Chapter 8

Carbon Chemistry

CALIFORNIA Standards Preview

S 8.3 Each of the more than 100 elements of matter has distinct properties and a distinct structure. All forms of matter are composed of one or more of the elements. As a basis for understanding this concept:

c. Students know atoms and molecules form solids by building up repeating patterns, such as the crystal structure of NaCl or long-chain polymers.

S 8.6 Principles of chemistry underlie the functioning of biological systems. As a basis for understanding this concept:

a. Students know that carbon, because of its ability to combine in many ways with itself and other elements, has a central role in the chemistry of living organisms.

b. Students know that living organisms are made of molecules consisting largely of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur.

c. Students know that living organisms have many different kinds of molecules, including small ones, such as water and salt, and very large ones, such as carbohydrates, fats, proteins, and DNA.

S 8.9 Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

c. Distinguish between variable and controlled parameters on a test.

Butterflies, flowers, and all other living things contain carbon compounds. ▶

Video Preview
Discovery Channel School
Carbon Chemistry

Focus on the BIG Idea

S 8.6.a

Why does carbon have a central role in the chemistry of living organisms?

Check What You Know

Natural gas contains mostly methane (CH_4), a compound made of carbon and hydrogen. When methane burns, is energy absorbed or released? How do you know?

Build Science Vocabulary

The images shown here represent some of the key terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some key terms in this chapter.

Vocabulary Skill

Use Clues to Determine Meaning

Science textbooks often contain unfamiliar words. When you are reading, use clues to figure out what these words mean. First, look for clues in the word itself. Then look at the surrounding words, sentences, and paragraphs. Look at the clues to determine the meaning of *nanotube* in the following paragraph.

> In 1991, scientists made another form of carbon—the nanotube. A **nanotube** is a form of carbon in which atoms are arranged in the shape of a long, hollow cylinder or tube. Only a few nanometers wide in diameter, nanotubes are tiny, light, flexible, and extremely strong. They also are good conductors of electricity and heat.

Unfamiliar word → nanotube

Definition → form of carbon in which atoms are arranged in the shape of a long, hollow cylinder or tube

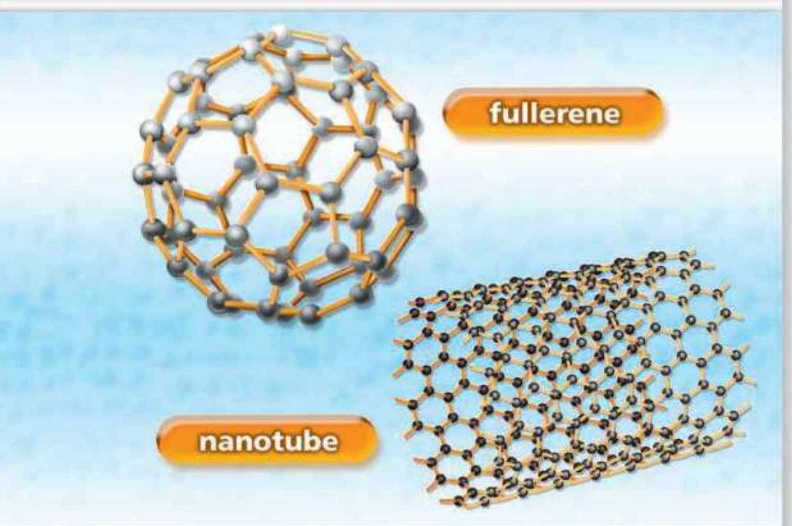
Additional information → few nanometers wide in diameter; tiny, light, flexible, and extremely strong; good conductors of electricity and heat

Apply It!

Review the clues to the meaning of *nanotube*. Then answer the following questions.

1. What is the definition of *nanotube*?
2. What additional information helps you understand nanotubes?

As you come across other unfamiliar words in the chapter, look for clues to unlock their meaning.



Chapter 8 Vocabulary

Section 1 (page 292)

diamond
graphite
fullerene
nanotube

Section 2 (page 296)

organic compound
hydrocarbon
structural formula
isomer
saturated hydrocarbon
unsaturated hydrocarbon
substituted hydrocarbon
hydroxyl group
alcohol
organic acid
carboxyl group
ester
polymer
monomer

Section 3 (page 306)

protein
amino acid
plastic
composite

Section 4 (page 316)

carbohydrate
glucose
complex carbohydrate
starch
cellulose
lipid
fatty acid
cholesterol
nucleic acid
DNA
RNA
nucleotide

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How to Read Science

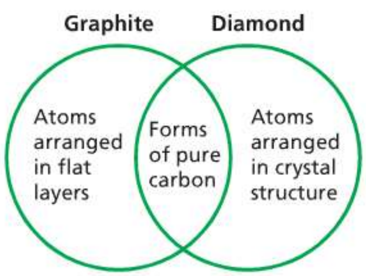
Reading Skill

Compare and Contrast

Science texts often make comparisons. When you compare and contrast, you examine the similarities and differences between things. When you are comparing two things, you can use a Venn diagram. Follow these steps to set up a Venn diagram.

- Draw two overlapping circles and label the two things being compared.
- Write the similarities in the center section, where the circles overlap.
- Write the differences in the outside parts of the circles.

In this chapter, you will learn about four forms of the element carbon. Look at the Venn diagram below comparing two forms—graphite and diamond.



Apply It!

Review the Venn diagram and answer the following questions.

1. What things are being compared in the diagram?
2. In what way are graphite and diamond different?

In your notebook, copy and add to the Venn diagram above after you read Section 1. After you read Section 2, create a Venn diagram comparing types of hydrocarbons.

Lab zone

Standards Investigation

S 8.6.c

Check Out the Fine Print

All the foods you eat and drink contain carbon compounds. In this investigation, you will look closely at the labels on food packages to find carbon compounds.

Your Goal

To identify carbon compounds found in different foods

To complete the investigation you must

- collect at least a dozen labels with lists of ingredients and nutrition facts
- identify the carbon compounds listed, as well as substances that do not contain carbon
- interpret the nutrition facts on labels to compare amounts of substances in each food
- classify compounds in foods into the categories of polymers found in living things

Plan It!

Brainstorm with your classmates about what kinds of packaged foods you want to examine. After your teacher approves your plan, start collecting and studying food labels.

Section 1

Properties of Carbon

CALIFORNIA Standards Focus

S 8.6.a Students know that carbon, because of its ability to combine in many ways with itself and other elements, has a central role in the chemistry of living organisms.

- Why does carbon play a central role in the chemistry of living organisms?
- What are four forms of pure carbon?

Key Terms
- diamond
- graphite
- fullerene
- nanotube

Lab zone Standards Warm-Up

Why Do Pencils Write?

1. Tear paper into two pieces about 5 cm by 5 cm. Rub the two pieces back and forth between your fingers.
2. Now rub pencil lead (graphite) on one side of each piece of paper. Try to get as much graphite as possible on the paper.
3. Rub together the two sides covered with graphite.
4. When you are finished, wash your hands.

Think It Over

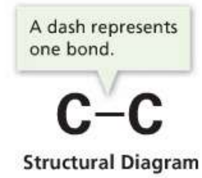
Observing Did you notice a difference between what you observed in Step 3 and what you observed in Step 1? How could the property of graphite that you observed be useful for purposes other than writing?

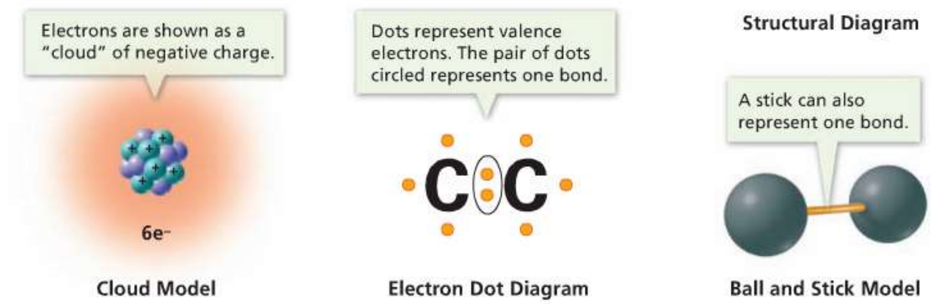
Open your mouth and say "aah." Uh-oh, you have a small cavity. Do you know what happens next? Your tooth needs a filling. But first the dentist's drill clears away the decayed part of your tooth.

Why is a dentist's drill hard enough and sharp enough to cut through teeth? The answer has to do with the element carbon. The tip of the drill is covered with diamond chips. Diamond is a form of carbon and the hardest substance on Earth. Because the drill tip is made of diamonds, a dentist's drill stays sharp and useful. To understand why diamond is such a hard substance, you need to take a close look at the carbon atom and the bonds it forms.

FIGURE 1
Uses of Carbon
This colorized photo shows the tip of a dentist's drill (yellow). The tip is made of diamond and is strong enough to bore into a tooth (blue).

FIGURE 2
Carbon Atoms and Bonding
Carbon atoms and the bonds between them can be modeled in several ways.





Carbon Atoms and Bonding

Recall that the atomic number of carbon is 6, which means that the nucleus of a carbon atom contains 6 protons. Surrounding the nucleus are 6 electrons. Of these electrons, four are valence electrons—the electrons available for bonding.

As you have learned, a chemical bond is the force that holds two atoms together. A bond between two atoms results from changes involving the atoms' valence electrons. Atoms gain, lose, or share valence electrons in a way that makes the atoms more stable. A carbon atom can share its valence electrons with other atoms, forming covalent bonds. Figure 2 shows ways that covalent bonds between atoms may be represented.

Because of its unique ability to combine in many ways with itself and other elements, carbon has a central role in the chemistry of living organisms. With four valence electrons, each carbon atom is able to form four bonds. So, it is possible to form molecules made of thousands of carbon atoms. By comparison, hydrogen, oxygen, and nitrogen can form only one, two or three bonds, respectively, and cannot form such long chains.

As you can see in Figure 3, it is possible to arrange the same number of carbon atoms in different ways. Carbon atoms can form straight chains, branched chains, and rings.

Reading Checkpoint **What happens to a carbon atom's valence electrons when it bonds to other atoms?**

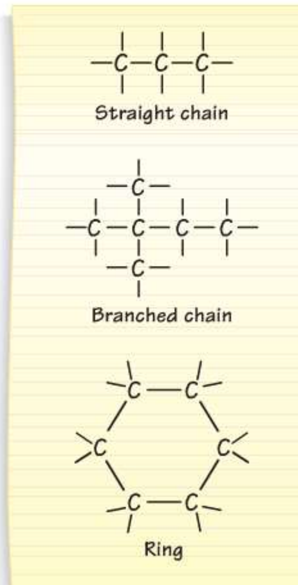
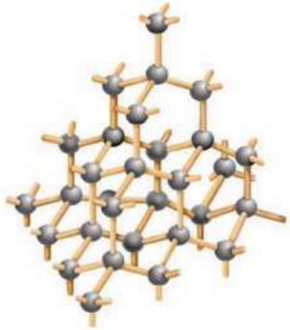
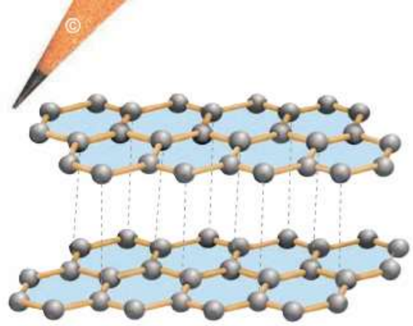


FIGURE 3
Arrangements of Carbon Atoms
Carbon chains and rings form the backbones for molecules that may contain other atoms.



Crystal Structure of Diamond
The carbon atoms in a diamond are arranged in a crystal structure.



Layered Structure of Graphite
The carbon atoms in graphite are arranged in layers. The dashed lines show the weak bonds between the layers.

FIGURE 4
Forms of Pure Carbon
Pure carbon exists in the form of diamond, graphite, fullerenes, and nanotubes. The properties of each form result from the unique repeating pattern of its carbon atoms. **Interpreting Diagrams** *Which form of carbon has a crystal structure?*

Forms of Pure Carbon

Because of the ways that carbon forms bonds, the pure element can exist in different forms. **Diamond, graphite, fullerenes, and nanotubes are four forms of the element carbon.**

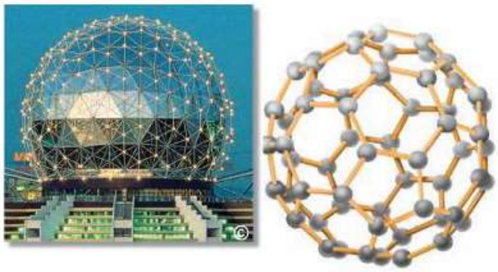
Diamond At very high temperatures and pressures, carbon atoms can form diamonds. **Diamond** is a crystalline form of carbon in which each carbon atom is bonded strongly to four other carbon atoms. The result is a solid that is extremely hard and nonreactive. The melting point of diamond is more than 3,500°C—as hot as the surface temperatures of some stars.

