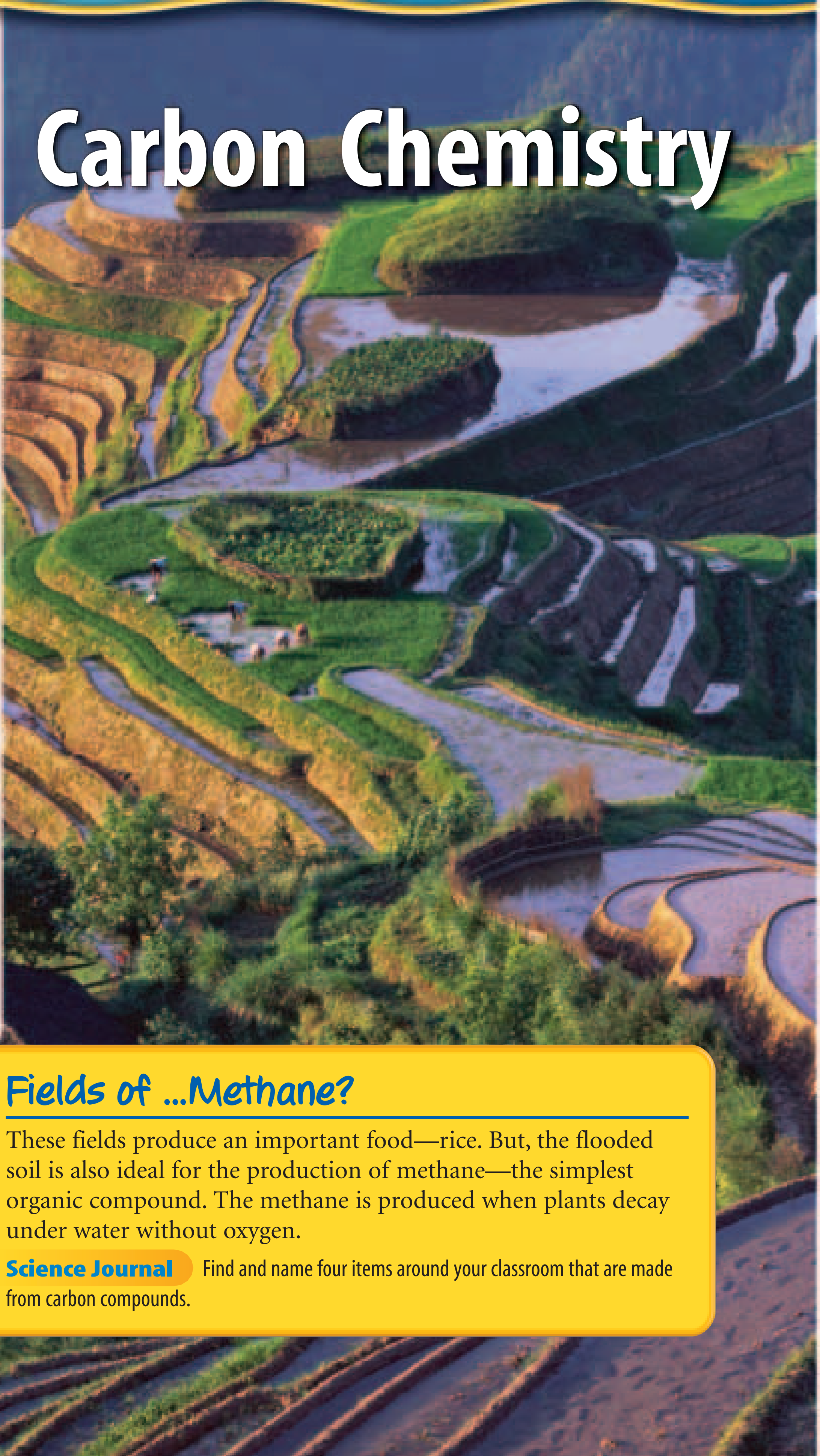
chapter

9

Carbon Chemistry



The BIG Idea

All living things are made of carbon-containing compounds.

SECTION 1
Simple Organic Compounds
Main Idea Carbon can form covalent bonds with four other atoms including other carbon atoms.

SECTION 2
Other Organic Compounds
Main Idea Substituted hydrocarbons are formed when hydrogen atoms are replaced by groups of atoms.

SECTION 3
Biological Compounds
Main Idea Proteins, carbohydrates, and lipids are biological compounds formed from chains or rings of carbon atoms.

Fields of ...Methane?

These fields produce an important food—rice. But, the flooded soil is also ideal for the production of methane—the simplest organic compound. The methane is produced when plants decay under water without oxygen.

Science Journal Find and name four items around your classroom that are made from carbon compounds.

Ariel Skelley/Masterfile

Start-Up Activities

Launch LAB

Model Carbon's Bonding

Many of the compounds that compose your body and other living things are carbon compounds. This lab demonstrates some of the atomic combinations possible with one carbon and four other atoms. The ball represents a carbon atom. The toothpicks represent chemical bonds.

WARNING: *Do not eat any foods from this lab. Wash your hands before and after this lab.*

1. Insert four toothpicks into a small clay or plastic foam ball so they are evenly spaced around the sphere.
2. Make models of as many molecules as possible by adding raisins, grapes, and gumdrops to the ends of the toothpicks. Use raisins to represent hydrogen atoms, grapes to represent chlorine atoms, and gumdrops to represent fluorine atoms.
3. **Think Critically** Draw each model and write the formula for it in your Science Journal. What can you infer about the number of compounds a carbon atom can form?

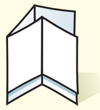
Science Online — Preview this chapter's content and activities at ips.msscience.com

FOLDABLES™ Study Organizer

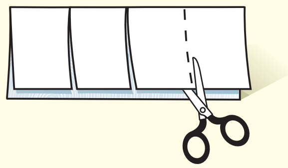
Hydrocarbons Make the following Foldable to help you learn the definitions of vocabulary words. This will help you understand the chapter content.

STEP 1 **Fold** a sheet of paper in half lengthwise. Make the back edge about 1.25 cm longer than the front edge.

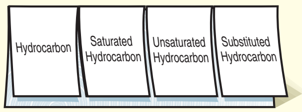
STEP 2 **Fold** in half, then fold in half again to make three folds.



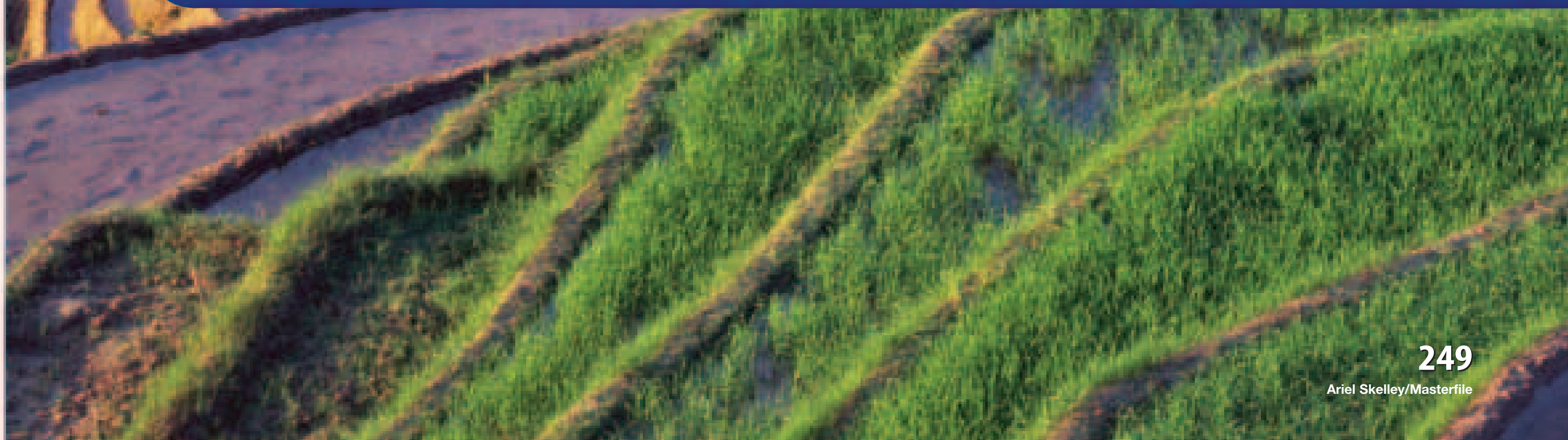
STEP 3 **Unfold and cut** only the top layer along the three folds to make four tabs.



STEP 4 **Label** the tabs as shown.



Find Main Ideas As you read the chapter, find the definitions for each vocabulary word and write them under the appropriate tabs. Add additional words and definitions to help you understand your reading. List examples of each type of hydrocarbon under the appropriate tab.



Ariel Skelley/Masterfile

Get Ready to Read

Make Connections

1 Learn It! Make connections between what you read and what you already know. Connections can be based on personal experiences (text-to-self), what you have read before (text-to-text), or events in other places (text-to-world).

As you read, ask connecting questions. Are you reminded of a personal experience? Have you read about the topic before? Did you think of a person, a place, or an event in another part of the world?

2 Practice It! Read the excerpt below and make connections to your own knowledge and experience.

Text-to-self:
Have you ever snapped together blocks in different arrangements?

Text-to-self:
What is an organic molecule?

Text-to-self:
Have you ever used a product that contained butane or isobutane?

Suppose you had ten blocks that could be snapped together in different arrangements. Each arrangement of the same ten blocks is different. The atoms in an organic molecule also can have different arrangements but still have the same molecular formula. Compounds that have the same molecular formula but different arrangements, or structures, are called **isomers** (I suh murz). Two isomers, butane and isobutane, are shown in Figure 7.

— *from page 254*

3 Apply It! As you read this chapter, choose five words or phrases that make a connection to something you already know.

Target Your Reading

Reading Tip

Make connections with things that you use or see every day.

Use this to focus on the main ideas as you read the chapter.

1. **Before you read** the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.
   - Write an **A** if you **agree** with the statement.
   - Write a **D** if you **disagree** with the statement.

2. **After you read** the chapter, look back to this page to see if you've changed your mind about any of the statements.
   - If any of your answers changed, explain why.
   - Change any false statements into true statements.
   - Use your revised statements as a study guide.

Before You Read A or D	Statement		After You Read A or D
	1	Only living things can make carbon compounds.	
	2	Hydrogen atoms often bond with carbon to form compounds.	
	3	Simple sugars are the building blocks of proteins.	
	4	Carbon atoms can form single, double, and triple covalent bonds.	
	5	The suffix in the name of an organic compound indicates the kind of bonds joining the carbon atoms.	
	6	Unsaturated fats contain only single covalent bonds.	
	7	Sugars, starches, and cellulose are carbohydrates.	
	8	Alcohols contain the hydroxyl group.	
	9	Carboxylic acids and amino acids contain nitrogen.	

Science Online
Print out a worksheet of this page at ips.msscience.com

section 1

Simple Organic Compounds

as you read

What You'll Learn

- **Explain** why carbon is able to form many compounds.
- **Describe** how saturated and unsaturated hydrocarbons differ.
- **Identify** isomers of organic compounds.

