CHAPTER 10

Organic chemistry

Did you ever wonder...

- **What gas is carried in that pipeline under your street?**
- **What causes the pain when you are bitten by an ant?**
- **What the difference is between a saturated and an unsaturated fat?**

Before you begin to study about organic chemistry, think about these questions and answer them *in your Journal*. When you finish the chapter, compare your Journal write-up with what you have learned.

Every day you wake up, get dressed, eat something, and head out the door. Maybe you listened to music on the radio. Do you ride a bus to school? Your nylon backpack holds your books, notebook paper, pens and pencils.

Is carbon a part of your life? Most things you come in contact with today involve carbon in some way. The clothes you wear, the food you eat, the fuel in the bus, the cassette tape you use to listen to music, even the basketball you play with are made of carbon compounds. Why is carbon found in so many different compounds? How can carbon be used to make fuels and foods? In this chapter you will learn about some carbon compounds and what they mean to you.

In the activity on the next page, explore one way that foods can be tested for carbon.

10-1 Simple Organic Compounds

Section Objectives

- Describe structures of organic compounds and explain why carbon forms so many compounds.
- Distinguish between saturated and unsaturated hydrocarbons.
- Identify isomers of organic compounds.

Key Terms

organic compounds
hydrocarbon
isomers

Organic Compounds

Would you eat a piece of charcoal? If you have ever eaten a marshmallow, you might be surprised to learn that both marshmallows and charcoal contain the element carbon. Most substances that contain carbon are **organic compounds.** For years, scientists thought that living things were needed to make organic compounds. In 1828, a German scientist accidentally formed the organic compound urea from inorganic materials. This made other scientists realize that living organisms weren't always necessary to form organic compounds.

Today, the term organic is used to describe nearly all carbon-containing substances, whether or not they are found in living organisms. Most of the millions of different organic compounds that exist can be synthesized from carbon-containing raw materials such as wood, oil, natural gas, and coal.

You have already seen how you can turn simple substances, such as bread and apple, into carbon. How can you make other forms of carbon, such as charcoal?

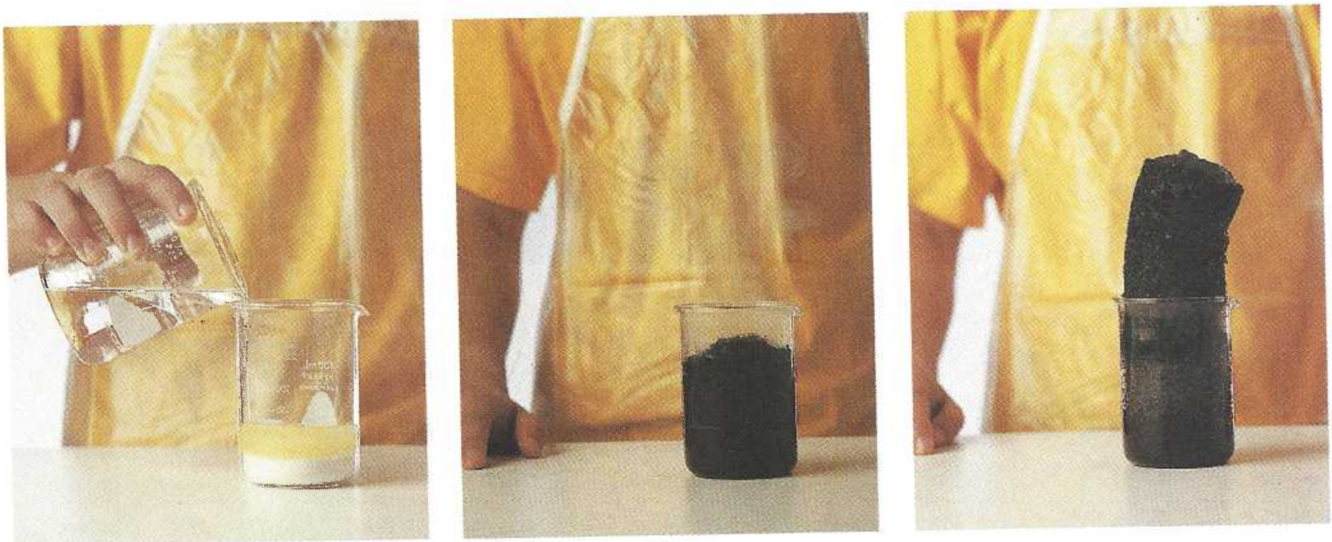


Figure 10-1

A An interesting reaction occurs when concentrated sulfuric acid is poured into a beaker containing sugar, or sucrose.

B How would you describe the reaction that is occurring?

C Carbon is produced when sulfuric acid pulls the water out of sucrose. What happened to the water in this reaction?

Find Out! ACTIVITY

How do you make charcoal from wood?

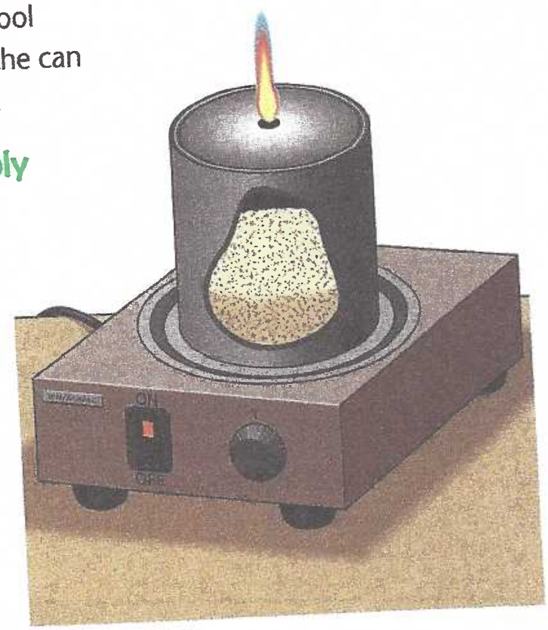
Although wood and charcoal appear different, they both contain carbon.