Diamonds are prized for their brilliance and clarity when cut as gems. Industrial chemists are able to make diamonds artificially, but these diamonds are not considered beautiful enough to use as gems. Both natural and artificial diamonds are used in industry. Diamonds work well in cutting tools, such as drills.

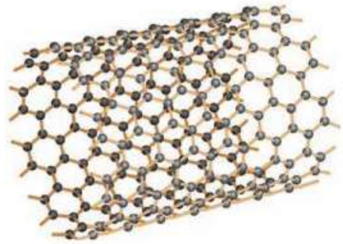
Graphite Another form of the element carbon is graphite. In **graphite**, each carbon atom is bonded tightly to three other carbon atoms in flat layers. However, the bonds between atoms in different layers are very weak, so the layers slide past one another easily.

The "lead" in a lead pencil is mostly graphite. If you run your fingers over pencil marks, you can feel how slippery graphite is. Because it is so slippery, graphite makes an excellent lubricant in machines. Graphite reduces friction between the moving parts. In your home, you might use a graphite spray to help a key work better in a sticky lock.

Reading Checkpoint **Why is diamond such a hard and nonreactive substance?**



Spherical Structure of a Fullerene
The carbon atoms in a fullerene form a sphere that resembles a geodesic dome.



Cylindrical Structure of a Nanotube
The carbon atoms in a nanotube are arranged in a cylinder.

Fullerenes and Nanotubes In 1985, scientists made a new form of carbon. It consists of carbon atoms arranged in the shape of a hollow sphere. This form of carbon was named a **fullerene** (FUL ur een), for the architect Buckminster Fuller, who designed dome-shaped buildings called geodesic domes. One type of fullerene has been nicknamed "buckyballs."

In 1991, yet another form of carbon was made—the nanotube. In a **nanotube,** carbon atoms are arranged in the shape of a long, hollow cylinder—something like a sheet of graphite rolled into a tube. Only a few nanometers wide in diameter, nanotubes are tiny, light, flexible, and extremely strong. Nanotubes are also good conductors of electricity and heat.

Scientists are looking for ways to use the unique properties of fullerenes and nanotubes. For example, chemists are studying how fullerenes and nanotubes may be used to deliver medicine molecules into cells. Nanotubes may also be used as conductors in electronic devices and as super-strong cables.

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Section 1 Assessment

S 8.6.a, E-LA: Reading 8.2.0, Writing 8.2.0

Target Reading Skill **Compare and Contrast** Complete your Venn diagram comparing diamond and graphite. What other differences did you add?

Reviewing Key Concepts

HINT **1. a. Identifying** How many bonds can a carbon atom form?

HINT **b. Explaining** Why is carbon unique among the elements?

HINT **2. a. Listing** List the four forms of pure carbon.

b. Describing Describe the carbon bonds in graphite. HINT

c. Relating Cause and Effect How do the differences in carbon bonds explain why graphite and diamonds have different properties? HINT

Writing in Science

Explanation Draw electron dot diagrams for a straight carbon chain and a branched chain. Then, write an explanation of what you did to show how the carbons are bonded.

Section 2

Carbon Compounds

CALIFORNIA Standards Focus

S 8.3.c Students know atoms and molecules form solids by building up repeating patterns, such as the crystal structure of NaCl or long-chain polymers.

S 8.6.a Students know that carbon, because of its ability to combine in many ways with itself and other elements, has a central role in the chemistry of living organisms.

- What are some similar properties shared by organic compounds?
- What are some properties of hydrocarbons?
- What kind of structures and bonding do hydrocarbons have?
- What are some characteristics of substituted hydrocarbons, esters, and polymers?

Key Terms

• organic compound • hydrocarbon • structural formula • saturated hydrocarbon • unsaturated hydrocarbon • isomer • substituted hydrocarbon • hydroxyl group • alcohol • organic acid • carboxyl group • ester • polymer • monomer

Lab zone Standards Warm-Up

What Do You Smell?

1. Your teacher will provide you with some containers. Wave your hand toward your nose over the top of each container.
2. Try to identify each of the odors.
3. After you record what you think is in each container, compare your guesses to the actual substance.

Think It Over

Developing Hypotheses Develop a hypothesis to explain the differences between the smell of one substance and another.

Imagine that you are heading out for a day of shopping. Your first purchase is a cotton shirt. Then you go to the drug store, where you buy a bottle of shampoo and a pad of writing paper. Your next stop is a hardware store. There, you buy propane fuel for your camping stove. Your final stop is the grocery store, where you buy olive oil, cereal, meat, and vegetables.

What do all of these purchases have in common? They all are made of carbon compounds. Carbon atoms act as the backbone or skeleton for the molecules of these compounds. Carbon compounds include gases (such as propane), liquids (such as olive oil), and solids (such as cotton). Mixtures of carbon compounds are found in foods, paper, and shampoo. In fact, more than 90 percent of all known compounds contain carbon.

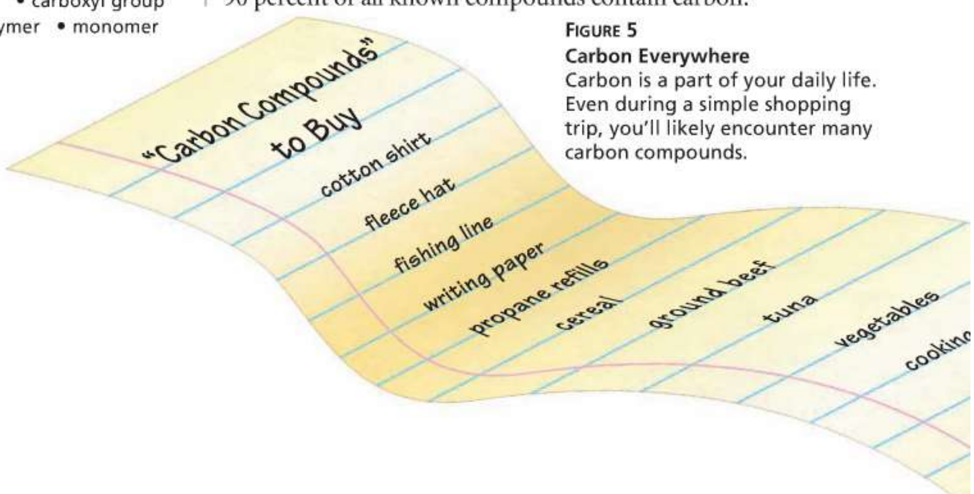


FIGURE 5
Carbon Everywhere
Carbon is a part of your daily life. Even during a simple shopping trip, you'll likely encounter many carbon compounds.

FIGURE 6
Where Organic Compounds Are Found
These three lists represent only a few of the places where organic compounds can be found. Organic compounds are in all living things, in products from living things, and in human-made materials.

Part of Living Things
- Muscle
- Blood
- Seeds
- Leaves
- Feathers
- Skin

From Living Things
- Wool
- Cotton
- Wood
- Silk
- Paper
- Natural gas

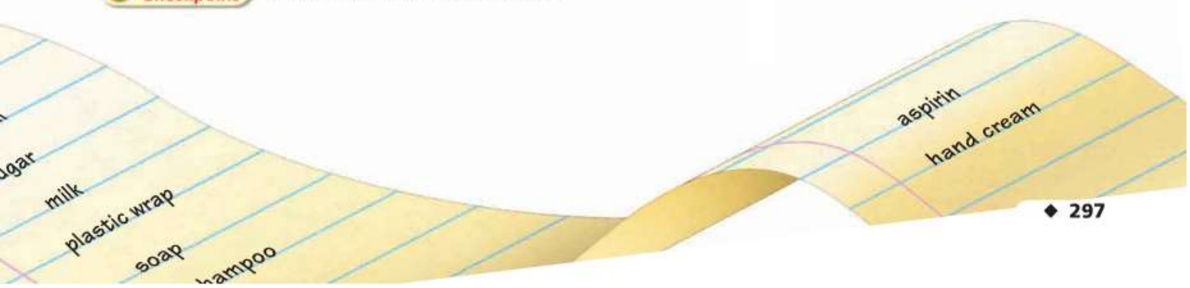
Produced Artificially
- Gasoline
- Fleece
- Plastics
- Shampoo
- Detergent
- Cosmetics

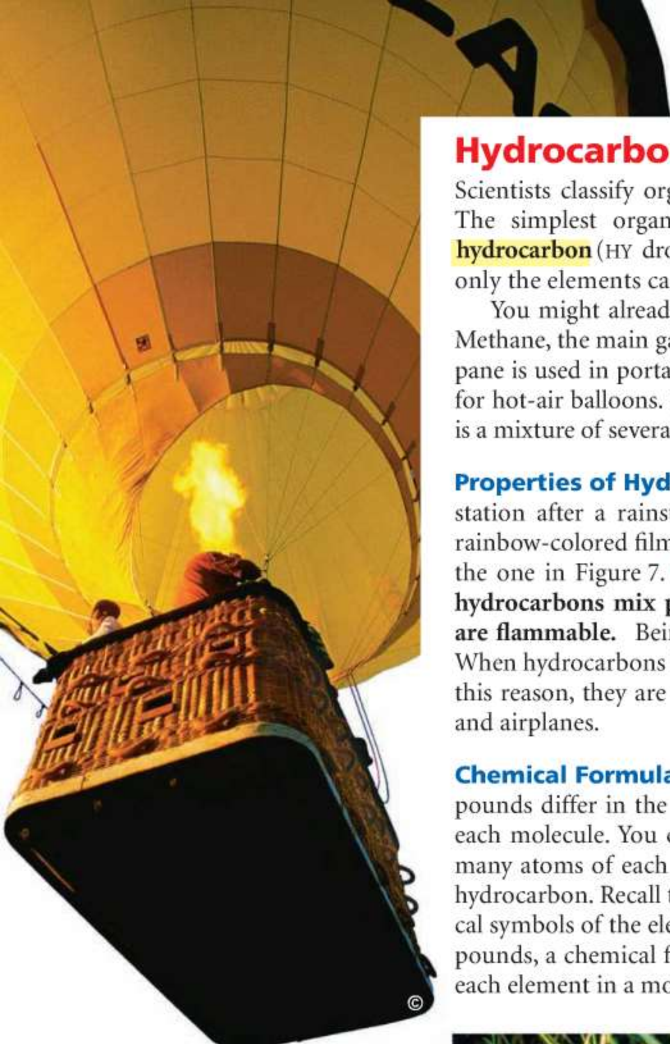
Organic Compounds

Carbon compounds are so numerous that they are given a specific name. With some exceptions, compounds that contain carbon are called **organic compounds.** This term is used because scientists once thought that organic compounds could be produced only by living things. (The word *organic* means "of living things.") Today, however, scientists know that organic compounds also can be found in products made from living things and in materials produced artificially in laboratories and factories. Organic compounds are part of the solid matter of every organism on Earth. They are part of products that are made from organisms, such as paper made from the wood of trees. Plastics, fuels, cleaning solutions, and many other such products also contain organic compounds. The raw materials for most manufactured organic compounds come from petroleum, or crude oil.

Many organic compounds have similar properties in terms of melting points, boiling points, odor, electrical conductivity, and solubility. Many organic compounds have low melting points and low boiling points. As a result, they are liquids or gases at room temperature. Organic liquids generally have strong odors. They also do not conduct electric current. Many organic compounds do not dissolve in water. You may have seen vegetable oil, which is a mixture of organic compounds, form a separate layer in a bottle of salad dressing.

Reading Checkpoint What is an organic compound?





Hydrocarbons

Scientists classify organic compounds into different categories. The simplest organic compounds are the hydrocarbons. A **hydrocarbon** (HY droh KAHR bun) is a compound that contains only the elements carbon and hydrogen.

You might already recognize several common hydrocarbons. Methane, the main gas in natural gas, is used to heat homes. Propane is used in portable stoves and gas grills and to provide heat for hot-air balloons. Butane is the fuel in most lighters. Gasoline is a mixture of several different hydrocarbons.

Properties of Hydrocarbons Have you ever been at a gas station after a rainstorm? If so, you may have noticed a thin rainbow-colored film of gasoline or oil floating on a puddle, like the one in Figure 7. **Like many other organic compounds, hydrocarbons mix poorly with water. Also, all hydrocarbons are flammable.** Being flammable means that they burn easily. When hydrocarbons burn, they release a great deal of energy. For this reason, they are used as fuel for stoves, heaters, cars, buses, and airplanes.

Chemical Formulas of Hydrocarbons Hydrocarbon compounds differ in the number of carbon and hydrogen atoms in each molecule. You can write a chemical formula to show how many atoms of each element makes up a molecule of a specific hydrocarbon. Recall that a chemical formula includes the chemical symbols of the elements in a compound. For molecular compounds, a chemical formula also shows the number of atoms of each element in a molecule.

FIGURE 7
Hydrocarbons
Hydrocarbons contain only the elements carbon and hydrogen. From the fuel that heats the air in hot-air balloons (above) to multicolored oil slicks (right), hydrocarbons are all around you.
Making Generalizations *What properties of hydrocarbons do the hot-air balloon and oil slick demonstrate?*

The simplest hydrocarbon is methane. Its chemical formula is CH_4. The number 4 indicates the number of hydrogen atoms (H). Notice that the 4 is a subscript. Subscripts are written lower and smaller than the letter symbols of the elements. The symbol for carbon (C) in the formula is written without a subscript. This means that there is one carbon atom in the molecule.