Why It's Important

Plants, animals, and many of the things that are part of your life are made of organic compounds.

Review Vocabulary

chemical bond: force that holds two atoms together

New Vocabulary

- organic compound
- hydrocarbon
- saturated hydrocarbon
- unsaturated hydrocarbon
- isomer

Organic Compounds

Earth's crust contains less than one percent carbon, yet all living things on Earth are made of carbon-containing compounds. Carbon's ability to bond easily and form compounds is the basis of life on Earth. A carbon atom has four electrons in its outer energy level, so it can form four covalent bonds with as many as four other atoms. When carbon atoms form four covalent bonds, they obtain the stability of a noble gas with eight electrons in their outer energy level. One of carbon's most frequent partners in forming covalent bonds is hydrogen.

Substances can be classified into two groups—those derived from living things and those derived from nonliving things, as shown in **Figure 1.** Most of the substances associated with living things contain carbon and hydrogen. These substances were called organic compounds, which means "derived from a living organism." However, in 1828, scientists discovered that living organisms are not necessary to form organic compounds. Despite this, scientists still use the term **organic compound** for most compounds that contain carbon.

Reading Check *What is the origin of the term organic compound?*

Figure 1 Most substances can be classified as living or nonliving things.

Living things and products made from living things such as this wicker chair contain carbon.

Most of the things in this photo are nonliving and are composed of elements other than carbon.

Hydrocarbons

Many compounds are made of only carbon and hydrogen. A compound that contains only carbon and hydrogen atoms is called a **hydrocarbon.** The simplest hydrocarbon is methane, the primary component of natural gas. If you have a gas stove or gas furnace in your home, methane usually is the fuel that is burned in these appliances. Methane consists of a single carbon atom covalently bonded to four hydrogen atoms. The formula for methane is CH_4. **Figure 2** shows a model of the methane molecule and its structural formula. In a structural formula, the line between one atom and another atom represents a pair of electrons shared between the two atoms. This pair forms a single bond. Methane contains four single bonds.

Now, visualize the removal of one of the hydrogen atoms from a methane molecule, as in **Figure 3A.** A fragment of the molecule called a methyl group, $-CH_3$, would remain. The methyl group then can form a single bond with another methyl group. If two methyl groups bond with each other, the result is the two-carbon hydrocarbon ethane, C_2H_6, which is shown with its structural formula in **Figure 3B.**

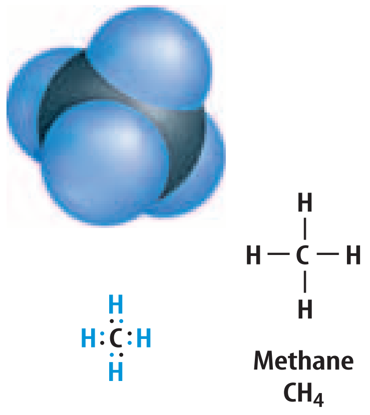
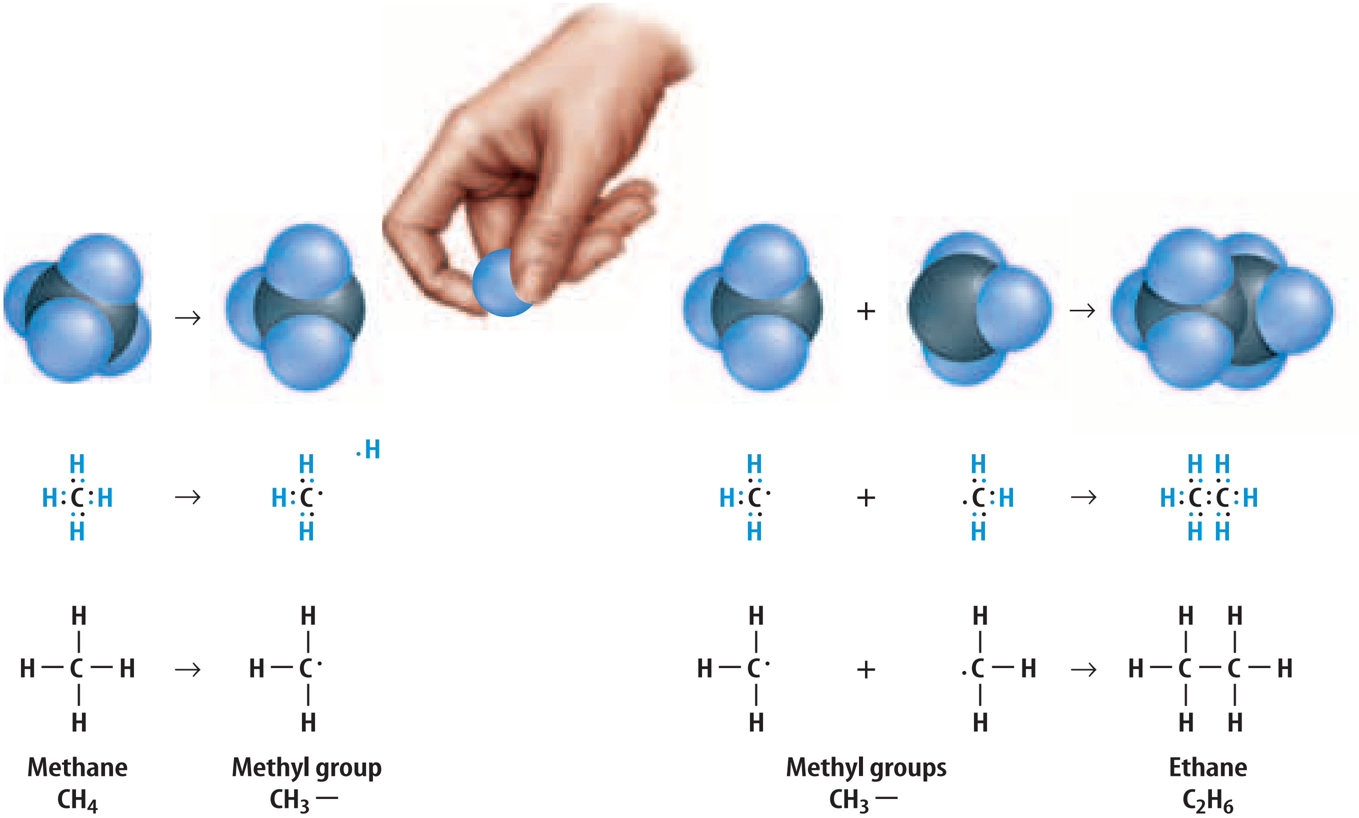


Figure 2 Methane is the simplest hydrocarbon molecule.
Explain *why this is true.*

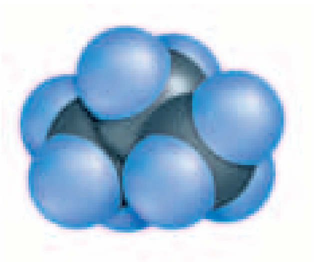
Figure 3 Here's a way to visualize how larger hydrocarbons are built up.

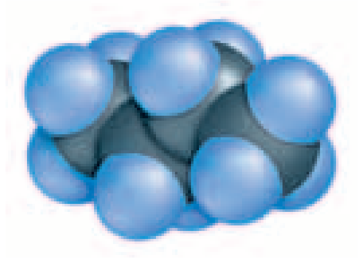


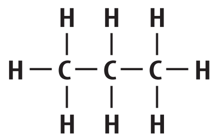
A A hydrogen is removed from a methane molecule, forming a methyl group.

B Each carbon atom in ethane has four bonds after the two methyl groups join.

Figure 4 Propane and butane are two useful fuels. **Explain** *why they are called "saturated."*

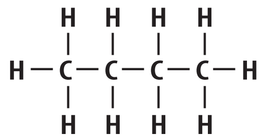






Propane
C_3H_8

When propane burns, it releases energy as the chemical bonds are broken. Propane often is used to fuel camp stoves and outdoor grills.



Butane
C_4H_{10}

Butane also releases energy when it burns. Butane is the fuel that is used in disposable lighters.

Saturated Hydrocarbons Methane and ethane are members of a series of molecules in which carbon and hydrogen atoms are joined by single covalent bonds. When all the bonds in a hydrocarbon are single bonds, the molecule is called a **saturated hydrocarbon.** It is called *saturated* because no additional hydrogen atoms can be added to the molecule. The carbon atoms are saturated with hydrogen atoms. The formation of larger hydrocarbons occurs in a way similar to the formation of ethane. A hydrogen atom is removed from ethane and replaced by a $-CH_3$ group. Propane, with three carbon atoms, is the third member of the series of saturated hydrocarbons. Butane has four carbon atoms. Both of these hydrocarbons are shown in **Figure 4.** The names and the chemical formulas of a few of the smaller saturated hydrocarbons are listed in **Table 1.** Saturated hydrocarbons are named with an *-ane* ending. Another name for these hydrocarbons is alkanes.

Reading Check *What is a saturated hydrocarbon?*

These short hydrocarbon chains have low boiling points, so they evaporate and burn easily. That makes methane a good fuel for your stove or furnace. Propane is used in gas grills, lanterns, and to heat air in hot-air balloons. Butane often is used as a fuel for camp stoves and lighters. Longer hydrocarbons are found in oils and waxes. Carbon can form long chains that contain hundreds or even thousands of carbon atoms. These extremely long chains make up many of the plastics that you use.

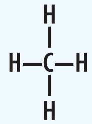
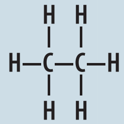
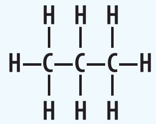
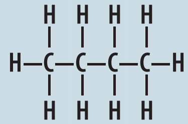
INTEGRATE Earth Science

Hydrocarbons Petroleum is a mixture of hydrocarbons that formed from plants and animals that lived in seas and lakes hundreds of millions of years ago. With the right temperature and pressure, this plant and animal matter, buried deep under Earth's surface, decomposed to form petroleum. Why is petroleum a nonrenewable resource?

Unsaturated Hydrocarbons Carbon also forms hydrocarbons with double and triple bonds. In a double bond, two pairs of electrons are shared between two atoms, and in a triple bond, three pairs of electrons are shared. Hydrocarbons with double or triple bonds are called **unsaturated hydrocarbons.** This is because the carbon atoms are not saturated with hydrogen atoms.

Ethene, the simplest unsaturated hydrocarbon, has two carbon atoms joined by a double bond. Propene is an unsaturated hydrocarbon with three carbons. Some unsaturated hydrocarbons have more than one double bond. Butadiene (byew tuh DI een) has four carbon atoms and two double bonds. The structures of ethene, propene, and butadiene are shown in **Figure 5.**

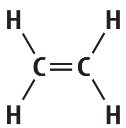
Table 1 The Structures of Hydrocarbons

Name	Structural Formula	Chemical Formula
Methane		CH_4
Ethane		C_2H_6
Propane		C_3H_8
Butane		C_4H_{10}

Unsaturated compounds with at least one double bond are named with an *-ene* ending. Notice that the names of the compounds below have an *-ene* ending. These compounds are called alkenes.

