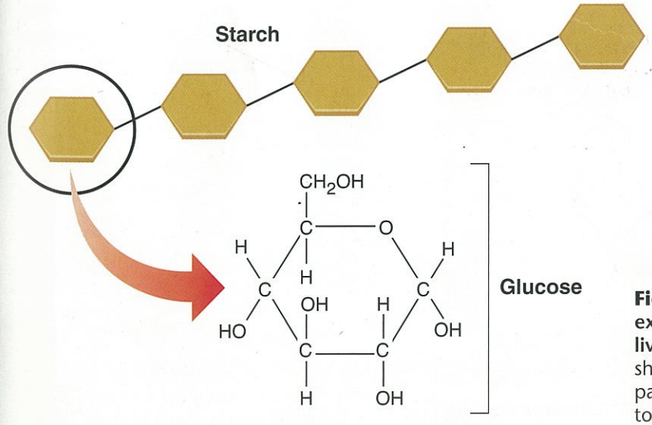
CHECKPOINT *What is polymerization?*



▲ **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?*

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.



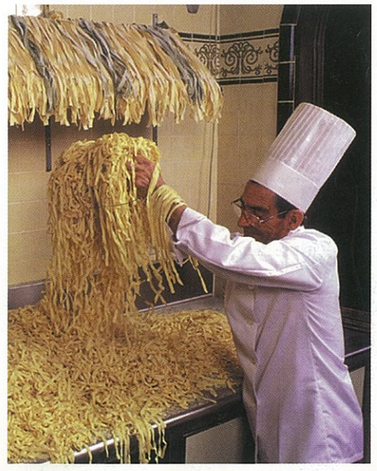


Figure 2–13 **Starches and sugars are examples of carbohydrates that are used by living things as a source of energy.** The chef shown here is drying pasta, which is made principally of starch. Starches form when sugars join together in a long chain.

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.

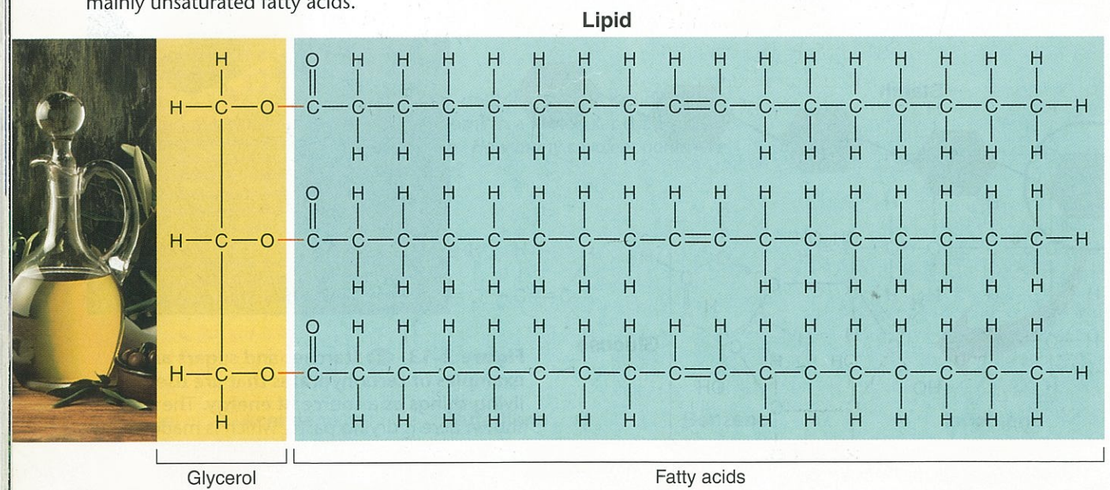
Plants use a slightly different polysaccharide, called plant starch, to store excess sugar. Plants also make another important polysaccharide called cellulose. Tough, flexible cellulose fibers give plants much of their strength and rigidity. Cellulose is the major component of both wood and paper, so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



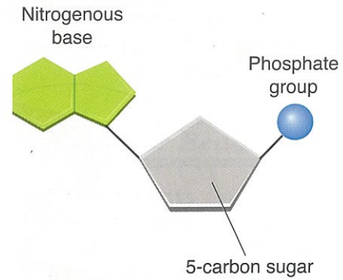
If there is at least one carbon-carbon double bond in a fatty acid, the fatty acid is said to be unsaturated. Lipids whose fatty acids contain more than one double bond are said to be polyunsaturated. If the terms *saturated* and *polyunsaturated* seem familiar, you have probably seen them on food package 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?*



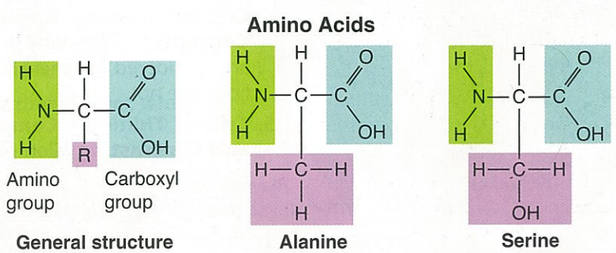
▲ **Figure 2–15** **Nucleic acids store and transmit genetic information.** The monomers that make up a nucleic acid are nucleotides. Each nucleotide has a 5-carbon sugar, a phosphate group, and a nitrogenous base.