A hydrocarbon with two carbon atoms is ethane (C_2H_6). An ethane molecule is made of two carbon atoms and six hydrogen atoms. A hydrocarbon with three carbon atoms is propane (C_3H_8).

Structure of Hydrocarbons

The properties of hydrocarbon compounds are related to the compound's structure. **The carbon chains in a hydrocarbon may be straight, branched, or ring-shaped.** If a hydrocarbon has two or more carbon atoms, the atoms can form a single line, that is, a straight chain. In hydrocarbons with four or more carbon atoms, it is possible to have branched arrangements of the carbon atoms as well as straight chains.

Structural Formulas To show how atoms are arranged in the molecules of a compound, chemists use a structural formula. A **structural formula** shows the kind, number, and arrangement of atoms in a molecule.

Figure 8 shows the structural formulas for molecules of methane, ethane, and propane. Each dash (—) represents a bond. In methane, each carbon atom is bonded to four hydrogen atoms. In ethane and propane, each carbon atom is bonded to at least one carbon atom as well as to hydrogen atoms. As you look at structural formulas, notice that every carbon atom forms four bonds. Every hydrogen atom forms one bond. There are never any dangling bonds. In other words, both ends of a dash are always connected to something.

Reading Checkpoint What is a structural formula?

Lab zone Try This Activity

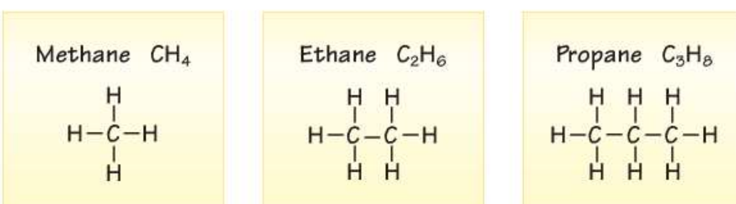
Dry or Wet?

Petroleum jelly is manufactured from hydrocarbons.

1. Carefully coat one of your fingers in petroleum jelly.
2. Dip that finger in water. Also dip a finger on your other hand in water.
3. Inspect the two fingers, and note how they feel.
4. Use a paper towel to remove the petroleum jelly, and then wash your hands thoroughly.

Inferring Compare how your two fingers looked and felt in Steps 2 and 3. What property of hydrocarbons does this activity demonstrate?

FIGURE 8
Structural Formulas
Each carbon atom in these structural formulas is surrounded by four dashes representing four bonds. **Interpreting Diagrams** *In propane, how many hydrogen atoms is each carbon bonded to?*



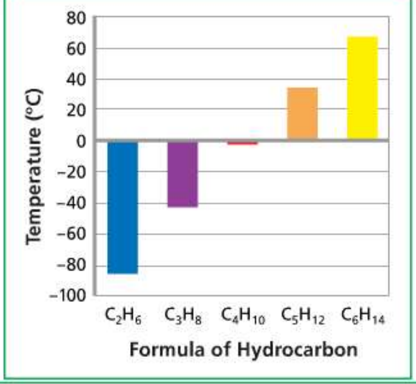
Reviewing Math: Statistics, Data Analysis, and Probability 7.1.1

Math Analyzing Data

Boiling Points of Hydrocarbons

The graph shows the boiling points of several hydrocarbons. Use the graph to answer the following questions.

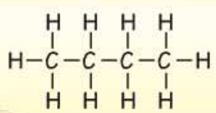
1. **Reading Graphs** Where is 0°C on the graph?
2. **Interpreting Data** What is the approximate boiling point of C_3H_8? C_5H_{12}? C_6H_{14}?
3. **Calculating** What is the temperature difference between the boiling points of C_3H_8 and C_5H_{12}?
4. **Drawing Conclusions** At room temperature (about 22°C), which of the hydrocarbons are gases? How can you tell?



Isomers Consider the chemical formula of butane: C_4H_{10}. This formula does not indicate how the atoms are arranged in the molecule. In fact, there are two different ways to arrange the carbon atoms in C_4H_{10}. These two arrangements are shown in Figure 9. Compounds that have the same chemical formula but different structural formulas are called **isomers** (EYE soh murz). Each isomer is a different substance with its own characteristic properties.

Notice in Figure 9 that a molecule of one isomer, butane, is a straight chain. A molecule of the other isomer, isobutane, is a branched chain. Both molecules have 4 carbon atoms and 10 hydrogen atoms, but the atoms are arranged differently in the two molecules. And these two compounds have different properties. For example, butane and isobutane have different melting points and boiling points.

Butane C_4H_{10}



Isobutane C_4H_{10}

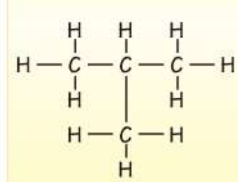


FIGURE 9
Isomers
C_4H_{10} has two isomers, butane and isobutane.
Applying Concepts *Which isomer is a branched chain?*

Double Bonds and Triple Bonds So far in this section, structural formulas have shown only single bonds between any two carbon atoms (C−C). A single dash means a single bond. **In addition to forming a single bond, two carbon atoms can form a double bond or a triple bond.** A carbon atom can also form a single or double bond with an oxygen atom. Structural formulas represent a double bond with a double dash (C=C). A triple bond is indicated by a triple dash (C≡C).

Saturated and Unsaturated Hydrocarbons A hydrocarbon can be classified according to the types of bonds between its carbon atoms. If there are only single bonds, it has the maximum number of hydrogen atoms possible on its carbon chain. These hydrocarbons are called **saturated hydrocarbons**. You can think of each carbon atom as being "saturated," or filled up, with hydrogens. Hydrocarbons with double or triple bonds have fewer hydrogen atoms for each carbon atom than a saturated hydrocarbon does. They are called **unsaturated hydrocarbons**.

Notice that the names of methane, ethane, propane, and butane all end with the suffix *-ane*. In general, a chain hydrocarbon with a name ending in *-ane* is saturated, while a hydrocarbon with a name ending in *-ene* or *-yne* is unsaturated.

The simplest unsaturated hydrocarbon with one double bond is ethene (C_2H_4). Many fruits produce ethene gas. Ethene gas helps the fruit to ripen. The simplest hydrocarbon with one triple bond is ethyne (C_2H_2), which is commonly known as acetylene. Acetylene torches are used in welding.

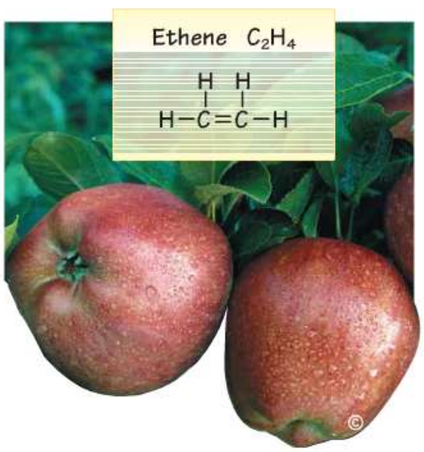
Reading Checkpoint **What is the difference between saturated and unsaturated hydrocarbons?**

Lab zone Skills Activity

Classifying

Determine whether each of the following hydrocarbons contains single, double, or triple bonds? (*Hint*: Remember that carbon forms four bonds and hydrogen forms one bond.)

C_2H_6	C_3H_8
C_2H_4	C_3H_4
C_2H_2	C_4H_{10}



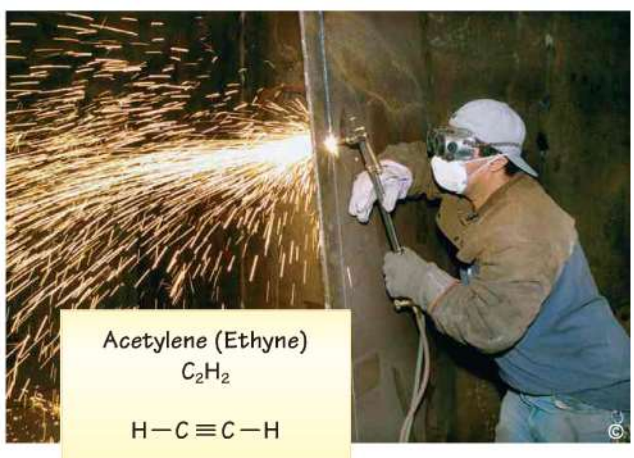


FIGURE 10
Unsaturated Hydrocarbons
Ethene gas (C_2H_4), which causes fruits such as apples to ripen, has one double bond. Acetylene (C_2H_2), the fuel in welding torches, has one triple bond.

Substituted Hydrocarbons

Hydrocarbons contain only carbon and hydrogen. But carbon can form stable bonds with several other elements, including oxygen, nitrogen, sulfur, and members of the halogen family. **If just one atom of another element is substituted for a hydrogen atom in a hydrocarbon, a different compound is created.** In a **substituted hydrocarbon,** atoms of other elements replace one or more hydrogen atoms in a hydrocarbon. Substituted hydrocarbons include halogen-containing compounds, alcohols, and organic acids.

Compounds Containing Halogens In some substituted hydrocarbons, one or more halogen atoms replace hydrogen atoms. Recall that the halogen family includes fluorine, chlorine, bromine, and iodine.

One compound, Freon (CCl_2F_2), was widely used as a cooling liquid in refrigerators and air conditioners. When Freon was found to damage the environment, its use was banned in the United States. However, a very hazardous compound that contains halogens, trichloroethane ($C_2H_3Cl_3$), is still used in dry-cleaning solutions. It can cause severe health problems.

Alcohols The group —OH can also substitute for hydrogen atoms in a hydrocarbon. Each —OH, made of an oxygen atom and a hydrogen atom, is called a **hydroxyl group** (hy DRAHKS il). An **alcohol** is a substituted hydrocarbon that contains one or more hydroxyl groups.

Most alcohols dissolve well in water. They also have higher boiling points than hydrocarbons with a similar number of carbons. Therefore, the alcohol methanol (CH_3OH) is a liquid at room temperature, while the hydrocarbon methane (CH_4) is a gas. Methanol, which is extremely toxic, is used to make plastics and synthetic fibers. It is also used in solutions that remove ice from airplanes.

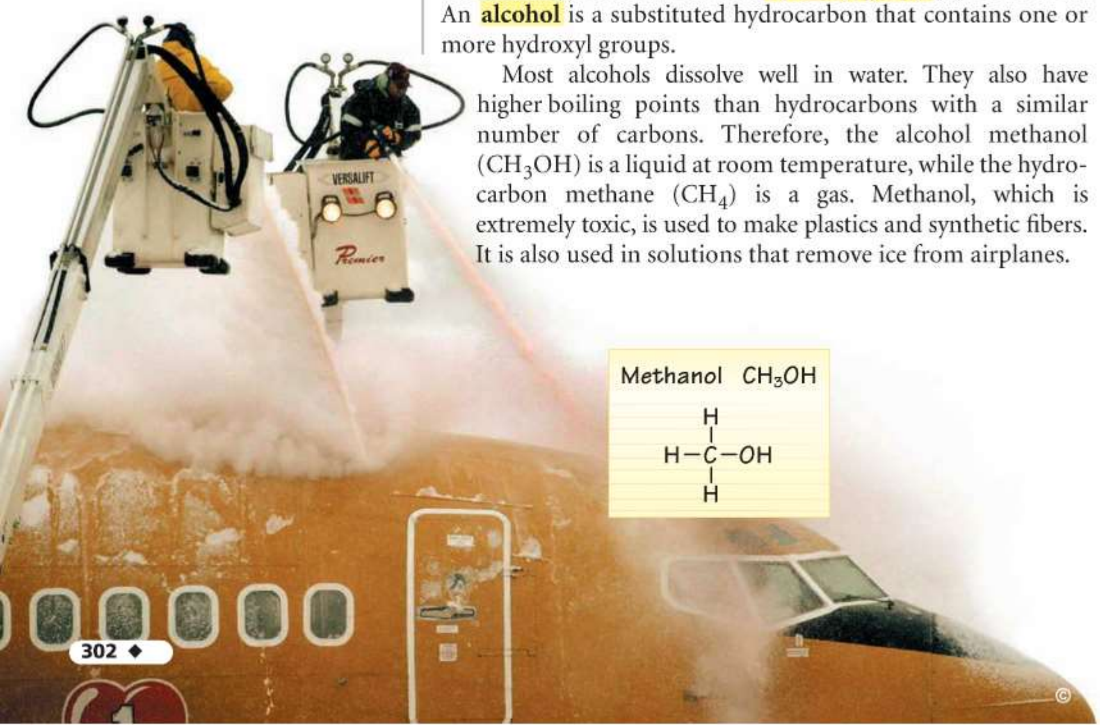


FIGURE 11
Alcohol
Methanol is used for de-icing an airplane in cold weather.
Classifying *What makes methanol a substituted hydrocarbon?*

Methanol CH_3OH

H
H—C—OH
H

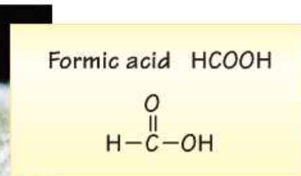


FIGURE 12
Organic Acid
Formic acid is the simplest organic acid. It is the acid produced by ants and is responsible for the pain caused by an ant bite.