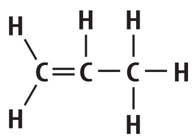
Reading Check *What type of bonds are found in unsaturated hydrocarbons?*

Figure 5 You'll find unsaturated hydrocarbons in many of the products you use every day.



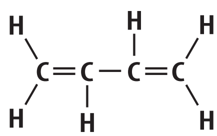
Ethene

Ethene helps ripen fruits and vegetables. It's also used to make milk and soft-drink bottles.



Propene

This detergent bottle contains the tough plastic polypropylene, which is made from propene.



Butadiene

Butadiene made it possible to replace natural rubber with synthetic rubber.

Figure 6 In the welder's torch, ethyne, also called acetylene, is combined with oxygen to form a mixture that burns, releasing intense light and heat. The two carbon atoms in ethyne are joined by a triple bond.

$$H-C\equiv C-H$$

Ethyne or Acetylene
C_2H_2

Mini LAB

Modeling Isomers

Procedure

WARNING: *Do not eat any foods in this lab.*

1. Construct a model of pentane, C_5H_{12}. Use **toothpicks** for covalent bonds and small balls of different **colored clay or gumdrops** for carbon and hydrogen atoms.
2. Using the same materials, build a molecule with a different arrangement of the atoms. Are there any other possibilities?
3. Make a model of hexane, C_6H_{14}.
4. Arrange the atoms of hexane in different ways.

Analysis

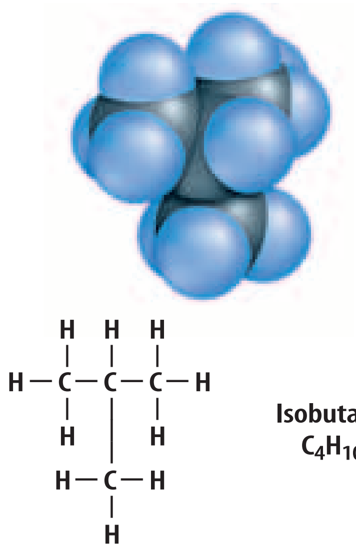
1. How many isomers of pentane did you build? How many isomers of hexane?
2. Do you think there are more isomers of heptane, C_7H_{16}, than hexane? Explain.

Try at Home

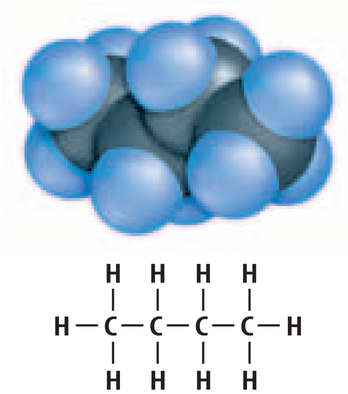
Triple Bonds Unsaturated hydrocarbons also can have triple bonds, as in the structure of ethyne (EH thine) shown in **Figure 6.** Ethyne, commonly called acetylene (uh SE tuh leen), is a gas used for welding because it produces high heat as it burns. Welding torches mix acetylene and oxygen before burning. These unsaturated compounds are called alkynes.

Hydrocarbon Isomers Suppose you had ten blocks that could be snapped together in different arrangements. Each arrangement of the same ten blocks is different. The atoms in an organic molecule also can have different arrangements but still have the same molecular formula. Compounds that have the same molecular formula but different arrangements, or structures, are called **isomers** (I suh murz). Two isomers, butane and isobutane, are shown in **Figure 7.** They have different chemical and physical properties because of their different structures. As the size of a hydrocarbon molecule increases, the number of possible isomers also increases.

By now, you might be confused about how organic compounds are named. **Figure 8** explains the system that is used to name simple organic compounds.



Isobutane
C_4H_{10}



Butane
C_4H_{10}

Figure 7 Butane and isobutane both have four carbons and ten hydrogens but their structures and properties are different.

Ted Horowitz/The Stock Market/CORBIS

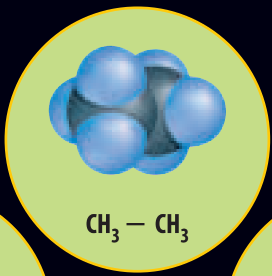
NATIONAL GEOGRAPHIC

VISUALIZING ORGANIC CHEMISTRY NOMENCLATURE

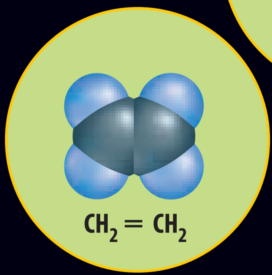
Figure 8

More than one million organic compounds have been discovered and created, and thousands of new ones are synthesized in laboratories every year. To keep track of all these carbon-containing molecules, the International Union of Pure and Applied Chemistry, or IUPAC, devised a special naming system (a nomenclature) for organic compounds. As shown here, different parts of an organic compound's name—its root, suffix, or prefix—give information about its size and structure.

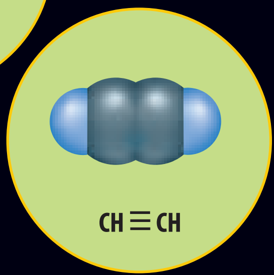
Carbon atoms	Name	Molecular formula
1	Methane	CH_4
2	Ethane	CH_3CH_3
3	Propane	$CH_3CH_2CH_3$
4	Butane	$CH_3CH_2CH_2CH_3$
5	Pentane	$CH_3CH_2CH_2CH_2CH_3$
6	Hexane	$CH_3CH_2CH_2CH_2CH_2CH_3$
7	Heptane	$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$
8	Octane	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$
9	Nonane	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$
10	Decane	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$



Ethane



Ethene



Ethyne

ROOT WORDS The key to every name given to a compound in organic chemistry is its root word. This word tells how many carbon atoms are found in the longest continuous carbon chain in the compound. Except for compounds with one to four carbon atoms, the root word is based on Greek numbers.

SUFFIXES The suffix of the name for an organic compound indicates the kind of covalent bonds joining the compound's carbon atoms. If the atoms are joined by single covalent bonds, the compound's name will end in *-ane*. If there is a double covalent bond in the carbon chain, the compound's name ends in *-ene*. Similarly, if there is a triple bond in the chain, the compound's name will end in *-yne*.

PREFIXES The prefix of the name for an organic compound describes how the carbon atoms in the compound are arranged. Organic molecules that have names with the prefix *cyclo-* contain a ring of carbon atoms. For example, cyclopentane contains five carbon atoms all joined by single bonds in a ring.

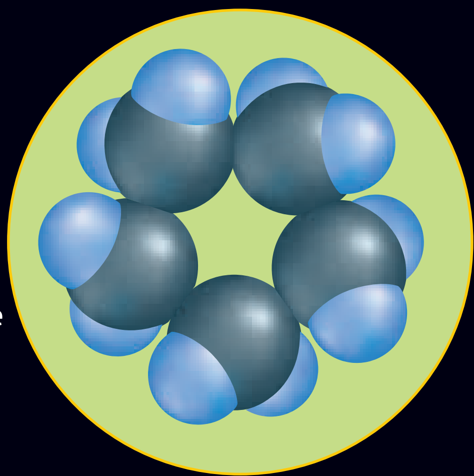
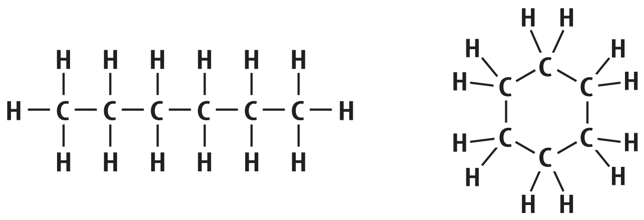

Cyclopentane

Figure 9 Visualize a hydrogen atom removed from a carbon atom on both ends of a hexane chain. The two end carbons form a bond with each other. **Describe** *how the chemical formula changes.*



Hexane C_6H_{14}

Cyclohexane C_6H_{12}

Topic: Cyclohexane

Visit ips.msscience.com for Web links to information about the manufacturing and the uses of cyclohexane.

Activity List the physical properties of cyclohexane. How does it compare with the physical properties of hexane?

Hydrocarbons in Rings You might be thinking that all hydrocarbons are chains of carbon atoms with two ends. Some molecules contain rings. You can see the structures of two different molecules in **Figure 9.** The carbon atoms of hexane bond together to form a closed ring containing six carbons. Each carbon atom still has four bonds. The prefix *cyclo-* in their names tells you that the molecules are cyclic, or ring shaped.

Ring structures are not uncommon in chemical compounds. Many natural substances such as sucrose, glucose, and fructose are ring structures. Ring structures can contain one or more double bonds.

Reading Check *What does the prefix* cyclo- *tell you about a molecule?*

section 1 review

Summary

Organic Compounds

- All living things contain carbon.
- Carbon atoms form covalent bonds.

Hydrocarbons

- Hydrocarbons are compounds that contain only hydrogen and carbon.
- The simplest hydrocarbon is methane.
- Saturated hydrocarbons are compounds that contain only single covalent bonds.
- Unsaturated hydrocarbons are compounds that form double and triple bonds.

Isomers

- Isomers are compounds that have the same molecular formula but different structures.
- Isomers also have different chemical and physical properties.

Self Check

1. **Describe** a carbon atom.
2. **Identify** Give one example of each of the following: a compound with a single bond, a compound with a double bond, and a compound with a triple bond. Write the chemical formula and draw the structure for each.
3. **Draw** all the possible isomers for heptane, C_7H_{16}.
4. **Think Critically** Are propane and cylcopropane isomers? Draw their structures. Use the structures and formulas to explain your answer.

Applying Math

5. **Make and Use Graphs** From **Table 1,** plot the number of carbon atoms on the *x*-axis and the number of hydrogen atoms on the *y*-axis. Predict the formula for the saturated hydrocarbon that has 11 carbon atoms.

section 2

Other Organic Compounds

Substituted Hydrocarbons

Suppose you pack an apple in your lunch every day. One day, you have no apples, so you substitute a pear. When you eat your lunch, you'll notice a difference in the taste and texture of your fruit. Chemists make substitutions, too. They change hydrocarbons to make compounds called substituted hydrocarbons. To make a substituted hydrocarbon, one or more hydrogen atoms are replaced by atoms such as halogens or by groups of atoms. Such changes result in compounds with chemical properties different from the original hydrocarbon. When one or more chlorine atoms are added to methane in place of hydrogens, new compounds are formed. **Figure 10** shows the four possible compounds formed by substituting chlorine atoms for hydrogen atoms in methane.

as you read

What You'll Learn

- **Describe** how new compounds are formed by substituting hydrogens in hydrocarbons.
- **Identify** the classes of compounds that result from substitution.

Why It's Important

Many natural and manufactured organic compounds are formed by replacing hydrogen with other atoms.

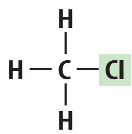
Review Vocabulary

chemical formula: chemical shorthand that uses symbols to tell what elements are in a compound and their ratios

New Vocabulary

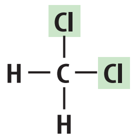
- hydroxyl group
- carboxyl group
- amino group
- amino acid

Chloromethane contains a single chlorine atom.