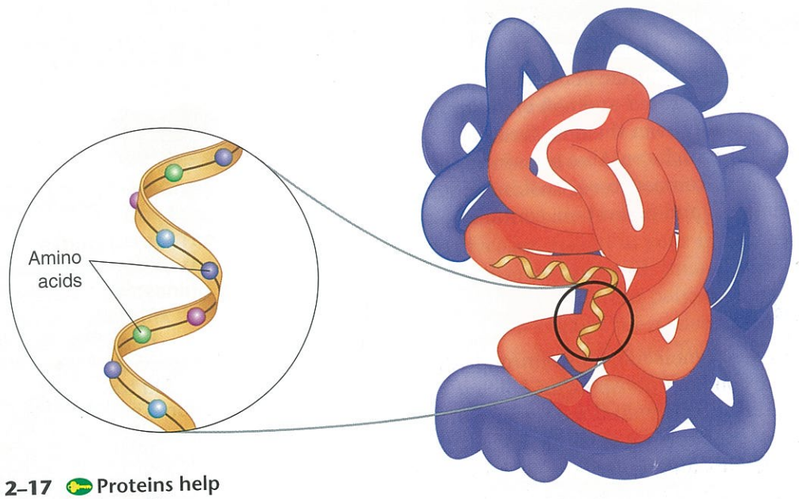
Proteins

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 ($-NH_2$) on one end and a carboxyl group (–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 2–16** 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?*





▲ **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.

Go Online SCIENCE NEWS

For: Articles on organic chemistry
Visit: PHSchool.com
Web Code: cbe-1023

2–3 Section Assessment

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

Connecting Concepts

Levels of Organization
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.

2–4 Chemical Reactions and Enzymes

Living things, as you have seen, are made of chemical compounds—some simple and some complex. The influence of chemistry doesn't stop, however, with the study of the composition of living organisms. To get the whole story, you have to look further. Chemistry isn't just what life is made of—chemistry is also what life does. Everything that happens in an organism—its growth, its interaction with the environment, its reproduction, and even its movement—is based on chemical reactions.

Chemical Reactions

A **chemical reaction** is a process that changes one set of chemicals into another set of chemicals. Some chemical reactions occur slowly, such as the combination of iron and oxygen to form an iron oxide called rust, shown in **Figure 2–18.** Other reactions occur quickly. When hydrogen gas is ignited in the presence of oxygen, the reaction is rapid and explosive. The elements or compounds that enter into a chemical reaction are known as **reactants.** The elements or compounds produced by a chemical reaction are known as **products.** **Chemical reactions always involve the breaking of bonds in reactants and the formation of new bonds in products.**

One example of an important chemical reaction that occurs in your body involves carbon dioxide. Your cells constantly produce carbon dioxide as a normal part of their activity. This carbon dioxide is carried to your lungs through the bloodstream, and then is eliminated as you exhale. However, carbon dioxide is not very soluble in water. The bloodstream could not possibly dissolve enough carbon dioxide to carry it away from your tissues were it not for a chemical reaction. As it enters the blood, carbon dioxide reacts with water to produce a highly soluble compound called carbonic acid, H_2CO_3.

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

The reaction shown above enables the bloodstream to carry carbon dioxide to the lungs. In the lungs, the reaction is reversed.

$$H_2CO_3 \longrightarrow CO_2 + H_2O$$

This reverse reaction produces carbon dioxide gas, which is released as you exhale.

▶ **Figure 2–18** **Chemical reactions always involve changes in chemical bonds.** The iron in these chain links gradually combined with oxygen to produce a compound known as rust.

Guide for Reading

Key Concepts
- What happens to chemical bonds during chemical reactions?
- How do energy changes affect whether a chemical reaction will occur?
- Why are enzymes important to living things?

Vocabulary
chemical reaction
reactant
product
activation energy
catalyst
enzyme
substrate

Reading Strategy: Building Vocabulary
After you read, write a phrase or sentence in your own words to define or describe each boldface term.