When a hydroxyl group is substituted for one hydrogen atom in ethane, the resulting alcohol is ethanol (C_2H_5OH). Ethanol is produced naturally by the action of yeast or bacteria on the sugar stored in corn, wheat, and barley. Ethanol is a good solvent for many organic compounds that do not dissolve in water. It is also added to gasoline to make a fuel for car engines called "gasohol." Ethanol is used in medicines and is found in alcoholic beverages. The ethanol used for industrial purposes is unsafe to drink. Poisonous compounds such as methanol have been added. The resulting poisonous mixture is called denatured alcohol.

Organic Acids Lemons, oranges, and grapefruits taste a little tart or sour, don't they? The sour taste of many fruits comes from citric acid, an organic acid. An **organic acid** is a substituted hydrocarbon that contains one or more carboxyl groups. A **carboxyl group** (kahr BAHKS il) is written as —COOH.

You can find organic acids in many foods. Acetic acid (CH_3COOH) is the main ingredient of vinegar. Malic acid is found in apples. Butyric acid makes butter smell rancid when it goes bad. Stinging nettle plants make formic acid (HCOOH), a compound that causes the stinging feeling. The pain from ant bites also comes from formic acid.

Esters

If you have eaten wintergreen candy, then you are familiar with the smell of an ester. An **ester** is a compound made by chemically combining an alcohol and an organic acid. **Many esters have pleasant, fruity smells.** Esters are responsible for the smells of pineapples, bananas, strawberries, and apples. If you did the Standards Warm-Up activity, you smelled different esters. Other esters are ingredients in medications, including aspirin and the local anesthetic used by dentists.

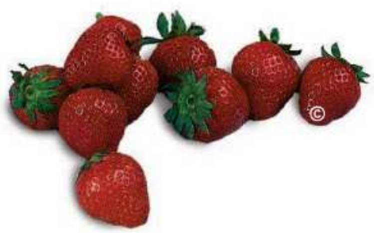


FIGURE 13
Esters
Strawberries contain esters, which give them a pleasant aroma and flavor.

FIGURE 14
Monomers and Polymers
This chain of plastic beads is somewhat like a polymer molecule. The individual beads are like the monomers that link together to build a polymer.
Comparing and Contrasting *How do polymers differ from monomers?*

Polymers

A very large molecule made of a chain of many smaller molecules bonded together is called a **polymer** (PAHL ih mur). The smaller molecules are called **monomers** (MAHN uh murz). The prefix *poly-* means "many," and the prefix *mono-* means "one." **Organic compounds, such as alcohols, esters, and others, can be linked together to build polymers with thousands or even millions of atoms.**

Some polymers are made by living things. For example, sheep grow coats of wool. Cotton fibers come from the seed pods of cotton plants. And silkworms make silk. Other polymers, called synthetic polymers, are made in factories. If you are wearing clothing made from polyester or nylon, you are wearing a synthetic polymer. Any plastic item you use is most certainly made of synthetic polymers.

Reading Checkpoint What is a monomer?

Section 2 Assessment

S 8.3.c, 8.6.a,
E-LA: Reading 8.2.0

Target Reading Skill **Compare and Contrast** Create a Venn diagram comparing saturated and unsaturated hydrocarbons. How are they similar? How are they different?

Reviewing Key Concepts

HINT **1. a. Listing** List properties common to many organic compounds.

HINT **b. Applying Concepts** You are given two solid materials, one that is organic and one that is not organic. Describe three tests you could perform to help you decide which is which.

HINT **2. a. Identifying** What are some properties of hydrocarbons?

HINT **b. Comparing and Contrasting** How are hydrocarbons similar? How are they different?

HINT **3. a. Reviewing** What are three kinds of carbon chains found in hydrocarbons?

HINT **b. Describing** Compare the chemical and structural formulas of butane and isobutane.

c. Problem Solving Draw a structural formula for a compound called butene. In terms of bonding, how does butene differ from butane? HINT

4. a. Defining What is a substituted hydrocarbon? HINT

b. Classifying What kinds of substituted hydrocarbons react to form an ester? HINT

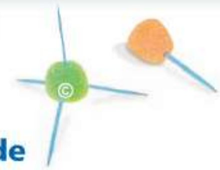
c. Drawing Conclusions What do you think the term *polyester fabric* refers to? HINT

Lab zone At-Home Activity

Mix It Up You can make a simple salad dressing to demonstrate one property of organic compounds. In a transparent container, thoroughly mix equal amounts of a vegetable oil and a fruit juice. Stop mixing, and observe the oil and juice mixture for several minutes. Explain your observations to your family.

How Many Molecules?

S 8.6.a, 8.9



Problem

In this lab you will use gumdrops to represent atoms and toothpicks to represent bonds. How many different ways can you put the same number of carbon atoms together?

Skills Focus

making models

Materials

- toothpicks
- multicolored gumdrops
- other materials supplied by your teacher

Procedure

1. You will need gumdrops of one color to represent carbon atoms and gumdrops of another color to represent hydrogen atoms. When building your models, always follow these rules:
   - Each carbon atom forms four bonds.
   - Each hydrogen atom forms one bond.

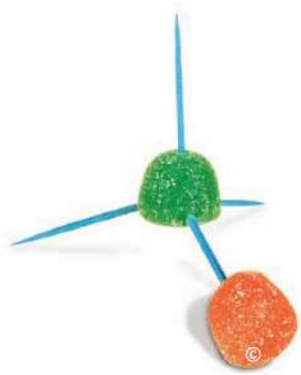
   CAUTION: *Do not eat any of the food substances in this experiment.*
2. Make a model of CH_4 (methane).
3. Now make a model of C_2H_6 (ethane).
4. Make a model of C_3H_8 (propane). Is there more than one way to arrange the atoms in propane? (*Hint:* Are there any branches in the carbon chain or are all the carbon atoms in one line?)
5. Now make a model of C_4H_{10} (butane) in which all the carbon atoms are in one line.
6. Make a second model of butane with a branched chain.
7. Compare the branched-chain model with the straight-chain model of butane. Are there other ways to arrange the atoms?
8. Predict how many different structures can be formed from C_5H_{12} (pentane).
9. Test your prediction by building as many different models of pentane as you can.

Analyze and Conclude

1. **Making Models** Did any of your models have a hydrogen atom between two carbon atoms? Why or why not?
2. **Observing** How does a branched chain differ from a straight chain?
3. **Drawing Conclusions** How many different structures have the formula C_3H_8? C_4H_{10}? C_5H_{12}? Use diagrams to explain your answers.
4. **Predicting** If you bend a straight chain of carbons, do you make a different structure? Why or why not?
5. **Communicating** Compare the information you can get from models to the information you can get from formulas like C_6H_{14}. How does using models help you understand the structure of a molecule?

More to Explore

Use a third color of gumdrops to model an oxygen atom. An oxygen atom forms two bonds. Use the rules in this lab to model as many different structures for the formula $C_4H_{10}O$ as possible.



Section 3

• Tech & Design •

Polymers and Composites

CALIFORNIA Standards Focus

S 8.3.c Students know atoms and molecules form solids by building up repeating patterns, such as the crystal structure of NaCl or long-chain polymers.

S 8.6.a Students know that carbon, because of its ability to combine in many ways with itself and other elements, has a central role in the chemistry of living organisms.

- How do polymers form?
- What are composites made of?
- How can you help reduce the amount of plastic waste?

Key Terms

- protein
- amino acid
- plastic
- composite

Lab zone Standards Warm-Up

What Did You Make?

1. Look at a sample of borax solution and write down the properties you observe. Do the same with white glue.
2. Put about 2 tablespoons of borax solution into a paper cup.
3. Stir the solution as you add about 1 tablespoon of white glue.
4. After 2 minutes, record the properties of the material in the cup. Wash your hands when you are finished.

Think It Over

Observing What evidence of a chemical reaction did you observe? How did the materials change? What do you think you made?

Delectable foods and many other interesting materials surround you every day. Have you ever wondered what makes up these foods and materials? You might be surprised to learn that many are partly or wholly polymers. Recall that a polymer is a large, complex molecule built from smaller molecules joined together in a repeating pattern.

The starches in pancakes and the proteins in meats and eggs are natural polymers. Many other polymers, however, are manufactured or synthetic. These synthetic polymers include plastics and polyester and nylon clothing. Whether synthetic or natural, most polymers rely on the element carbon for their fundamental structures.

FIGURE 15
Polymers
The clothing, boots, goggles, and helmet worn by this climber are all made of polymers.

Forming Polymers

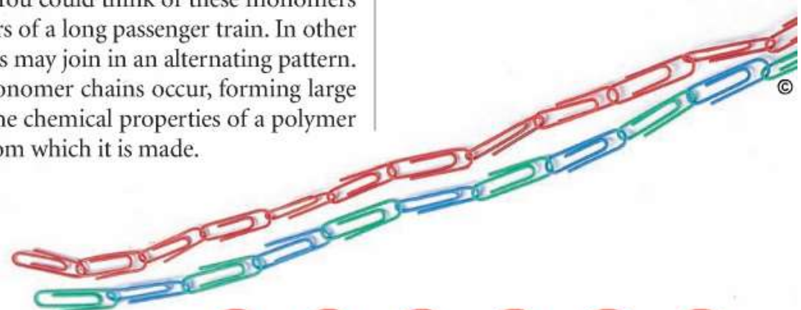
Food materials, living things, and plastic have something in common. All are made of organic compounds. Organic compounds consist of molecules that contain carbon atoms bonded to each other and to other kinds of atoms. Carbon is present in several million known compounds, and more organic compounds are being discovered or invented every day.

Carbon's Chains and Rings Carbon's unique ability to form so many compounds comes from two properties. First, carbon atoms can form four covalent bonds. Second, as you have learned, carbon atoms can bond to each other in straight and branched chains and ring-shaped groups. These structures form the "backbones" to which other atoms attach.

Hydrogen is the most common element found in compounds with carbon. Other elements include oxygen, nitrogen, phosphorus, sulfur, and the halogens—especially chlorine.

Carbon Compounds and Polymers Molecules of some organic compounds can bond together, forming larger molecules, such as polymers. Recall that the smaller molecules from which polymers are built are called monomers. **Polymers form when chemical bonds link large numbers of monomers in a repeating pattern.** A polymer may consist of hundreds or even thousands of monomers. In organic polymers, carbon, hydrogen, nitrogen, and in some cases oxygen atoms combine to form long, repetitive, stringlike molecules.

Many polymers consist of a single kind of monomer that repeats over and over again. You could think of these monomers as linked like the identical cars of a long passenger train. In other cases, two or three monomers may join in an alternating pattern. Sometimes links between monomer chains occur, forming large webs or netlike molecules. The chemical properties of a polymer depend on the monomers from which it is made.



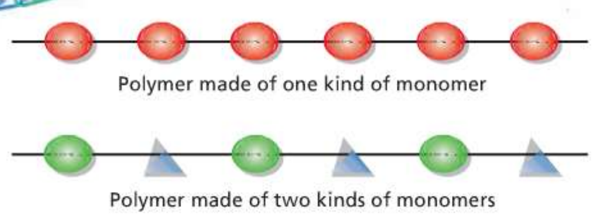
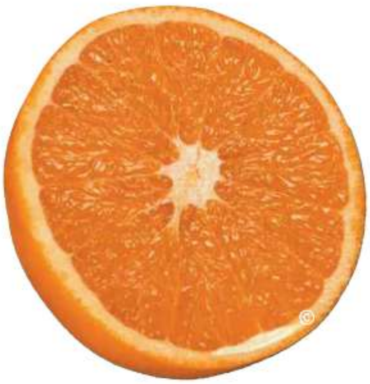


FIGURE 16
Building Polymers
Like chains made of similar or different paper clips, polymers can form from similar or different kinds of monomers.

FIGURE 17
Natural Polymers
Cellulose, the proteins in snake venom, and spider's silk are three examples of natural polymers.



▲ The cellulose in fruits and vegetables serves as dietary fiber that keeps the human digestive system healthy.

▲ Snake venom is a mixture containing approximately 90 percent proteins.

A spider's web is a silken polymer that is one of the strongest materials known. ▶

Polymers and Composites

Polymers have been around as long as life on Earth. Plants, animals, and other living things produce many natural materials made of large polymer molecules.

Natural Polymers Cellulose (SEL yoo lohs) is a flexible but strong natural polymer found in the cell walls of fruits and vegetables. Cellulose is made in plants when sugar molecules are joined into long strands. Humans cannot digest cellulose. But plants also make digestible polymers called starches, formed from sugar molecules that are connected in a different way. Starches are found in pastas, breads, and many vegetables.