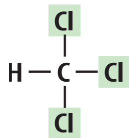
CH_3Cl

Dichloromethane contains two chlorine atoms. This is used in some paint and varnish removers.



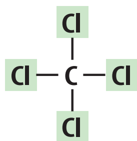
CH_2Cl_2

Trichloromethane, or chloroform, has three chlorine atoms. It is used in the production of fluoropolymers—one of the raw materials used to make nonstick coating.



$CHCl_3$

Carbon tetrachloride is a fully substituted methane molecule with four chlorines.



CCl_4

Figure 10 Chlorine can replace hydrogen atoms in methane.

(l)Gary A. Conner/PhotoEdit/PictureQuest, (r)Stephen Frisch/Stock Boston/PictureQuest

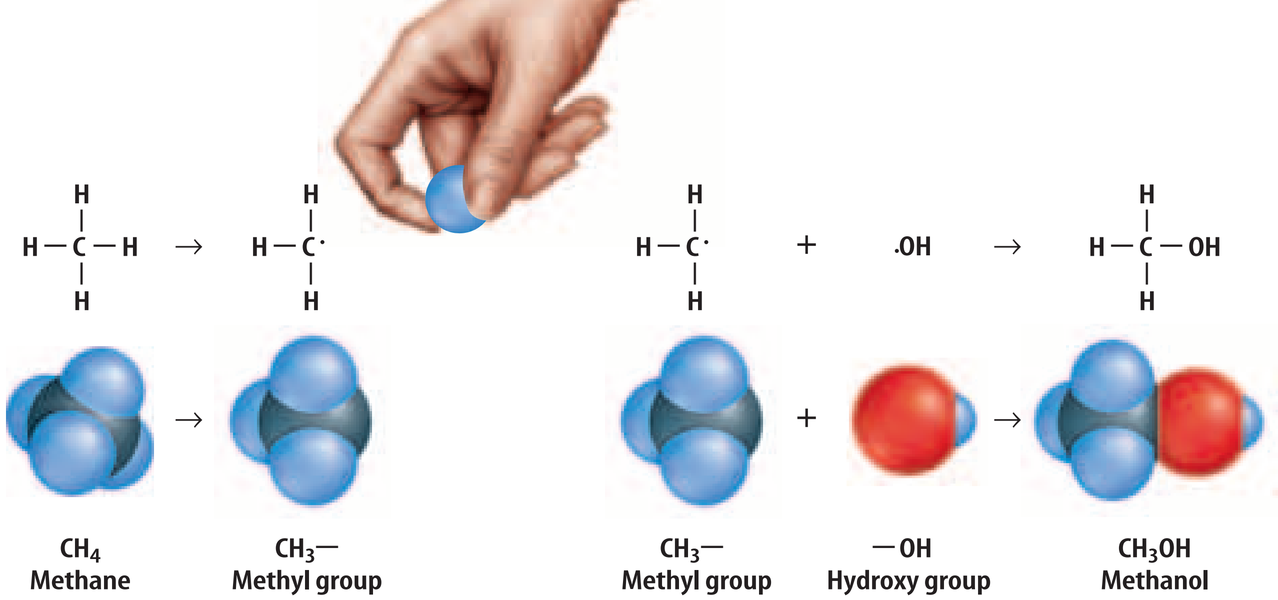


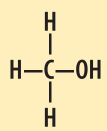
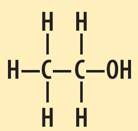
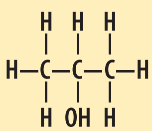
Figure 11 After the methane molecule loses one of its hydrogen atoms, it has an extra electron to share, as does the hydroxyl group. **Identify** *the type of bond formed.*

Alcohols Groups of atoms also can be added to hydrocarbons to make different compounds. The **hydroxyl** (hi DROK sul) **group** is made up of an oxygen atom and a hydrogen atom joined by a covalent bond. A hydroxyl group is represented by the formula —OH. An alcohol is formed when a hydroxyl group replaces a hydrogen atom in a hydrocarbon. **Figure 11** shows the formation of the alcohol methanol. A hydrogen atom in the methane molecule is replaced by a hydroxyl group.

Reading Check *What does the formula* —OH *represent?*

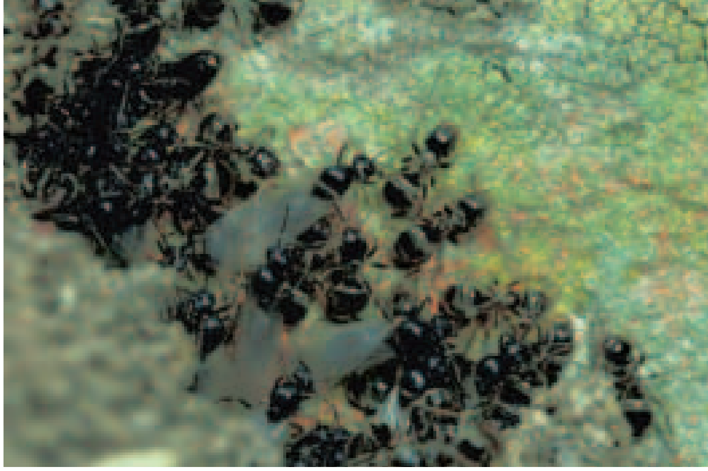
Larger alcohol molecules are formed by adding more carbon atoms to the chain. Ethanol is an alcohol produced naturally when sugar in corn, grains, and fruit ferments. It is a combination of ethane, which contains two carbon atoms, and an —OH group. Its formula is C_2H_5OH. Isopropyl alcohol forms when the hydroxyl group is substituted for a hydrogen atom on the middle carbon of propane rather than one of the end carbons. **Table 2** lists three alcohols with their structures and uses. You've probably used isopropyl alcohol to disinfect injuries. Did you know that ethanol can be added to gasoline and used as a fuel for your car?

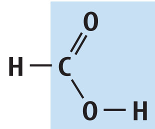
Table 2 Common Alcohols

Uses	 Methanol	 Ethanol	 Isopropyl Alcohol
Fuel	yes	yes	no
Cleaner	yes	yes	yes
Disinfectant	no	yes	yes
Manufacturing chemicals	yes	yes	yes

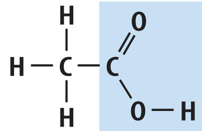
Carboxylic Acids Have you ever tasted vinegar? Vinegar is a solution of acetic acid and water. You can think of acetic acid as the hydrocarbon methane with a carboxyl (car BOK sul) group substituted for a hydrogen. A **carboxyl group** consists of a carbon atom that has a double bond with one oxygen atom and a single bond with a hydroxyl group. Its formula is −COOH. When a carboxyl group is substituted in a hydrocarbon, the substance formed is called a carboxylic acid. The simplest carboxylic acid is formic acid. Formic acid consists of a single hydrogen atom and a carboxyl group. You can see the structures of formic acid and acetic acid in **Figure 12.**

You probably can guess that many other carboxylic acids are formed from longer hydrocarbons. Many carboxylic acids occur in foods. Citric acid is found in citrus fruits such as oranges and grapefruit. Lactic acid is present in sour milk. Acetic acid dissolved in water—vinegar—often is used in salad dressings.





Methanoic, or formic, acid
HCOOH

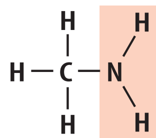


Ethanoic, or acetic, acid
CH_3COOH

Figure 12 *Crematogaster* ants make the simplest carboxylic acid, formic acid. Notice the structure of the −COOH group.
Describe *how the structures of formic acid and acetic acid differ.*

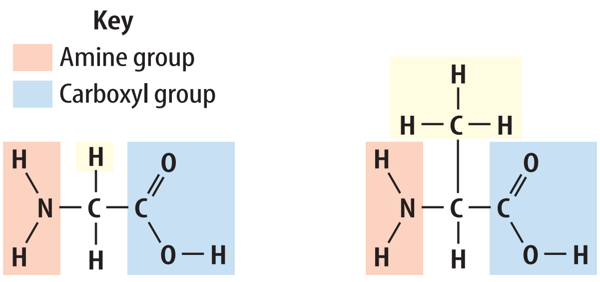
Amines Substituted hydrocarbons, called amines, formed when an amino (uh ME noh) group replaces a hydrogen atom. An **amino group** is a nitrogen atom joined by covalent bonds to two hydrogen atoms. It has the formula $-NH_2$. Methylamine, shown in **Figure 13,** is formed when one of the hydrogens in methane is replaced with an amino group. A more complex amine is the novocaine dentists once used to numb your mouth during dental work. Amino groups are important because they are a part of many biological compounds that are essential for life. When an amino group bonds with one additional hydrogen atom, the result is ammonia, NH_3.

Amino Acids You have seen that a carbon group can be substituted onto one end of a chain to make a new molecule. It's also possible to substitute groups on both ends of a chain and even to replace hydrogen atoms bonded to carbon atoms in the middle of a chain. When both an amino group ($-NH_2$) and a carboxyl acid group (−COOH) replace hydrogens on the same carbon atom in a molecule, a type of compound known as an **amino acid** is formed. Amino acids are essential for human life.



Methylamine
CH_3NH_2

Figure 13 Complex amines account for the strong smells of cheeses such as these.



Glycine   Alanine

Figure 14 The 20 amino acids needed for protein synthesis each contain a central carbon atom bonded to an amine group, a hydrogen atom, and a carboxyl group. The fourth bond, shown in yellow, is different for each amino acid.

The Building Blocks of Protein

Amino acids are the building blocks of proteins, which are an important class of biological molecules needed by living cells. Twenty different amino acids bond in different combinations to form the variety of proteins that are needed in the human body. Glycine and alanine are shown in **Figure 14.** Glycine is the simplest amino acid. It is a methane molecule in which one hydrogen atom has been replaced by an amine group and another has been replaced by a carboxyl group. The other 19 amino acids are formed by replacing the yellow highlighted hydrogen atom with different groups. For example, in alanine, one hydrogen atom is replaced by a methyl ($-CH_3$) group.

Reading Check ***What are the building blocks of protein?***

Some amino acids, such as glycine and alanine, are manufactured within the human body. They are called nonessential amino acids. This means that it is not essential to consume these types of amino acids. More than half of the twenty amino acids are considered nonessential. The essential amino acids, those that must be consumed, are obtained by eating protein-rich foods. These foods include meat, eggs, and milk.

section 2 review

Summary

Substituted Hydrocarbons

- A substituted hydrocarbon has one or more hydrogen atoms replaced.
- The chemical properties of the substituted hydrocarbon are different from the original hydrocarbon.

Types of Substitutions

- Alcohols are made when a hydroxyl group is substituted for a hydrogen atom.
- Carboxylic acids are formed when the carboxyl group is substituted for a hydrogen atom.
- When an amino group is substituted for hydrogen, an amine is formed.
- Amino acids have both an amino group and a carboxyl group.
- Twenty amino acids are building blocks of proteins needed in the human body.

Self Check

1. **Draw** Tetrafluoroethylene is a substituted hydrocarbon in which all four of the hydrogen atoms are replaced by fluorine. Draw the structural formula for this molecule.
2. **Describe** how the 20 amino acids differ from each other.
3. **Identify** Starting with a hexane molecule, C_6H_{14}, draw and label each new molecule when adding an alcohol group, a carboxylic group, and an amino group.
4. **Think Critically** The formula for one compound that produces the odor in skunk spray is $CH_3CH_2CH_2CH_2SH$. Draw and examine the structural formula. Does it fit the definition of a substituted hydrocarbon? Explain.