You can wear polymers made by animals. Silk is made from the fibers of the cocoons spun by silkworms. Wool is made from sheep's fur. These polymers can be woven into thread and cloth. Your own body makes polymers, too. For example, your fingernails and muscles are made of polymers called proteins. Within your body, **proteins** are formed from smaller molecules called amino acids. An **amino acid** is a monomer that is a building block of proteins. The properties of a protein depend on which amino acids are used and in what order. One combination builds the protein that forms your fingernails. Yet another combination forms the protein that carries oxygen in your blood.

Lab zone Skills Activity

Calculating

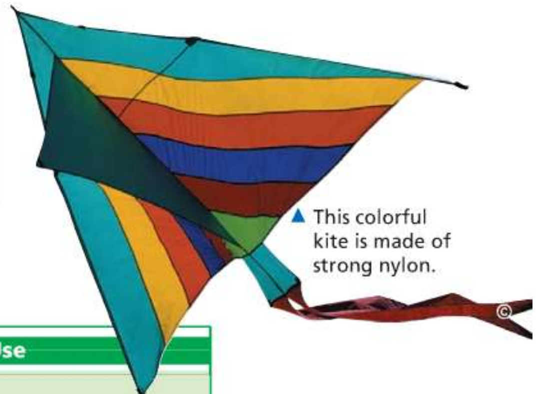
Sit or stand where you have a clear view of the room you are in. Slowly sweep the room with your eyes, making a list of the objects you see. Do the same sweep of the clothes you are wearing. Check off those items on your list made (completely or partly) of natural or synthetic polymers. Calculate the percent of items that were *not* made with polymers.

Synthetic Polymers Many polymers you use every day are synthesized—or made—from simpler materials. The starting materials for many synthetic polymers come from coal or oil. **Plastics,** which are synthetic polymers that can be molded or shaped, are the most common products. But there are many others. Carpets, clothing, glue, and even chewing gum can be made of synthetic polymers.

Figure 18 lists just a few of the hundreds of polymers people use. Although the names seem like tongue twisters, see how many you recognize. You may be able to identify some polymers by their initials printed on the bottoms of plastic bottles.

Compare the uses of polymers shown in the figure with their characteristics. Notice that many products require materials that are flexible, yet strong. Others must be hard or lightweight. When chemical engineers develop a new product, they have to think about how it will be used. Then they synthesize a polymer with properties to match.

Reading Checkpoint **What are plastics?**



▲ This colorful kite is made of strong nylon.

Some Synthetic Polymers You Use

Name	Properties	Uses
Low-density polyethylene (LDPE)	Flexible, soft, melts easily	Plastic bags, squeeze bottles, electric wire insulation
High-density polyethylene (HDPE)	Stronger than LDPE; higher melting temperatures	Detergent bottles, gas cans, toys, milk jugs
Polypropylene (PP)	Hard, keeps its shape	Toys, car parts, bottle caps
Polyvinyl chloride (PVC)	Tough, flexible	Garden hoses, imitation leather, plumbing pipes
Polystyrene (PS)	Lightweight, can be made into foam	Foam drinking cups, insulation, furniture, "peanut" packing material
Nylon	Strong, can be drawn into flexible thread	Stockings, parachutes, fishing line, fabric
Teflon (polytetrafluoroethylene)	Nonreactive, low friction	Nonstick coating for cooking pans

FIGURE 18
The properties of synthetic polymers make them ideal starting materials for many common objects.
Applying Concepts *Which synthetic polymer would you use to make a cover for a picnic table?*

Comparing Polymers Synthetic polymers are often used in place of natural materials that are too expensive or wear out too quickly. Polyester and nylon fabrics, for example, are frequently used instead of wool, silk, and cotton to make clothes. Laminated countertops and vinyl floors replace wood in many kitchens. Other synthetic polymers have uses for which there is no suitable natural material. Compact discs, computer parts, artificial heart valves, and even bicycle tires couldn't exist without synthetic polymers.

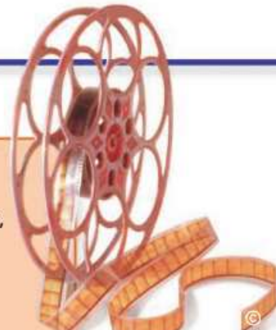
Composites Every substance has its desirable and undesirable properties. What would happen if you could take the best properties of two substances and put them together? A **composite** combines two or more substances in a new material with different properties.

• Tech & Design in History •

The Development of Polymers

The first synthetic polymers were made by changing natural polymers in some way. Later, crude oil and coal became the starting materials. Now, new polymers are designed regularly in laboratories.

1839 Synthetic Rubber
Charles Goodyear invented a process that turned natural rubber into a hard, stretchable polymer. It did not get sticky and soft when heated or become brittle when cold, as natural rubber does. Bicycle tires were an early use.



1869 Celluloid
Made using cellulose, celluloid became a substitute for ivory in billiard balls and combs and brushes. It was later used to make movie film. Because celluloid is very flammable, other materials have replaced it for almost all purposes.

1909 Bakelite
Bakelite was the first commercial polymer made from compounds in coal tar. Bakelite doesn't get soft when heated, and it doesn't conduct electricity. These properties made it useful for handles of pots and pans, for telephones, and for parts in electrical outlets.

1800 1850 1900

By combining the useful properties of two or more substances in a composite, chemists can make a new material that works better than either one alone. **Many composites include one or more polymers.** The idea of putting two different materials together to get the advantages of both was inspired by the natural world. Many synthetic composites are designed to imitate a common natural composite—wood.

Wood is made of long fibers of cellulose, held together by another plant polymer called lignin. Cellulose fibers are flexible and can't support much weight. Lignin is brittle and would crack under the weight of the tree branches. But the combination of the two polymers makes a strong tree trunk.

Reading Checkpoint Why is wood a composite?

Writing in Science

Research and Write Find out more about the invention of one of these polymers. Write a newspaper headline announcing the invention. Then write the first paragraph of the news report telling how the invention will change people's lives.

1934 Nylon

A giant breakthrough came with a synthetic fiber that imitates silk. Nylon replaced expensive silk in women's stockings and fabric for parachutes and clothing. It can also be molded to make objects like buttons, gears, and zippers.

1971 Kevlar

Kevlar is five times stronger than steel. Kevlar is tough enough to substitute for steel ropes and cables in offshore oil rigs but light enough to use in spacecraft parts. It is also used in protective clothing for firefighters and police officers.

2002 Light-Emitting Polymers

Discovered accidentally in 1990, light-emitting polymers (LEPs) are used commercially in products such as MP3 audio players and electric shavers with display screens. LEPs give off light when exposed to low-voltage electricity. Newer, more colorful LEPs may be useful as flexible monitors for computers, TV screens, and watch-sized phones.

1950 2000 2050

FIGURE 19
Synthetic Composites
The composites in the fishing rod above make it flexible so that it will not break when reeling in a fish. Fiberglass makes the snowboard at right both lightweight and strong.

Uses of Composites The idea of combining the properties of two substances to make a more useful one has led to many new products. Fiberglass composites are one example. Strands of glass fiber are woven together and strengthened with a liquid plastic that sets like glue. The combination makes a strong, hard solid that can be molded around a form to give it shape. These composites are lightweight but strong enough to be used as a boat hull or car body. Also, fiberglass will not rust as metal does.

Many other useful composites are made from strong polymers combined with lightweight ones. Bicycles, automobiles, and airplanes built from such composites are much lighter than the same vehicles built from steel or aluminum. Some composites are used to make fishing rods, tennis rackets, and other sports equipment that needs to be flexible but strong.

Reading Checkpoint **What are two examples of composites?**

Recycling Plastics

You can hardly look around without seeing something made of synthetic polymers. They have replaced many natural materials for several reasons. Synthetic polymers are inexpensive to make, strong, and last a long time.

But synthetic polymers have caused some problems, too. Many of the disadvantages of using plastics come from the same properties that make them so useful. For example, it is often cheaper to throw plastics away and make new ones than it is to reuse them. As a result, plastics increase the volume of trash.

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One of the reasons that plastics last so long is that most plastics don't react very easily with other substances. As a result, plastics don't break down—or degrade—into simpler materials in the environment. In contrast, natural polymers do. Some plastics are expected to last thousands of years. How do you get rid of something that lasts that long?

You can help reduce the amount of plastic waste by recycling. When you recycle, you collect waste plastics that can be used as raw material for making new plastic products. Recycling has led to industries that create new products from discarded plastics. Bottles, fabrics for clothing, and parts for new cars are just some of the many items that can come from waste plastics. A pile of empty soda bottles can even be turned into synthetic wood. Look around your neighborhood. You may see park benches or "wooden" fences made from recycled plastics. Through recycling, the disposal problem is eased and new, useful items are created.

FIGURE 20
Recycling Plastics
Plastics can be recycled to make many useful products. This boardwalk, for example, is made of recycled plastics. **Making Judgments** *What advantages or disadvantages does this material have compared to wood?*

Section 3 Assessment

S 8.3.c, 8.6.a, E-LA: Reading 8.1.3, Writing 8.2.0

Vocabulary Skill **Use Clues to Determine Meaning** Reread the paragraphs that follow the heading Composites. What clues help you understand the meaning of the word *composite?*

Reviewing Key Concepts

HINT
HINT
HINT
HINT
HINT
HINT

1. a. **Defining** What are polymers made of?
   b. **Identifying** What properties enable carbon atoms to form polymers and so many other compounds?
   c. **Interpreting Diagrams** How do the two kinds of polymers modeled in Figure 16 differ?
2. a. **Reviewing** Distinguish between natural polymers, synthetic polymers, and composites.
   b. **Classifying** Make a list of polymers you can find in your home. Classify them as natural or synthetic.
   c. **Drawing Conclusions** Why are composites often more useful than the individual materials from which they are made?
3. a. **Listing** List two benefits and two problems associated with the use of synthetic polymers. HINT
   b. **Explaining** What happens to waste plastics when they are recycled? HINT
   c. **Making Judgments** Think of something plastic that you have used today. Is there some other material that would be better than plastic for this use? HINT

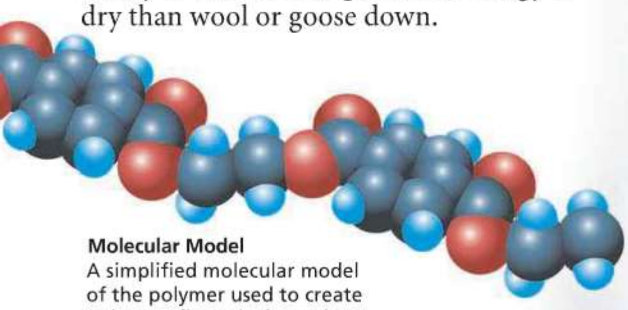
Writing in Science

Advertisement You are a chemist. You invent a polymer that can be a substitute for a natural material such as wood, cotton, or leather. Write an advertisement for your polymer, explaining why you think it is a good replacement for the natural material.

S 8.3.c

Polyester Fleece

Would you go hiking in the freezing Antarctic wearing a bunch of plastic beverage bottles? If you are like most serious hikers, you would. Polyester fleece is a lightweight, warm fabric made from plastic, including recycled soda bottles. The warmth of the fabric is due to its ability to trap and hold air. Polyester fleece is easy to wash and requires less energy to dry than wool or goose down.



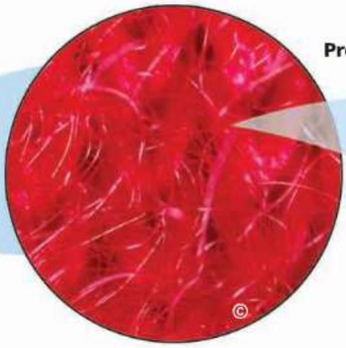
Molecular Model
A simplified molecular model of the polymer used to create polyester fleece is shown here. The molecules form long, straight chains.

It takes about 25 recycled plastic bottles to make a polyester fleece jacket.

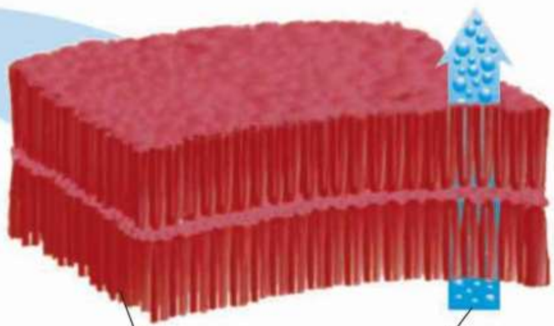
Making Polyester Fleece

Polyethylene terephthalate, or PET, is the polymer that is used to make polyester fleece. The first step in the process is creating the polyester fiber or thread. It can be made from raw materials or recycled PET plastic. The thread is then knit into fabric, which can be dyed or printed. It is then dried and "napped." In the napping process, the fibers are first raised and then clipped to an even height. This process increases the amount of air the fabric can hold, which helps keep you warm in cold weather.

Properties of Polyester Fleece



▲ **Fleece Fabric**
Similar to yarn in a sweater, fleece fibers are knit together to create a stretchy, dense fabric that is soft, lightweight, and durable.



Air pockets between fibers trap body heat.

Moisture from the body passes through the fabric.

Polyester Fleece and the Environment

Making polyester fleece fabric uses water and energy, like other fabric-making processes. Using recycled materials to create polyester fleece saves energy and reduces wastes. One trade-off involves the safety of workers in the fleece factories. The clipping process creates dust particles in the air that workers then breathe. Some companies that produce fleece are developing technology that should reduce dust in the workplace, as well as technologies that conserve and reuse energy and water.

Plastic Bottle Granules
PET plastic bottles are chipped to create granules like those shown here. The granules can be used in making polyester fleece.▼

Weigh the Impact

1. Identify the Need
What are some benefits of using polyester fleece to make clothing and blankets?

2. Research
Use the Internet to find companies that make or sell polyester fleece made from recycled plastic. Identify ways in which this form of recycling helps the environment.

3. Write
Create a pamphlet to encourage your classmates to recycle plastics. Describe how PET plastic can be used to create polyester fleece.

Go Online
PHSchool.com

For: More on polyester fleece
Visit: PHSchool.com
Web Code: cgh-1040

Section 4

Integrating Life Science

Life With Carbon

California Standards Focus

S 8.6.b Students know that living organisms are made of molecules consisting largely of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur.

S 8.6.c Students know that living organisms have many different kinds of molecules, including small ones, such as water and salt, and very large ones, such as carbohydrates, fats, proteins, and DNA.

- What are four classes of organic compounds required by living things, and how are they used in the body?
- Why do organisms need water, vitamins, minerals, and salts?

Key Terms

- carbohydrate
- glucose
- complex carbohydrate
- starch
- cellulose
- lipid
- fatty acid
- cholesterol
- nucleic acid
- DNA
- RNA
- nucleotide

Lab zone Standards Warm-Up

What Is in Milk?

1. Pour 30 mL of milk into a plastic cup.
2. Pour another 30 mL of milk into a second plastic cup. Rinse the graduated cylinder. Measure 15 mL of vinegar and add it to the second cup. Swirl the two liquids together and let the mixture sit for a minute.
3. Set up two funnels with filter paper, each supported in a narrow plastic cup.
4. Filter the milk through the first funnel. Filter the milk and vinegar through the second funnel.
5. What is left in each filter paper? Examine the liquid that passed through each filter paper.

Think It Over

Observing Where did you see evidence of solids? What do you think was the source of these solids?

Have you ever been told to eat all the organic compounds on your plate? Have you heard how eating a variety of polymers and monomers contributes to good health? What? No one has ever said those things to you? Well, maybe what you really heard was something about eating all the vegetables on your plate, or eating a variety of foods to give you a healthy balance of carbohydrates, proteins, fats, and other nutrients. All these nutrients are organic compounds, which are the building blocks of all living things.

A bowl of soup contains a variety of nutrients. ▼

Foods provide organic compounds, which the cells of living things use, change, or store. **The four classes of organic compounds required by living things are carbohydrates, proteins, lipids, and nucleic acids.** Carbohydrates, proteins, and lipids are nutrients. Nutrients (NOO tree unts) are substances that provide the energy and raw materials the body needs to grow, repair worn parts, and function properly.

Carbohydrates

A **carbohydrate** (kahr boh HY drayt) is an energy-rich organic compound made of the elements carbon, hydrogen, and oxygen. The word *carbohydrate* is made of two parts: *carbo-* and *-hydrate*. *Carbo-* means "carbon" and *-hydrate* means "combined with water." If you remember that water is made up of the elements hydrogen and oxygen, then you should be able to remember the three elements in carbohydrates.

Simple Carbohydrates The simplest carbohydrates are sugars. You may be surprised to learn that there are many different kinds of sugars. The sugar listed in baking recipes, which you can buy in bags or boxes at the grocery store, is only one kind. Other sugars are found naturally in fruits, milk, and some vegetables.

One of the most important sugars in your body is **glucose**. Its chemical formula is $C_6H_{12}O_6$. Glucose is sometimes called "blood sugar" because the body circulates glucose to all body parts through blood. The structural formula for a glucose molecule is shown in Figure 21.

The white sugar that sweetens cookies, candies, and many soft drinks is called sucrose. Sucrose is a more complex molecule than glucose and has a chemical formula of $C_{12}H_{22}O_{11}$.

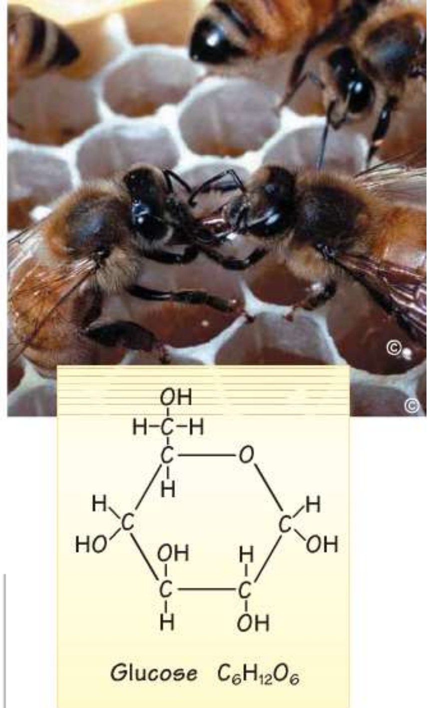


FIGURE 21
Carbohydrates
The honey made by honeybees contains glucose, a simple carbohydrate. **Applying Concepts** *What are some other examples of foods that contain carbohydrates?*

Lab zone Try This Activity

Alphabet Soup

Here's how you can model the rearrangement of amino acids in your body.

1. Rearrange the letters of the word *proteins* to make a new word or words. (Don't worry if the new words don't make sense together.)
2. Choose three other words with ten or more letters. Repeat the activity.

Making Models What words did you make from *proteins*? What new words did you make from the words you chose? How does this activity model the way your body uses proteins in food to make new proteins?

Complex Carbohydrates When you eat plants or food products made from plants, you are often eating complex carbohydrates. Each molecule of a simple carbohydrate, or sugar, is relatively small compared to a molecule of a complex carbohydrate. A **complex carbohydrate** is a polymer made of smaller molecules that are simple carbohydrates bonded to one another. As a result, just one molecule of a complex carbohydrate may have hundreds of carbon atoms.

Two of the complex carbohydrates assembled from glucose molecules are starch and cellulose. Starch and cellulose are both polymers built from glucose, but the glucose molecules are arranged differently in each case. Having different arrangements means that starch and cellulose are different compounds. They serve different functions in the plants that make them. Your body also uses starch very differently from the way it uses cellulose.

Starch Plants store energy in the form of the complex carbohydrate **starch.** You can find starches in food products such as bread, cereal, pasta, rice, and potatoes.

The process of breaking large molecules, such as starch, into smaller ones involves chemical reactions that occur during digestion. The body digests the large starch molecules from these foods into individual glucose molecules. The body then breaks apart the glucose molecules, releasing energy in the process. **The energy released by breaking down starch allows the body to carry out its life functions.**

Cellulose Plants build strong stems and roots with the complex carbohydrate **cellulose** and other polymers. Most fruits and vegetables are high in cellulose. So are foods made from whole grains. Even though the body can break down starch, it cannot break down cellulose into individual glucose molecules. Therefore the body cannot use cellulose as an energy source. In fact, when you eat foods with cellulose, the molecules pass through you undigested. However, this undigested cellulose helps keep your digestive tract active and healthy. Cellulose is sometimes called fiber.

Reading Checkpoint What foods are high in cellulose?

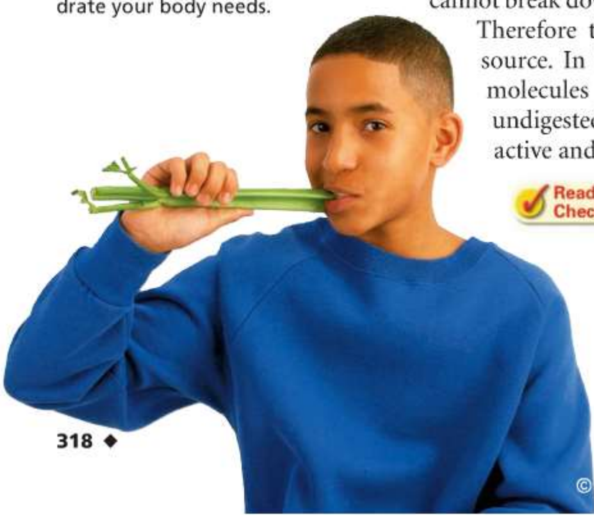


FIGURE 22
Cellulose
Cellulose, found in celery and other vegetables, is a carbohydrate your body needs.

Proteins

If the proteins in your body suddenly disappeared, you would not have much of a body left! Your muscles, hair, skin, and fingernails are all made of proteins. A bird's feathers, a spider's web, a fish's scales, and the horns of a rhinoceros are also made of proteins.

Chains of Amino Acids As you have learned, proteins are polymers formed from combinations of monomers called amino acids. There are 20 kinds of amino acids found in living things. Different proteins are made when different sequences of amino acids are linked into long chains. Since proteins can be made of combinations of amino acids in any order and number, a huge variety of proteins is possible.

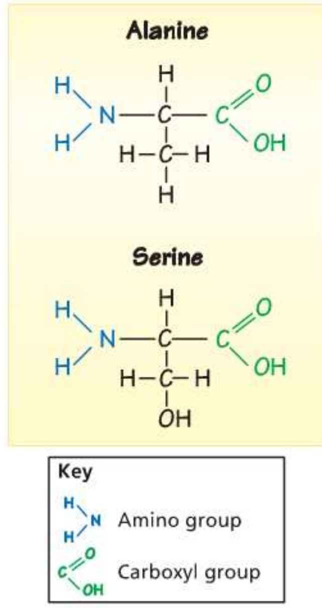
The structure of an amino acid is shown in Figure 23. Each amino acid molecule has a carboxyl group (—COOH). The *acid* in the term *amino acid* comes from this part of the molecule. An amino group, with the structure —NH_2, is the source of the *amino* half of the name. The remaining part of the molecule differs for each kind of amino acid.

Food Proteins Become Your Proteins Some of the best sources of protein include meat, fish, eggs, and milk or milk products. If you did the Discover activity, you used vinegar to separate proteins from milk. Some plant products, such as beans, are good sources of protein as well.

The body uses proteins from food to build and repair body parts and to regulate cell activities. But first the proteins must be digested. Just as starch is broken down into glucose molecules, proteins are broken down into amino acids. Then the body reassembles those amino acids into thousands of different proteins that can be used by cells.

Reading Checkpoint What are good sources of dietary protein?

FIGURE 23
Amino Acids
Alanine and serine are two of the 20 amino acids in living things. Each amino acid has a carboxyl group (—COOH) and an amino group (—NH_2).



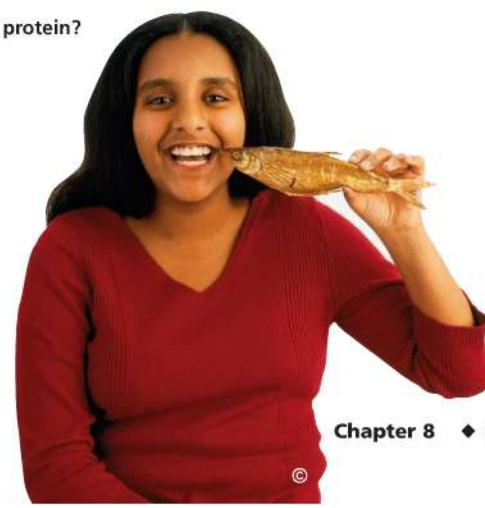


FIGURE 24
Proteins
Your body needs proteins, which are available in fish and meat. **Drawing Conclusions** *How are amino acids related to proteins?*

Lab zone Try This Activity

Like Oil or Water?

Oils mix poorly with water. They also do not evaporate very quickly when exposed to air.

1. Obtain a piece of brown paper and some samples of liquids provided by your teacher.
2. Using a dropper, place one drop of liquid from each sample on the paper.
3. Wait 5 minutes.
4. Note which of the liquids leaves a spot.

Inferring Which of the liquids is a fat or oil? How can you tell?

Lipids

The third class of organic compounds in living things is lipids. Like carbohydrates, **lipids** are energy-rich compounds made of carbon, oxygen, and hydrogen. Lipids include fats, oils, waxes, and cholesterol. **Gram for gram, lipids release twice as much energy in your body as do carbohydrates.** Like hydrocarbons, lipids mix poorly with water.

Fats and Oils Have you ever gotten grease on your clothes from foods that contain fats or oils? Fats are found in foods such as meat, butter, and cheese. Oils are found in foods such as corn, sunflower seeds, peanuts, and olives.

Fats and oils have the same basic structure. Each fat or oil is made from three **fatty acids** and one alcohol named glycerol. There is one main difference between fats and oils, however. Fats are usually solid at room temperature, whereas oils are liquid. The temperature at which a fat or an oil becomes a liquid depends on the chemical structure of its fatty acid molecules.