Applying Skills

5. **Define** Compounds in which hydrogen atoms have been replaced by chlorine and fluorine atoms are known as chlorofluorocarbons (CFCs). Draw the structures of the four CFCs using CH_4 as the starting point.

Science Online ips.msscience.com/self_check_quiz

LAB

Conversion of Alcohols

Have you ever wondered how chemists change one substance into another? In this lab, you will change an alcohol into an acid.

Real-World Question

What changes occur when ethanol is exposed to conditions like those produced by exposure to air and bacteria?

Goals

- **Observe** a chemical change in an alcohol.
- **Infer** the product of the chemical change.

Materials

test tube and stopper
test-tube rack
pH test paper
10-mL graduated cylinders (2)
dropper
0.01*M* potassium permanganate solution (1 mL)
6.0*M* sodium hydroxide solution (1 mL)
ethanol (3 drops)

Safety Precautions

WARNING: *Handle these chemicals with care. Immediately flush any spills with water and call your teacher. Keep your hands away from your face.*

Procedure

1. Measure 1 mL of potassium permanganate solution and pour it into a test tube. Carefully measure 1 mL of sodium hydroxide solution and add it to the test tube.
2. With your teacher's help, dip a piece of pH paper into the mixture in the test tube. Record the result in your Science Journal.

Alcohol Conversion

Procedure Step	Observations
Step 2	
Step 3	Do not write in this book.
Step 4	
Step 5	

3. Add three drops of ethanol to the test tube. Put a stopper on the test tube and gently shake it for one minute. Record any changes.
4. Place the test tube in a test-tube rack. Observe and record any changes you notice during the next five minutes.
5. Test the sample with pH paper again. Record what you observe.
6. Your teacher will dispose of the solutions.

Conclude and Apply

1. **Analyze Results** Did a chemical reaction take place? What leads you to infer this?
2. **Predict** Alcohols can undergo a chemical reaction to form carboxylic acids in the presence of potassium permanganate. If the alcohol used is ethanol, what would you predict to be the chemical formula of the acid produced?

Communicating Your Data

Compare your conclusions with other students in your class. **For more help, refer to the Science Skill Handbook.**

section 3

Biological Compounds

as you read

What You'll Learn

- **Describe** how large organic molecules are made.
- **Explain** the roles of organic molecules in the body.
- **Explain** why eating a balanced diet is important for good health.

Why It's Important

Polymers are organic molecules that are important to your body processes and everyday living.

Review Vocabulary

chemical reaction: process that produces chemical change, resulting in new substances that have properties different from those of the original substances

New Vocabulary

- polymer
- monomer
- polymerization
- protein
- carbohydrate
- sugars
- starches
- lipids
- cholesterol

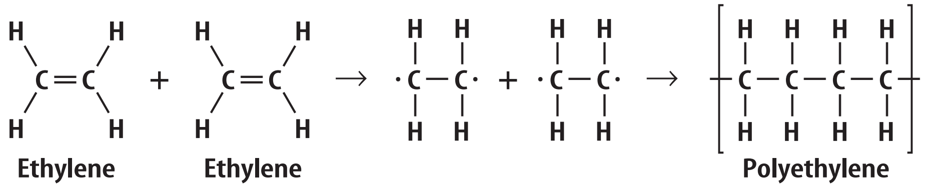
What's a polymer?

Now that you know about some simple organic molecules, you can begin to learn about more complex molecules. One type of complex molecule is called a polymer (PAH luh mur). A **polymer** is a molecule made up of many small organic molecules linked together with covalent bonds to form a long chain. The small, organic molecules that link together to form polymers are called **monomers.** Polymers can be produced by living organisms or can be made in a laboratory. Polymers produced by living organisms are called natural polymers. Polymers made in a laboratory are called synthetic polymers.

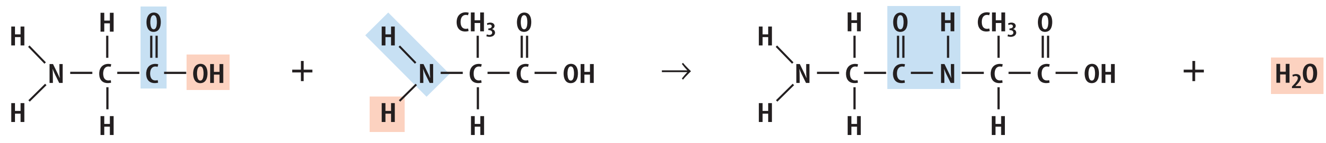
Reading Check *What is a polymer, and how does it resemble a chain?*

To picture what polymers are, it is helpful to start with small synthetic polymers. You use such polymers every day. Plastics, synthetic fabrics, and nonstick surfaces on cookware are polymers. The unsaturated hydrocarbon ethylene, C_2H_4, is the monomer of a common polymer used often in plastic bags. The monomers are bonded together in a chemical reaction called **polymerization** (puh lih muh ruh ZAY shun). As you can see in **Figure 15,** the double bond breaks in each ethylene molecule. The two carbon atoms then form new bonds with carbon atoms in other ethylene molecules. This process is repeated many times and results in a much larger molecule called polyethylene. A polyethylene molecule can contain 10,000 ethylene units.

Figure 15 Small molecules called monomers link into long chains to form polymers.



The carbon atoms that were joined by the double bond each have an electron to share with another carbon in another molecule of ethylene. The process goes on until a long molecule is formed.



Glycine Alanine

Figure 16 Both ends of an amino acid can link with other amino acids.
Identify *the molecule that is released in the process.*

Proteins are Polymers

You've probably heard about proteins when you've been urged to eat healthful foods. A **protein** is a polymer that consists of a chain of individual amino acids linked together. Your body cannot function properly without them. Proteins in the form of enzymes serve as catalysts and speed up chemical reactions in cells. Some proteins make up the structural materials in ligaments, tendons, muscles, cartilage, hair, and fingernails. Hemoglobin, which carries oxygen through the blood, is a protein polymer, and all body cells contain proteins.

The various functions in your body are performed by different proteins. Your body makes many of these proteins by assembling 20 amino acids in different ways. Nine of the amino acids that are needed to make proteins cannot be produced by your body. These amino acids, which are called essential amino acids, must come from the food you eat. That's why you need to eat a diet containing protein-rich foods, like those in **Table 3.**

The process by which your body converts amino acids to proteins is shown in **Figure 16.** In this reaction, the amino group of the amino acid alanine forms a bond with the carboxyl group of the amino acid glycine, and a molecule of water is released. Each end of this new molecule can form similar bonds with another amino acid. The process continues in this way until the amino acid chain, or protein, is complete.

Reading Check *How is an amino acid converted to protein?*

Table 3 Protein Content (Approximate)

Foods	Protein Content (g)
Chicken breast (113 g)	28
Eggs (2)	12
Whole milk (240 mL)	8
Peanut butter (30 g)	8
Kidney beans (127 g)	8

Mini LAB

Summing Up Protein

Procedure

1. Make a list of the foods you ate during the last 24 h.
2. Use the data your teacher gives you to find the total number of grams of protein in your diet for the day. Multiply the grams of protein in one serving of food by the number of units of food you ate. The recommended daily allowance (RDA) of protein for girls 11 to 14 years old is 46 g per day. For boys 11 to 14 years old, the RDA is 45 g per day.

Analysis

1. Was your total greater or less than the RDA?
2. Which of the foods you ate supplied the largest amount of protein? What percent of the total grams of protein did that food supply?

Figure 17 These foods contain a high concentration of carbohydrates.

Carbohydrates

The day before a race, athletes often eat large amounts of foods containing carbohydrates like the ones in **Figure 17.** What's in pasta and other foods like bread and fruit that gives the body a lot of energy? These foods contain sugars and starches, which are members of the family of organic compounds called carbohydrates. A **carbohydrate** is an organic compound that contains only carbon, hydrogen, and oxygen, usually in a ratio of two hydrogen atoms to one oxygen atom. In the body, carbohydrates are broken down into simple sugars that the body can use for energy. The different types of carbohydrates are divided into groups—sugars, starches, and cellulose.

Table 4 below gives some approximate carbohydrate content for some of the common foods.

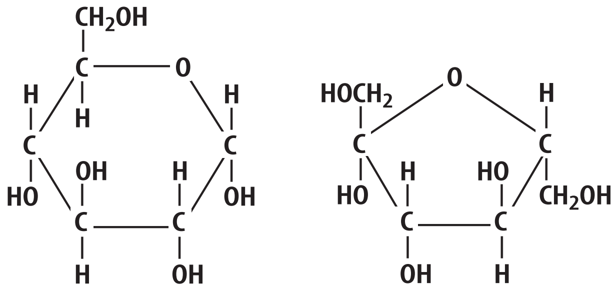
INTEGRATE Career

Nutrition Science A dietician studies the science of nutrition. Their main focus is to help people maintain good health and prevent and control disease through the foods they eat. Dieticians assess the individual's nutritional needs and build a dietary program specifically to meet these needs. Dieticians work in a variety of fields from schools and company cafeterias to hospitals and nursing homes.

Table 4 Carbohydrates in Foods (Approximate)

Foods	Carbohydrate Content (g)
Apple (1)	21
White rice ($\frac{1}{2}$ cup)	17
Baked potato ($\frac{1}{2}$ cup)	15
Wheat bread (1 slice)	13
Milk (240 mL)	12

Figure 18 Glucose and fructose are simple six-carbon carbohydrates found in many fresh and packaged foods. Glucose and fructose are isomers.
Explain *why they are isomers.*

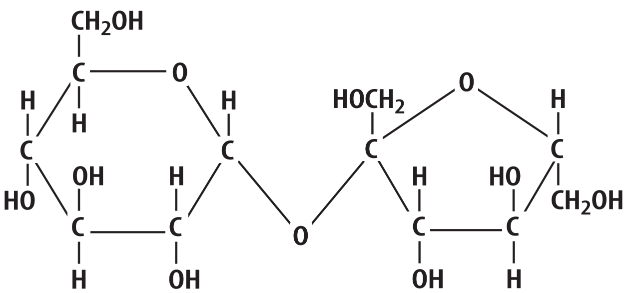


Glucose   Fructose

Sugars If you like chocolate-chip cookies or ice cream, then you're familiar with sugars. They are the substances that make fresh fruits and candy sweet. Simple **sugars** are carbohydrates containing five, six, or seven carbon atoms arranged in a ring. The structures of glucose and fructose, two common simple sugars, are shown in **Figure 18.** Glucose forms a six-carbon ring. It is found in many naturally sweet foods, such as grapes and bananas. Fructose is the sweet substance found in ripe fruit and honey. It often is found in corn syrup and added to many foods as a sweetener. The sugar you probably have in your sugar bowl or use in baking a cake is sucrose. Sucrose, shown in **Figure 19,** is a combination of the two simple sugars glucose and fructose. In the body, sucrose cannot move through cell membranes. It must be broken down into glucose and fructose to enter cells. Inside the cells, these simple sugars are broken down further, releasing energy for cell functions.

Starches Starches are large carbohydrates that exist naturally in grains such as rice, wheat, corn, potatoes, lima beans, and peas. **Starches** are polymers of glucose monomers in which hundreds or even thousands of glucose molecules are joined together. Because each sugar molecule releases energy when it is broken down, starches are sources of large amounts of energy.

Figure 19 Sucrose is a molecule of glucose combined with a molecule of fructose.
Identify *What small molecule must be added to sucrose when it separates to form the two six-carbon sugars?*



Sucrose

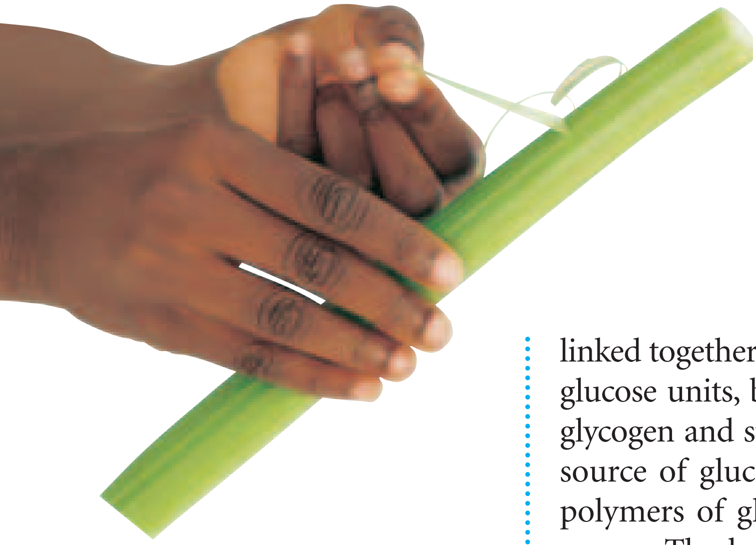


Figure 20 Your body cannot chemically break down the long cellulose fibers in celery, but it needs fiber to function properly.

Other Glucose Polymers Two other important polymers that are made up of glucose molecules are cellulose and glycogen. Cellulose makes up the long, stiff fibers found in the walls of plant cells, like the strands that pull off the celery stalk in **Figure 20.** It is a polymer that consists of long chains of glucose units linked together. Glycogen is a polymer that also contains chains of glucose units, but the chains are highly branched. Animals make glycogen and store it mainly in their muscles and liver as a ready source of glucose. Although starch, cellulose, and glycogen are polymers of glucose, humans can't use cellulose as a source of energy. The human digestive system can't convert cellulose into sugars. Grazing animals, such as cows, have special digestive systems that allow them to break down cellulose into sugars.

Reading Check *How do the location and structure of glycogen and cellulose differ?*

Applying Science

Which foods are best for quick energy?

Foods high in carbohydrates are sources of energy.

Identifying the Problem

The chart shows some foods and their carbohydrate count. Look at the differences in how much energy they might provide, given their carbohydrate count.

Solving the Problem

1. Create a high-energy meal with the most carbohydrates. Include one choice from each category. Create another meal that contains a maximum of 60 g of carbohydrates.
2. Meat and many vegetables have only trace amounts of carbohydrates. How many grams of carbohydrates would a meal of turkey, stuffing, lettuce salad, and lemonade contain?

Carbohydrate Counts for Common Foods

Main Dish		Side Dish		Drink	
two slices wheat bread	26 g	fudge brownie	25 g	orange juice	27 g
macaroni and cheese	29 g	apple	21 g	cola	38 g
two pancakes	28 g	baked beans	27 g	sweetened iced tea	22 g
chicken and noodles	39 g	blueberry muffin	27 g	lemon-lime soda	38 g
hamburger with bun	34 g	cooked carrots	8 g	hot cocoa	25 g
hot oatmeal	25 g	banana	28 g	apple juice	29 g
plain bagel	38 g	baked potato	34 g	lemonade	28 g
bran flakes with raisins	47 g	stuffing	22 g	whole milk	12 g
lasagna	50 g	brown rice	22 g	chocolate milk	26 g
spaghetti with marinara	50 g	corn on the cob	14 g	sports drink	24 g

Lipids

A **lipid** is an organic compound that contains the same elements as carbohydrates—carbon, hydrogen, and oxygen—but in different proportions. They are the reaction products of glycerol, which has three –OH groups and three long-chain carboxylic acids, as pictured in **Figure 21.** Lipids are in many of the foods you eat such as the ones shown in **Figure 22.** Lipids are commonly called fats and oils, but they also are found in greases and waxes such as beeswax. Wax is a lipid, but it is harder than fat because of its chemical composition. Bees secrete wax from a gland in the abdomen to form beeswax, which is part of the honeycomb.

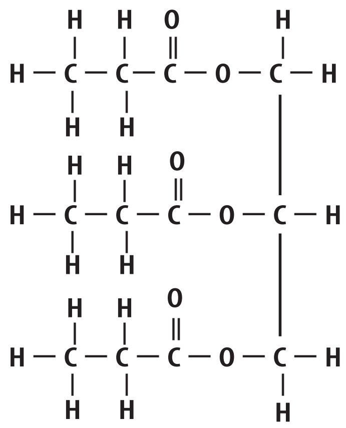


Figure 21 Lipids consist of two parts—glycerol and three molecules of carboxylic acid.
Identify *which portion is from glycerol and which portion is from carboxylic acid.*

Lipids Store Energy Lipids store energy in their bonds, just as carbohydrates do, but they are a more concentrated source of energy than carbohydrates. If you eat more food than your body needs to supply you with the energy for usual activities, the excess energy from the food is stored by producing lipids.

How can energy be stored in a molecule? The chemical reaction that produces lipids is endothermic. An endothermic reaction is one in which energy is absorbed. This means that energy is stored in the chemical bonds of lipids. When your body needs energy, the bonds are broken and energy is released. This process protects your body when you need extra energy or when you might not be able to eat. If you regularly eat more food than you need, large amounts of lipids will be produced and stored as fat on your body.

Science Online
Topic: Lipids
Visit ips.msscience.com for Web links to information about your body's requirement for lipids.

Activity Lipids (fats) are important to your body's dietary needs. Make a table of saturated and unsaturated lipids that you consume. Try to list a total of ten.

Reading Check ***What is a lipid and how does your body use lipids to store energy?***

Figure 22 Many of the foods that you eat contain fats and oils, which are lipids.

KS Studios

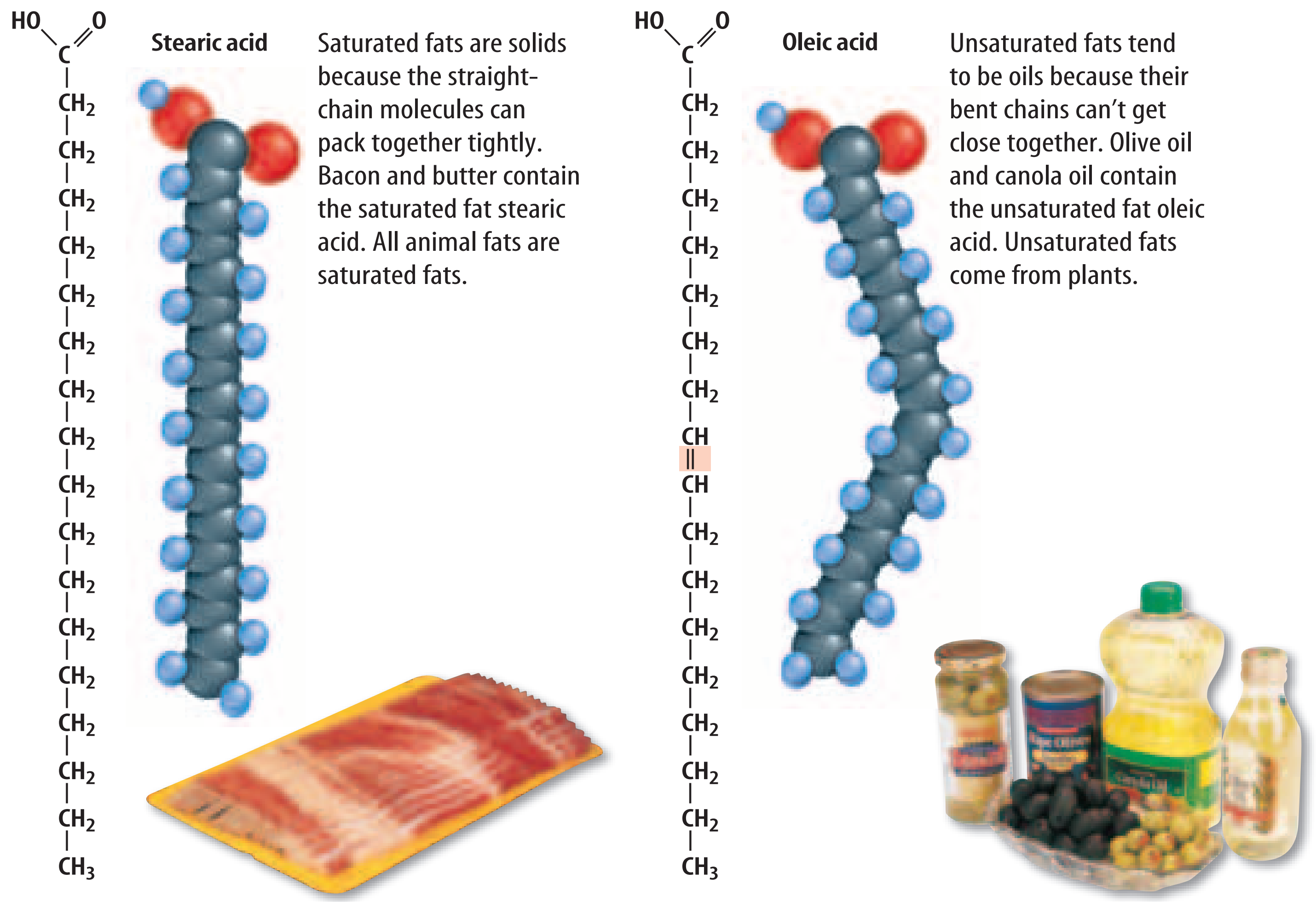


Figure 23 Whether a lipid is a liquid or a solid depends on the type of bonds it has.

Saturated and Unsaturated Lipids Not all lipids are the same. Recall the difference between saturated and unsaturated hydrocarbons. Unsaturated molecules have one or more double or triple bonds between carbon atoms. Lipid molecules also can be saturated or unsaturated. As you can see in **Figure 23,** when a lipid is saturated, the acid chains are straight because all the bonds are single bonds. They are able to pack together closely. A compact arrangement of the molecules is typical of a solid such as margarine or shortening. These solid lipids consist mainly of saturated fats.

When a lipid is unsaturated, as in **Figure 23,** the molecule bends wherever there is a double bond. This prevents the chains from packing close together, so these lipids tend to be liquid oils such as olive or corn oil.