You may hear fats and oils described as "saturated" or "unsaturated." Like saturated hydrocarbons, the fatty acids of saturated fats have no double bonds between carbon atoms. Unsaturated fatty acids are found in oils. Monounsaturated oils have fatty acids with one double bond. Polyunsaturated oils have fatty acids with many double bonds. Saturated fats tend to have higher melting points than unsaturated oils have.

Cholesterol Another important lipid is **cholesterol** (kuh LES tuh rawl), a waxy substance found in all animal cells. The body needs cholesterol to build cell structures and to form compounds that serve as chemical messengers. Unlike other lipids, cholesterol is not a source of energy. The body produces the cholesterol it needs from other nutrients. Foods that come from animals—cheese, eggs, and meat—also provide cholesterol. Plants do not produce cholesterol.

Although cholesterol is often found in the same foods as saturated fats, they are different compounds. An excess level of cholesterol in the blood can contribute to heart disease. So can saturated fats. And saturated fats can affect the level of cholesterol in the blood. For this reason it is wise to limit your intake of both nutrients.

Reading Checkpoint What are sources of cholesterol in the diet?

FIGURE 25
Fats and Oils
Foods that contain fats and oils include peanut butter, butter, cheese, corn, and olives.

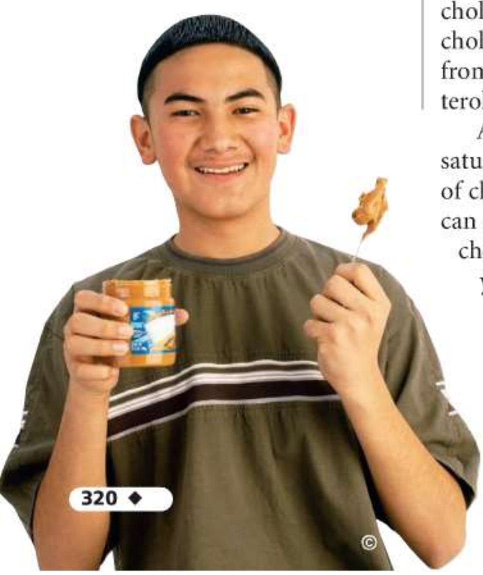
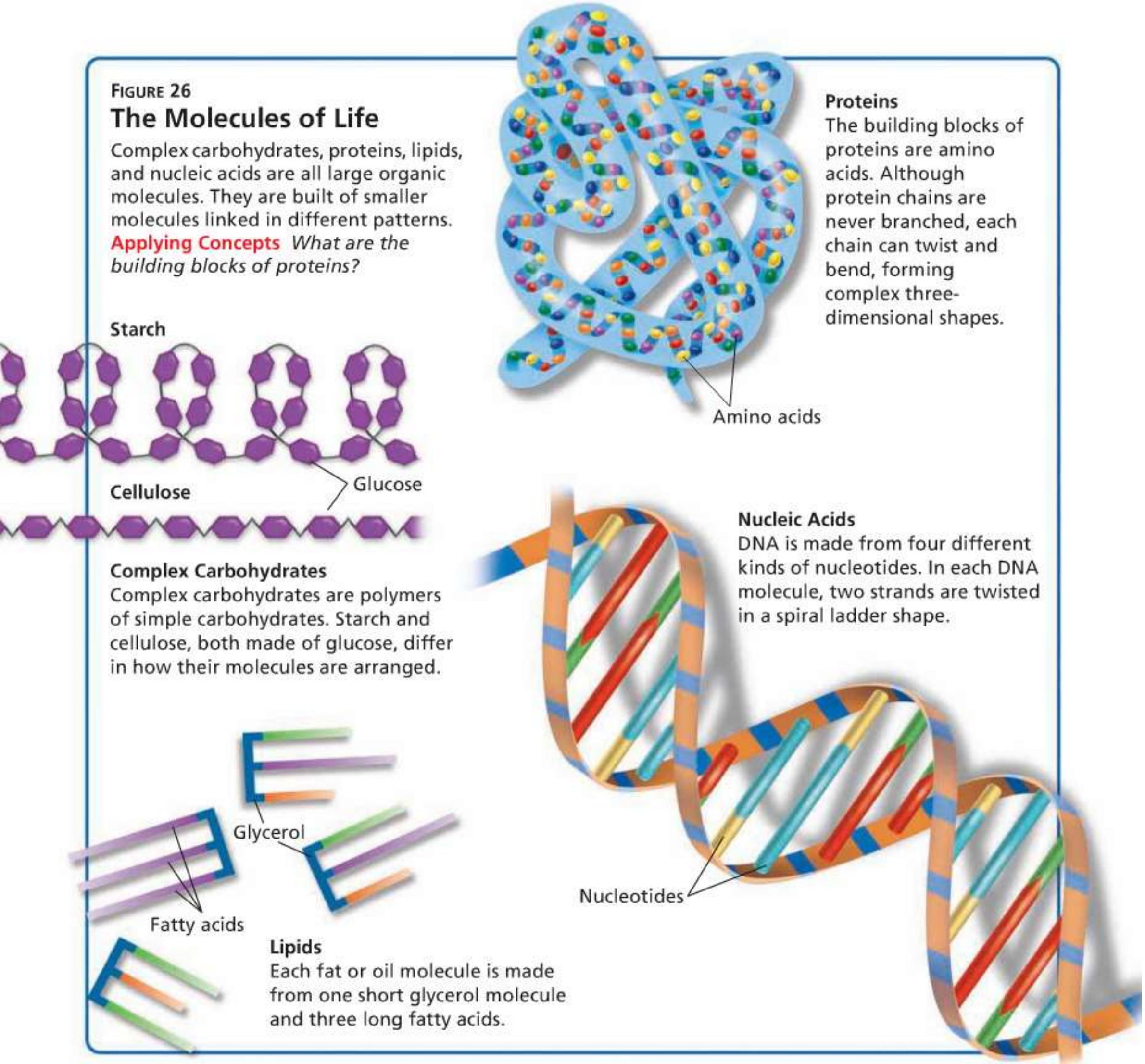


FIGURE 26
The Molecules of Life

Complex carbohydrates, proteins, lipids, and nucleic acids are all large organic molecules. They are built of smaller molecules linked in different patterns. **Applying Concepts** *What are the building blocks of proteins?*



Proteins
The building blocks of proteins are amino acids. Although protein chains are never branched, each chain can twist and bend, forming complex three-dimensional shapes.

Complex Carbohydrates
Complex carbohydrates are polymers of simple carbohydrates. Starch and cellulose, both made of glucose, differ in how their molecules are arranged.

Nucleic Acids
DNA is made from four different kinds of nucleotides. In each DNA molecule, two strands are twisted in a spiral ladder shape.

Lipids
Each fat or oil molecule is made from one short glycerol molecule and three long fatty acids.

Nucleic Acids

The fourth class of organic compounds in living things is nucleic acids. **Nucleic acids** (noo KLEE ik) are very large organic molecules made up of carbon, oxygen, hydrogen, nitrogen, and phosphorus. There are two types of nucleic acids—DNA and RNA. You have probably heard of **DNA,** or deoxyribonucleic acid (dee ahk see ry boh noo KLEE ik). **RNA** stands for ribonucleic acid (ry boh noo KLEE ik).

Video Field Trip
Discovery Channel School
Carbon Chemistry

Nucleotides DNA and RNA are made of different kinds of small molecules connected in a pattern. The building blocks of nucleic acids are called **nucleotides** (NOO klee oh tydz). In even the simplest living things, the DNA contains billions of nucleotides! There are only four kinds of nucleotides in DNA. RNA is also built of only four kinds of nucleotides, but the nucleotides in RNA differ from those in DNA.

DNA and Proteins The differences among living things depend on the order of nucleotides in their DNA. The order of DNA nucleotides determines a related order in RNA. The order of RNA nucleotides, in turn, determines the sequence of amino acids in proteins made by a living cell.

Remember that proteins regulate cell activities. Living things differ from one another because their DNA, and therefore their proteins, differ from one another. The cells in a hummingbird grow and function differently from the cells in a flower or in you. **When living things reproduce, they pass DNA and the information it carries to the next generation.**

Reading Checkpoint What are the building blocks of nucleic acids?

FIGURE 27
Vitamins and Minerals
Sources of vitamins and minerals include fruits, vegetables, nuts, meats, and dairy products.
Observing *Which of these foods can you identify in the painting?*

Other Nutrients

Living organisms are made of molecules consisting largely of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. These elements make up most of Earth's biomass, or the total mass of living organisms. The molecules that make up organisms are usually large molecules, such as DNA, proteins, carbohydrates, and fats. But living things also need simple molecules such as water. **Organisms require water, vitamins, minerals, and salts to support the functioning of large molecules.**

Water Your body needs water to survive. Water makes up most of your body's fluids, including about 90 percent of the liquid part of your blood. Nutrients and other important substances are dissolved in the watery part of the blood and carried throughout the body. Many chemical reactions, such as the breakdown of nutrients, take place in water. Wastes from cells dissolve in the blood and are carried away.

Vitamins Vitamins are organic compounds that serve as helper molecules in a variety of chemical reactions in your body. For example, vitamin C, or ascorbic acid, is important for keeping your skin and gums healthy. Vitamin D helps your bones and teeth develop and keeps them strong.

Minerals Minerals are elements in the form of ions needed by your body. Unlike the other nutrients discussed in this chapter, minerals are not organic compounds. Minerals include calcium, iron, iodine, sodium, and potassium. They are important in many body processes.

Salts Salts are ionic compounds found in your body as dissolved ions. One important salt is sodium chloride. It supplies sodium ions, which help in the contraction of muscles and in the transmission of messages through nerves. Other salts are vital to such functions as the healthy growth of bones and teeth or keeping blood pH balanced. If you eat a variety of foods, you are more likely to get the vitamins, minerals, and salts you need. A balanced diet of fruits, vegetables, and sources of protein and calcium contains the nutrients your body uses.

Reading Checkpoint What is a vitamin?

Go Online SCI LINKS NSTA

For: Links on organic compounds
Visit: www.SciLinks.org
Web Code: scn-1243

Section 4 Assessment

S 8.6.b, 8.6.c, E-LA: Reading 8.1.3, Writing 8.2.0

Vocabulary Skill **Use Clues to Determine Meaning** Reread the paragraph on cholesterol under the heading Lipids. What clues help you understand the meaning of the word *cholesterol*?

Reviewing Key Concepts

HINT **1. a.** **Naming** What are the four main classes of organic compounds required by living things?

HINT **b.** **Classifying** To what class of organic compounds does each of the following belong: glucose, RNA, cholesterol, cellulose, and oil?

HINT **c.** **Making Generalizations** How is each class of organic compounds used by the body?

HINT **d.** **Comparing and Contrasting** Compare the building blocks found in complex carbohydrates with those found in proteins.

HINT **2. a.** **Identifying** What nutrients help support the functioning of large molecules in organisms?

b. **Explaining** Why does your body need water to survive? HINT

c. **Comparing and Contrasting** How do vitamins and salts differ? HINT

Writing in Science

Advertisement Collect several food advertisements from magazines and watch some TV commercials. What do the ads say about nutrients? What do they emphasize? What do they downplay? Choose one ad and rewrite it to reflect the nutritional value of the product.

Lab zone **Consumer Lab**

Are You Getting Your Vitamins?

S 8.6.c, 8.9.c

Problem

Fruit juices contain vitamin C, an important nutrient. Which juice should you drink to obtain the most vitamin C?

Skills Focus

controlling variables, interpreting data, inferring

Materials

- 6 small cups
- 6 plastic droppers
- starch solution
- iodine solution
- vitamin C solution
- samples of beverages (orange juice, apple juice, sports drink, fruit-flavored drink)

Procedure

PART 1 Vitamin C Test

1. Using a plastic dropper, place 25 drops of tap water into one of the small cups. Add 2 drops of starch solution.
2. Add 1 drop of iodine solution to the cup. **CAUTION:** *Iodine solution can stain skin or clothing.* Observe the color of the mixture. Save this cup to use for comparison in Step 4.
3. Using a fresh dropper, place 25 drops of vitamin C solution into another cup. Add 2 drops of starch solution.
4. Add 1 drop of iodine solution to the cup and swirl. Continue adding iodine a drop at a time, swirling after each drop, until you get a dark blue color similar to the color obtained in Step 2. Record the number of iodine drops.
5. Save the cup from Step 4 and use it for comparison during Part 2.

PART 2 Comparison Test

6. Make a data table in your notebook similar to the one on the next page.
7. Which beverage sample do you think has the most vitamin C? Which do you think has the least? Rank your beverage samples according to your predictions.

Data Table			
Test Sample	Drops of Iodine	Predicted Rank	Actual Rank
Vitamin C			
Orange juice			
Apple juice			
Sports drink			
Fruit-flavored drink			

8. Adapt the procedure from Part 1 so you can compare the amount of vitamin C in your beverage samples to the vitamin C solution.
9. Carry out your procedure after your teacher approves.