Doctors have observed that people who eat a diet high in saturated fats have an increased risk of developing cardiovascular problems such as heart disease. The effect of saturated fat seems to be increased blood cholesterol, which may be involved in the formation of deposits on artery walls. Fortunately, many foods containing unsaturated fats are available. Making wise choices in the foods that you eat can help keep your body healthy.

Cholesterol

Cholesterol is a complex lipid that is present in foods that come from animals, such as meat, butter, eggs, and cheese. However, cholesterol is not a fat. Even if you don't eat foods containing cholesterol, your body makes its own supply. Your body needs cholesterol for building cell membranes. Cholesterol is not found in plants, so oils derived from plants are free of cholesterol. However, the body can convert fats in these oils to cholesterol.

Deposits of cholesterol, called plaque, can build up on the inside walls of arteries. This condition, known as atherosclerosis, is shown in **Figure 24.** When arteries become clogged, the flow of blood is restricted, which results in high blood pressure. This, in turn, can lead to heart disease. Although the cause of plaque build up on the inside walls of arteries is unknown, limiting the amount of saturated fat and cholesterol might help to lower cholesterol levels in the blood and might help reduce the risk of heart problems.

Heart disease is a major health concern in the United States. As a result, many people are on low-cholesterol diets. What types of foods should people choose to lower their cholesterol level?

Figure 24 This view of an artery shows atherosclerosis, a dangerous condition in which arteries in the body become clogged. Deposits build up on the inside walls of the artery, leaving less room for blood to flow.

Reading Check *What is atherosclerosis and why is this condition dangerous?*

section 3 review

Summary

Polymers and Proteins

- A polymer is a molecule made up of small, repeating units.
- The small molecules that link together to form a polymer are called monomers.
- A protein is a polymer that consists of individual amino acids linked together.

Carbohydrates, Lipids, and Cholesterol

- Carbohydrates and lipids are organic compounds that contain carbon, hydrogen, and oxygen.
- Lipids store energy in their bonds.
- Unsaturated lipids have one or more double or triple bonds between carbon atoms.
- Cholesterol is a complex lipid.

Self Check

1. **Define** the process by which proteins are made. What other product is formed along with a protein molecule?
2. **Explain** how carbohydrates, proteins, and lipids are important to body functions.
3. **Analyze** how cellulose, starch, and glycogen are different.
4. **Describe** how your body obtains and uses cholesterol.
5. **Think Critically** Explain why even people who eat a healthful diet might gain weight if they don't get enough exercise.

Applying Skills

6. **Draw a Conclusion** Polyunsaturated fats are recommended for a healthful diet. Using what you know about lipids, what might *polyunsaturated* mean?

Science Online ips.msscience.com/self_check_quiz

LAB

Looking for Vitamin C

Goals
- **Prepare** an indicator solution.
- **Verify** a positive test by using a known material.
- **Apply** the test to various foods.
- **Infer** some foods your diet should contain.

Possible Materials
starch solution
iodine solution
vitamin-C solution
water
droppers (10)
15-mL test tubes (10)
test-tube rack
250-mL beaker
stirrer
10-mL graduated cylinder
mortar and pestle
liquid foods such as milk, orange juice, vinegar, and cola
solid foods such as tomatoes, onions, citrus fruits, potatoes, bread, salt, and sugar

Safety Precautions


WARNING: *Do not taste any materials used in the lab. Use care when mashing food samples.*

Real-World Question


Vitamin C is essential to humans for good health and the prevention of disease. Your body cannot produce this necessary organic molecule, so you must consume it in your food. How do you know which foods are good sources of vitamin C? Reactions that cause color changes are useful as chemical tests. This activity uses the disappearance of the dark-blue color of a solution of starch and iodine to show the presence of vitamin C. Can you test foods for vitamin C? Could the starch-iodine solution be used to show the presence of vitamin C in food?

Procedure
1. Collect all the materials and equipment you will need.
2. Obtain 10 mL of the starch solution from your teacher.
3. Add the starch solution to 200 mL of water in a 250-mL beaker. Stir.
4. Add four drops of iodine solution to the beaker to make a dark-blue indicator solution. Stir in the drops.

(t)Geoff Butler, (b)Aaron Haupt

5. Obtain your teacher's approval of your indicator solution before proceeding.
6. **Measure** and place 5 mL of the indicator solution in a clean test tube.
7. Obtain 5 mL of vitamin-C solution from your teacher.
8. Using a clean dropper, add one drop of the vitamin-C solution to the test tube. Stir. Continue adding drops and stirring until you notice a color change. Place a piece of white paper behind the test tube to show the color clearly. Record the number of drops added and any observations.

9. Using a clean test tube and dropper for each test, repeat steps 6 through 8, replacing the vitamin-C solution with other liquids and solids. Add drops of liquid foods or juices until a color change is noted or until you have added about 40 drops of the liquid. Mash solid foods such as onion and potato. Add about 1 g of the food directly to the test tube and stir. Test at least four liquids and four solids.
10. Record the amount of each food added and observations in a table.

Analyze Your Data

1. **Infer** What indicates a positive test for vitamin C? How do you know?
2. **Describe** a negative test for vitamin C.
3. **Observe** Which foods tested positive for vitamin C? Which foods, if any, tested negative for vitamin C?

Conclude and Apply

1. **Explain** which foods you might include in your diet to make sure you get vitamin C every day.
2. **Determine** if a vitamin-C tablet could take the place of these foods. Explain.

Communicating Your Data

Compare your results with other class members. Were your results consistent? Make a record of the foods you eat for two days. Does your diet contain the minimum RDA of vitamin C?

Aaron Haupt

From Plants to Medicine

Wild plants help save lives

Look carefully at those plants growing in your backyard or neighborhood. With help from scientists, they could save a life. Many of the medicines that doctors prescribe were first developed from plants. For example, aspirin was extracted from the bark of a willow tree. A cancer medication was extracted from the bark of the Pacific yew tree. Aspirin and the cancer medication are now made synthetically—their carbon structures are duplicated in the lab and factory.

Throughout history, and in all parts of the world, traditonal healers have used different parts of plants and flowers to help treat people. Certain kinds of plants have been mashed up and applied to the body to heal burns and sores, or have been swallowed or chewed to help people with illnesses.

Modern researchers are studying the medicinal value of plants and then figuring out the plants' properties and makeup. This is giving scientists important information as they turn to more and more plants to help make medicine in the lab. Studying these plants—and how people in different cultures use them—is the work of scientists called ethnobotanists (eth noh BAH tuhn ihsts). Ethnobotanist Memory Elvin-Lewis notes that plants help treat illnesses.

Promising cancer medications are made from the bark of the Pacific yew tree.

She visits healers who show her the plants that they find most useful. "Plants are superior chemists producing substances with sophisticated molecular structures that protect the plant from injury and disease," writes Professor Michele L. Trankina. It's these substances in plants that are used as sources of medicines. And it's these substances that are giving researchers and chemists leads to making similar substances in the lab. That can only mean good news—and better health—for people!

Memory Elvin-Lewis has spent part of her career studying herbal medicines.

Investigate **Research the work of people like Carole L. Cramer. She's modifying common farm plants so that they produce human antibodies used to treat human illnesses. Use the link on the right or your school's media center to get started in your search.**

Science Online

For more information, visit ips.msscience.com/time

Reviewing Main Ideas

Section 1 Simple Organic Compounds

1. Hydrocarbons are compounds containing only carbon and hydrogen.
2. If a hydrocarbon has only single bonds, it is called a saturated hydrocarbon.
3. Unsaturated hydrocarbons have one or more double or triple bonds in their structure.

Section 2 Other Organic Compounds

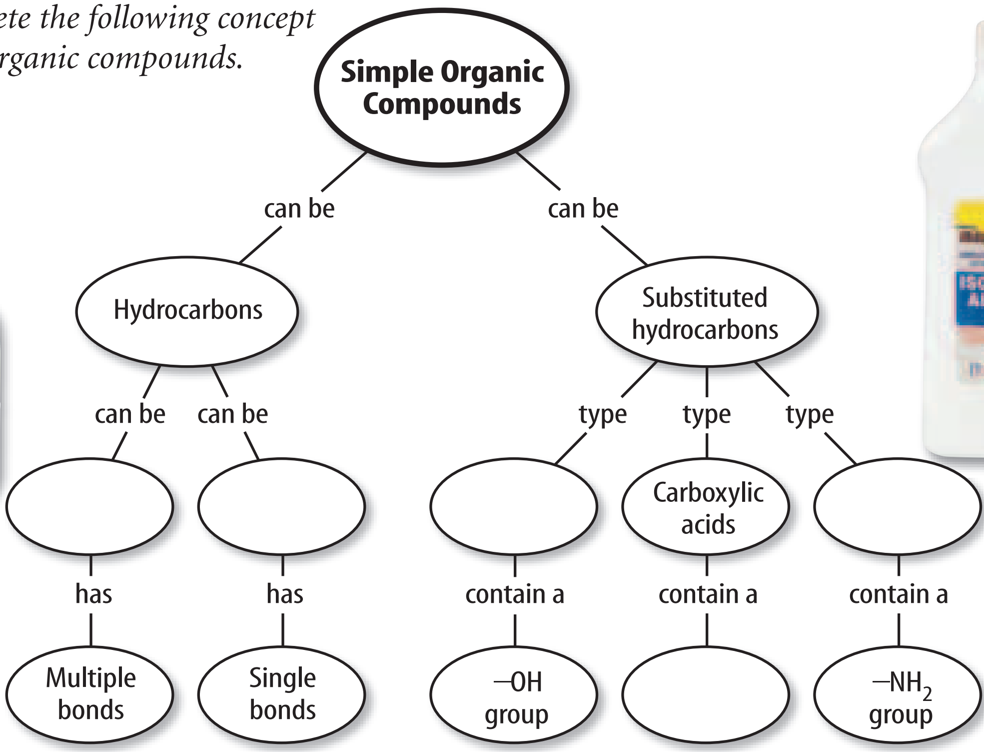
1. Hydrogens can be substituted with other atoms or with groups of atoms.
2. An amino acid contains an amino group and a carboxyl group substituted on the same carbon atom.
3. An alcohol is formed when a hydroxyl group is substituted for a hydrogen atom in a hydrocarbon.
4. A carboxylic acid is made when a carboxyl group is substituted and an amine is formed when an amino group ($-NH_2$) is substituted.

Section 3 Biological Compounds

1. Many biological compounds are large molecules called polymers.
2. Proteins serve a variety of functions, including catalyzing many cell reactions.
3. Carbohydrates and lipids are energy sources and the means of storing energy.

Visualizing Main Ideas

Copy and complete the following concept map on simple organic compounds.



Science Online ips.msscience.com/interactive_tutor

Aaron Haupt

chapter 9 Review

Using Vocabulary

amino acid p. 259	organic compound p. 250
amino group p. 259	polymer p. 262
carbohydrate p. 264	polymerization p. 262
carboxyl group p. 259	protein p. 263
cholesterol p. 269	saturated hydrocarbon p. 252
hydrocarbon p. 251	starches p. 265
hydroxyl group p. 258	sugars p. 265
isomer p. 254	unsaturated hydrocarbon p. 253
lipid p. 267	
monomer p. 262	

Answer the following questions using complete sentences.

1. Explain the difference between an amino group and an amino acid.
2. How does a hydroxyl group differ from a carboxyl group?
3. Explain why eating carbohydrates would be beneficial to an athlete before a race.
4. What is the connection between a polymer and a protein?
5. What do carbohydrates and lipids have in common?
6. Explain the difference between a saturated and an unsaturated compound.

Checking Concepts

Choose the word or phrase that best answers the question.

7. A certain carbohydrate molecule has ten oxygen atoms. How many hydrogen atoms does it contain?
   A) five **C)** ten
   B) 20 **D)** 16

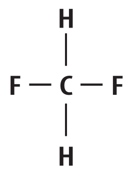
8. Which is NOT a group that can be substituted in a hydrocarbon?
   A) amino **C)** hydroxyl
   B) carboxyl **D)** lipid

9. Which chemical formula represents an alcohol?
   A) CH_3COOH **C)** CH_3OH
   B) CH_3NH_2 **D)** CH_4

10. Which substance can build up in arteries and lead to heart disease?
    A) cholesterol **C)** glucose
    B) fructose **D)** starch

11. What is an organic molecule that contains a triple bond called?
    A) polymer
    B) saturated hydrocarbon
    C) isomer
    D) unsaturated hydrocarbon

12. What is the name of the substituted hydrocarbon with the chemical formula CH_2F_2?
    A) methane
    B) fluoromethane
    C) difluoromethane
    D) trifluoromethane



13. Which chemical formula below represents an amino acid?
    A) CH_3COOH **C)** NH_2CH_2COOH
    B) CH_3NH_2 **D)** CH_4

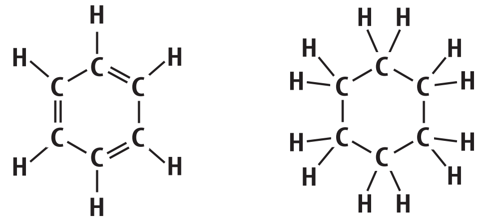
14. Proteins are biological polymers made up of what type of monomers?
    A) alcohols **C)** ethene molecules
    B) amino acids **D)** propene molecules

15. Excess energy is stored in your body as which of the following?
    A) proteins
    B) isomers
    C) lipids
    D) saturated hydrocarbons

16. Which is a ring-shaped molecule?
    A) acetone **C)** cyclopentane
    B) ethylene **D)** dichloroethane

Thinking Critically

Use the figures below to answer question 17.



17. Compare and Contrast Benzene and cyclohexane are both ring molecules. Discuss the similarities and differences of the two molecules.

18. Explain Ethanol is used as a fuel for cars. Explain how energy is obtained from ethanol to fuel a car.

19. Analyze Candle wax is one of the longer hydrocarbons. Explain why heat and light are produced in a burning candle.

20. Infer In the polymerization of amino acids to make proteins, water molecules are produced as part of the reaction. However, in the polymerization of ethylene, no water is produced. Explain.

21. Recognize Cause and Effect Marathon runners go through a process known as hitting the wall. They have used up all their readily available glucose and start using stored lipids as fuel. What is the advantage of eating lots of carbohydrates the day before a race?

22. Hypothesize PKU is a genetic disorder that can lead to brain damage. People with this disorder cannot process one of the amino acids. Luckily, damage can be prevented by a proper diet. How is this possible?

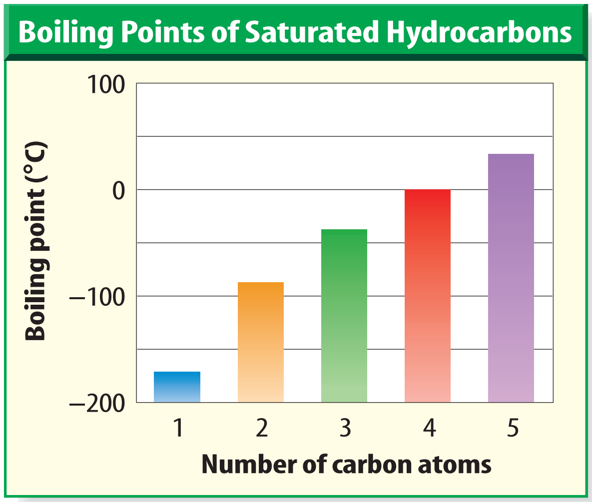
23. Explain Medicines previously obtained from plants are now manufactured. Can these two medicines be the same?

Performance Activities

24. Scientific Drawing Research an amino acid that was not mentioned in the chapter. Draw its structural formula and highlight the portion that substitutes for a hydrogen atom.

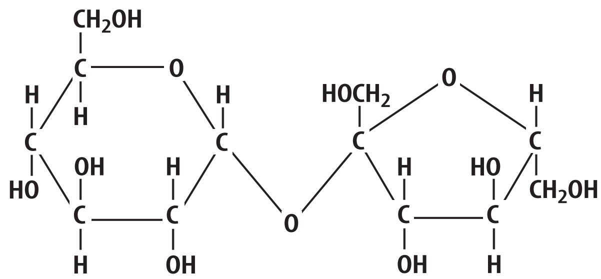
Applying Math

Use the graph below to answer question 25.



25. Hydrocarbons Using the graph above, explain how the boiling point varies with the number of carbon atoms. What do you predict would be the approximate boiling point of hexane?

Use the figure below to answer question 26.



Sucrose

26. Simple Sugar What are the percentages of carbon, oxygen, and hydrogen in a sucrose molecule?

27. Polyethylene If one polyethylene molecule contains 10,000 ethylene units, how many can be made from 3 million ethylene units?

chapter 9 Standardized Test Practice

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the table below to answer questions 1 and 2.

Double Bonded Hydrocarbons			
Name	**Formula**	**Name**	**Formula**
Ethene	C_2H_4	Pentene	C_5H_{10}
Propene	C_3H_6	Octene	?
Butene	C_4H_8	Decene	$C_{10}H_{20}$

1. What is the general formula for this family?
A. $C_{2n}H_n$ **C.** C_nH_{2n}
B. C_nH_{2n+2} **D.** C_nH_{2n-2}

2. What is the formula of octene?
A. C_6H_{12} **C.** C_6H_{10}
B. C_8H_{16} **D.** C_8H_{18}

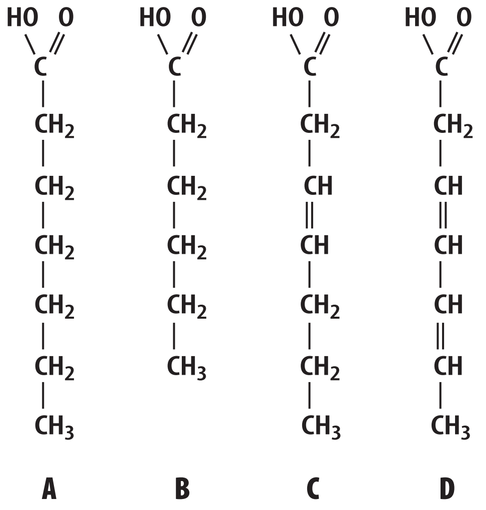
3. Based on its root name and suffix, what is the structural formula of propyne?
A. $H-C\equiv C-CH_3$
B. $CH_3-CH_2-CH_3$
C. $H_2C=CHCH_3$
D. $HC\equiv CH$

4. As five amino acids polymerize to form a protein, how many water molecules split off?
A. 6 **C.** 4
B. 5 **D.** none

5. As a NH_2 group replaces a hydrogen in a hydrocarbon, which type of compound is formed?
A. carboxylic acid **C.** alcohol
B. amino acid **D.** amine

6. One of the freons used in refrigerators is dichloro-difluoromethane. How many H atoms are in this molecule ?
A. 4 **C.** 1
B. 2 **D.** none

Use the structures below to answer questions 7–9.



7. Which is saturated and has the fewest number of carbon atoms?
A. A **C.** C
B. B **D.** D

8. Which is a polyunsaturated acid?
A. A **C.** C
B. B **D.** D

9. These are all considered to be carboxylic acids because they contain which of the following?
A. a $-COOH$ group
B. a $-CH_3$ group
C. a double bond
D. C, H, and O atoms

Test-Taking Tip

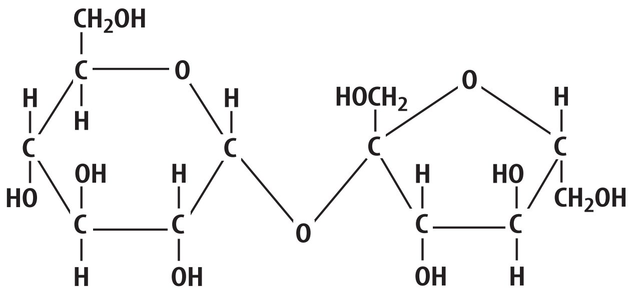
Figures and Illustrations Be sure you understand all symbols in a figure or illustration before attempting to answer any questions about them.

Question 7 Even though the hydrogen molecules are shown on the same side of the carboxylic acid molecules, the structural formula places one hydrogen on either side of the carbon.

Part 2 Short Response/Grid In

Record answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the illustration below to answer questions 10 and 11.



Sucrose

10. If its formula is given as $C_xH_yO_z$ what are the values of x, y, and z?

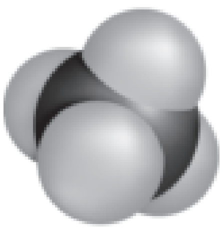
11. Sucrose is a carbohydrate. What ratio between atoms denotes a carbohydrate?

12. What is the structural formula of the propyl group?

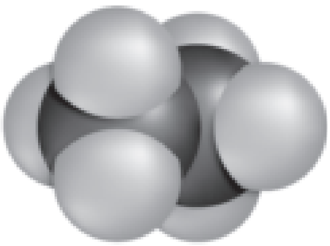
13. What is the molecular formula of propylamine?

Use the following explanation to answer questions 14 and 15.

A carbon atom has a mass of 12 units and hydrogen 1. A molecule of methane has a molecular mass of $(12 \times 1) + (1 \times 4) = 16$ units, and is $\frac{4}{16} = 25\%$ hydrogen by mass.



Methane



Ethane

14. What is molecular mass of C_2H_6?

15. What is the percent carbon by mass for methane and ethane?

Part 3 Open Ended

Record your answers on a sheet of paper.

Use the following explanation to answer questions 16–18.

Glycol is a chief component of antifreeze. It IUPAC name is 1, 2-ethanediol.

16. The root "eth" indicates how many carbon atoms?

17. The "ane" suffix indicates which bond between carbons: single, double, or triple?

18. What functional group does "ol" indicate?

Use the table below to answer questions 19 and 20.

Hydrocarbon Isomers	
Formula	**Number of Isomers**
C_2H_6	1
C_4H_{10}	2
C_6H_{14}	5
C_8H_{18}	18
$C_{10}H_{22}$	75

19. Sketch a graph of this data. Is it linear?

20. Predict how many isomers of C_5H_{12} might exist. Draw them.

21. Draw a reasonable structural formula for carbon dioxide. Recall how many bonds each carbon atom can form.

Science Online ips.msscience.com/standardized_test