Analyze and Conclude

1. **Controlling Variables** What was the purpose for the test of the mixture of starch and water in Step 2?
2. **Controlling Variables** What was the purpose for the test of the starch, water, and vitamin C in Step 4?
3. **Drawing Conclusions** What do you think caused differences between your data from Step 2 and Step 4?
4. **Controlling Variables** Why did you have to add the same amount of starch to each of the beverages?
5. **Predicting** What would happen if someone forgot to add the starch to the beverage before they began adding iodine?
6. **Measuring** Of the four drinks you tested, which took the most drops of iodine before changing color? Which took the fewest?
7. **Interpreting Data** Which beverage had the most vitamin C? Which had the least? How do you know?
8. **Inferring** When you tested orange juice, the color of the first few drops of the iodine faded away. What do you think happened to the iodine?
9. **Communicating** If a beverage scored low in your test for vitamin C, does that mean it isn't good for you? Write a paragraph in which you explain what other factors might make a beverage nutritious or take away from its nutrient value.

Design an Experiment

Foods are often labeled with expiration dates. Labels often also say to "refrigerate after opening." Design an experiment to find out if the vitamin C content of orange juice changes over time at different temperatures. *Obtain your teacher's permission before carrying out your investigation.*

Chapter 8 Study Guide

The BIG Idea — **Because of its ability to combine in many ways with itself and with other elements, carbon has a central role in the chemistry of living organisms.**

1 Properties of Carbon

Key Concepts — S 8.6.a

- Because of its ability to combine in many ways with itself and other elements, carbon has a central role in the chemistry of organisms.
- Diamond, graphite, fullerenes, and nanotubes are four forms of the element carbon.

Key Terms

diamond
graphite
fullerene
nanotube

2 Carbon Compounds

Key Concepts — S 8.3.c, 8.6.a

- Many organic compounds have similar properties in terms of melting points, boiling points, odor, electrical conductivity, and solubility.
- Hydrocarbons mix poorly with water. Also, all hydrocarbons are flammable.
- The carbon chains in a hydrocarbon ring may be straight, branched, or ring-shaped. In addition to forming a single bond, two carbon atoms can form a double bond or a triple bond.
- If just one atom of another element is substituted for a hydrogen atom in a hydrocarbon, a different compound is created.
- Many esters have pleasant, fruity smells.
- Organic compounds can be linked together to build polymers with thousands or even millions of atoms.

Key Terms

organic compound
hydrocarbon
structural formula
isomer
saturated hydrocarbon
unsaturated hydrocarbon
substituted hydrocarbon
hydroxyl group
alcohol
organic acid
carboxyl group
ester
polymer
monomer

3 Polymers and Composites

Key Concepts — S 8.3.c, 8.6.a

- Polymers form when chemical bonds link large numbers of monomers in a repeating pattern.
- Many composites include one or more polymers.
- You can help reduce the amount of plastic waste by recycling.

Key Terms

protein
amino acid
plastic
composite

4 Life With Carbon

Key Concepts — S 8.6.b, 8.6.c

- The four classes of organic compounds required by living things are carbohydrates, proteins, lipids, and nucleic acids.
- The energy released by breaking down starch allows the body to carry out its life functions.
- The body uses proteins from food to build and repair body parts and to regulate cell activities.
- Gram for gram, lipids release twice as much energy in your body as do carbohydrates.
- When living things reproduce, they pass DNA and the information it carries to the next generation.
- Organisms require water, vitamins, minerals, and salts to help support the functioning of large molecules.

Key Terms

carbohydrate
glucose
complex carbohydrate
starch
cellulose
lipid
fatty acid
cholesterol
nucleic acid
DNA
RNA
nucleotide

Review and Assessment

Go Online
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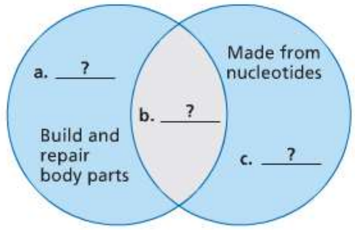
Visit: PHSchool.com
Web Code: cxa-2080

Target Reading Skill

Comparing and Contrasting In your notebook, copy the Venn diagram comparing proteins and nucleic acids. Complete the diagram and add a title.



Reviewing Key Terms

Choose the letter of the best answer.

HINT **1.** A form of carbon in which the carbon bonds are arranged in a repeating pattern similar to a geodesic dome is
a. a fullerene.
b. graphite.
c. diamond.
d. a nanotube.

HINT **2.** A compound that contains only hydrogen and carbon is defined as
a. a monomer.
b. an isomer.
c. a hydrocarbon.
d. a polymer.

HINT **3.** Fiberglass is a type of
a. polymer.
b. alloy.
c. ceramic.
d. composite.

HINT **4.** The smaller molecules from which cellulose is made are
a. glucose.
b. amino acids.
c. nucleotides.
d. fatty acids.

HINT **5.** Cholesterol is a type of
a. nucleic acid.
b. carbohydrate.
c. lipid.
d. cellulose.

Complete the following sentences so that your answers clearly explain the key terms.

6. Methane and acetic acid are examples of **organic compounds,** which are defined as __________ . HINT

7. Butane and isobutane are **isomers,** or compounds that __________ . HINT

8. Fingernails and muscles are made of **proteins,** which are polymers of __________ . HINT

9. Sucrose and starch are examples of **carbohydrates,** which are defined as __________ . HINT

10. Glucose is considered a **monomer** because __________ . HINT

Writing in Science

Web Site You are writing a feature article on carbon for a chemistry Web site. In your article, describe four forms of the element carbon. Include in your descriptions how the carbon atoms are arranged and how the bonds between the carbon atoms affect the properties of the substance. Include any helpful illustrations.

Video Assessment
Discovery Channel School
Carbon Chemistry

Review and Assessment

Checking Concepts

11. What does a dash represent when written between two carbon symbols in a diagram of a chain or ring of carbon atoms?

12. What do diamonds, graphite, fullerenes, and nanotubes have in common?

13. How would you notice the presence of esters in a fruit such as a pineapple?

14. Name some polymers that are produced in nature. Tell where they come from.

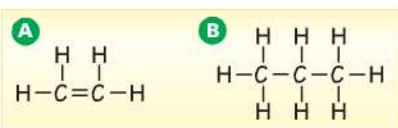
15. Starch and cellulose are both complex carbohydrates. How does your body treat these compounds differently?

16. Compare and contrast the fatty acids in fats that are solid at room temperature with fatty acids in oils that are liquids.

Thinking Critically

17. **Relating Cause and Effect** What features of the element carbon allow it to form the "backbone" of such a varied array of different compounds?

18. **Applying Concepts** Which of the diagrams below represents a saturated hydrocarbon? Which represents an unsaturated hydrocarbon? Explain your answer.

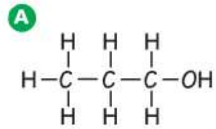


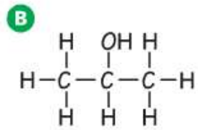
19. **Making Judgments** The plastic rings that hold beverage cans together are sometimes hazardous to living things in the ocean. Do you think companies that make soft drinks should be allowed to continue using plastic rings? Consider what could replace them.

20. **Posing Questions** Glucose and fructose are both simple carbohydrates with the formula $C_6H_{12}O_6$. What else do you need to know about glucose and fructose to decide if they should be considered different compounds?

Applying Skills

Use the following structural formulas to answer Questions 21–25.





21. **Classifying** Which type of substituted hydrocarbons are compounds A and B? What information in the structural formulas did you use to decide your answer?

22. **Observing** What is the correct subscript for the carbon atoms (C) in the chemical formula that corresponds to each structural formula?

23. **Inferring** Are compounds A and B isomers? How can you tell?

24. **Predicting** Would you expect these two compounds to have identical properties or different properties? Explain.

25. **Problem Solving** What kind of compound would result if an organic acid were chemically combined with compound A? What properties would you expect the new compound to have?

Lab zone Standards Investigation

Performance Assessment Display your data table classifying compounds in foods, along with the labels from which you collected your data. Point out the nutrients that are found in almost all foods and the nutrients found in only a few.

CALIFORNIA

Standards Practice

Success Tracker™
Online at PHSchool.com

Choose the letter of the best answer.

1. What kind of molecule is made of a chain of many smaller molecules bonded together?
A monomer
B polymer
C carboxyl group
D amino acid
S 8.3.c

2. Living organisms are made of molecules consisting largely of the elements hydrogen, nitrogen, oxygen, phosphorus, sulfur, and
A calcium.
B sodium.
C carbon.
D iron.
S 8.6.b

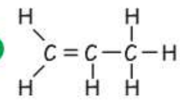
3. The formula $C_5H_{11}OH$ represents an
A amino acid.
B organic acid.
C alcohol.
D ester.
S 8.6.c

4. Material X is an organic compound that mixes poorly with water and is highly flammable. Of the following choices, material X is most likely a(n)
A carbohydrate.
B ester.
C alcohol.
D hydrocarbon.
S 8.6.c

5. Which of the following is an example of a synthetic polymer?
A cellulose
B protein
C nylon
D starch
S 8.3.c

6. The smaller molecules that make up complex carbohydrates are called
A sugars.
B amino acids.
C fatty acids.
D nucleotides.
S 8.6.c

Use the structural diagrams below and your knowledge of science to answer Questions 7–9.

1


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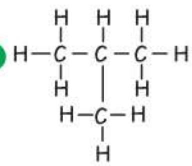

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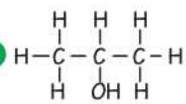

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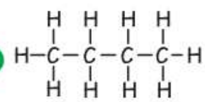

7. Isomers are organic compounds having the same chemical formula, but different structural formulas. Which pair of compounds are isomers?
A 1 and 2
B 1 and 3
C 2 and 3
D 2 and 4
S 8.6.a

8. Which structural diagram represents an unsaturated hydrocarbon?
A 1
B 2
C 3
D 4
S 8.6.a

9. What is the ratio of carbon atoms to hydrogen atoms in the compound represented by 1?
A 1 to 9
B 9 to 1
C 3 to 6
D 6 to 3
S 8.6.a

Apply the BIG Idea

10. Explain why carbohydrates, lipids, and proteins are important parts of a well-balanced diet.
S 8.6.c

Chemical Interactions

Unit 2 Review

Chapter 5

Atoms and Bonding

The BIG Idea

Atoms of different elements combine to form compounds by gaining, losing, or sharing electrons.

- How is the reactivity of elements related to valence electrons?
- How do ions form bonds?
- What holds covalently bonded atoms together?
- How do metal atoms combine?

Chapter 6

Chemical Reactions

The BIG Idea

Chemical reactions are processes in which atoms are rearranged into different combinations of molecules.

- How can you tell when a chemical reaction occurs?
- How is matter conserved during chemical reactions?
- What factors affect the rate of a chemical reaction?
- What are the three things necessary to maintain a fire?

Chapter 7

Solutions, Acids, and Bases

The BIG Idea

Acids taste sour, turn blue litmus paper red, and produce hydrogen ions (H^+) in water. Bases taste bitter, turn red litmus paper blue, and produce hydroxide ions (OH^-) in water.

- What are the characteristics of solutions, colloids, and suspensions?
- Why is solubility useful in identifying substances?
- What are the properties of acids and bases?
- What does pH tell you about a solution?

Chapter 8

Carbon Chemistry

The BIG Idea

Because of its ability to combine in many ways with itself and with other elements, carbon has a central role in the chemistry of living organisms.

- What are four forms of pure carbon?
- What are some properties shared by organic compounds?
- What organic compounds are required by living things?

Unit 2 Assessment

Connecting the BIG Ideas

Bob and Ted are cooking a meal to share with friends. For the side dish, they decide to make a potato dish using a recipe they found in a cookbook. The main ingredients for the recipe are potatoes, vinegar, and sea salt.

As Bob places the potatoes into a pot of cold water, Ted goes to the pantry and takes out the salt. Another name for salt is sodium chloride, because it is a compound made up of sodium ions and chlorine ions. Ted pours the salt into the pot and turns on the stove so that the potatoes can simmer. When raw potatoes are boiled, they become softer because the boiling breaks down the cell membranes, allowing water and carbohydrates to leave. The breaking down of the cell membranes is a chemical reaction.

After thirty minutes, Ted drains the potatoes and puts them in a bowl, while Bob gets the vinegar out of the pantry. Vinegar contains acetic acid, which gives it its sour taste. They add the vinegar and the rest of the salt to the potatoes and stir.

The last ingredient they add is olive oil. Although the oil mixes with the rest of the ingredients, no chemical reaction takes place when it is added.

1. How many valence electrons does a sodium atom have? *(Chapter 5)*
a. 1 **b.** 2
c. 7 **d.** 8

2. Which of the following is not a chemical reaction? *(Chapter 6)*
a. synthesis **b.** decomposition
c. replacement **d.** conservation of matter

3. Which of the following pH values would be closest to that of vinegar? *(Chapter 7)*
a. 3 **b.** 7
c. 11 **d.** 14

4. Which of the following is a polymer that humans can digest? *(Chapter 8)*
a. cellulose **b.** polyester
c. starch **d.** nylon

5. **Summary** Write a paragraph summarizing the changes that take place while the potato recipe is prepared. Which changes are chemical, and which are physical? Explain.