What To Do

1. Fill a clean, empty 1/4-pint varnish or paint can with sawdust from either a white pine or an oak.
2. Punch a small round hole (about 1/4" in diameter) through the center of the lid with a nail. Press the lid firmly in place and place the can on a hot plate.
3. Begin heating until white smoke comes out of the hole. Carefully light the smoke with a match until a yellow flame appears.
4. Continue heating until the flame disappears from the hole.
5. Turn off the hot plate and allow the can to cool overnight. Open the can the following day.

Conclude and Apply

1. What do you observe?
2. *In your Journal,* record what happened to the sawdust.



Carbon forms many different compounds because it has an atomic structure that allows it to combine with a tremendous number of different elements. A carbon atom has four electrons in its outer energy level. This electron arrangement means that the carbon atom can form four covalent bonds, as shown in **Figure 10-2**, with other carbon atoms or with atoms of other elements such as hydrogen and nitrogen.

In chapter 6 you learned that a covalent bond forms when two atoms share a pair of electrons. Carbon can form single, double, or triple covalent bonds with other atoms. Single covalent bonds contain one pair of shared electrons. Double bonds contain two shared electron pairs. Triple bonds contain three shared electron pairs.

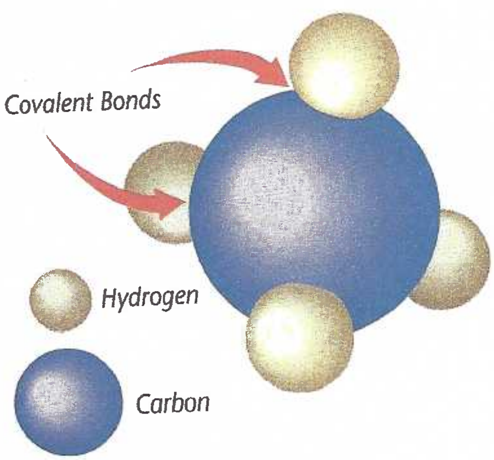


Figure 10-2

This model of a carbon atom is bonded covalently with four hydrogen atoms. Is there a limit to the number of covalent bonds this carbon atom can form? Why or why not?

Connect to... Earth Science

Natural gas, which contains methane, is one type of fossil fuel. Coal is another type of fossil fuel. Prepare a table that contains the appearance and characteristics of each of the three types of coal.

Hydrocarbons

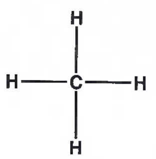
Carbon atoms form an enormous number of compounds with hydrogen alone. A **hydrocarbon** is a compound that contains only carbon and hydrogen. Hydrocarbons form the basis for the structure and chemistry of a number of other organic compounds.

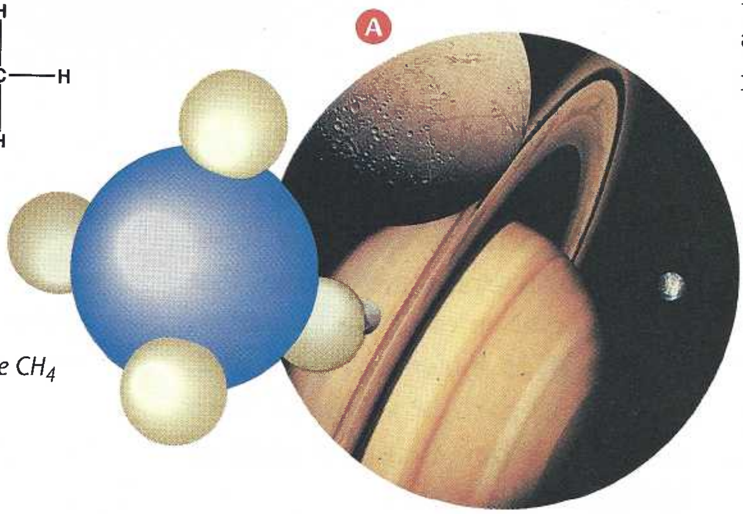
The shorter hydrocarbons are lighter molecules. In general, these compounds have low boiling points, and so they evaporate and burn more easily. This makes them useful as fuel gases. Longer hydrocarbons are heavy molecules that form solids or liquids at room temperature. They can be used as oils, waxes, or in asphalt.

Does the furnace, stove, or water heater in your home burn natural gas? This fuel, methane, is brought to homes through the pipeline underneath the street. Why do you suppose it's called natural gas?

Methane is the first and simplest member of the hydrocarbon family. Each line between atoms in a structural formula represents a single covalent bond. In methane, the carbon atom has four single covalent bonds to hydrogen atoms.

Other hydrocarbon molecules in this family are made by joining additional carbon and hydrogen atoms to methane. Every time another carbon atom is added, a new molecule is formed with its own set of properties.

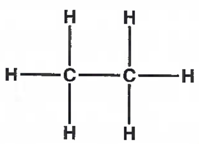


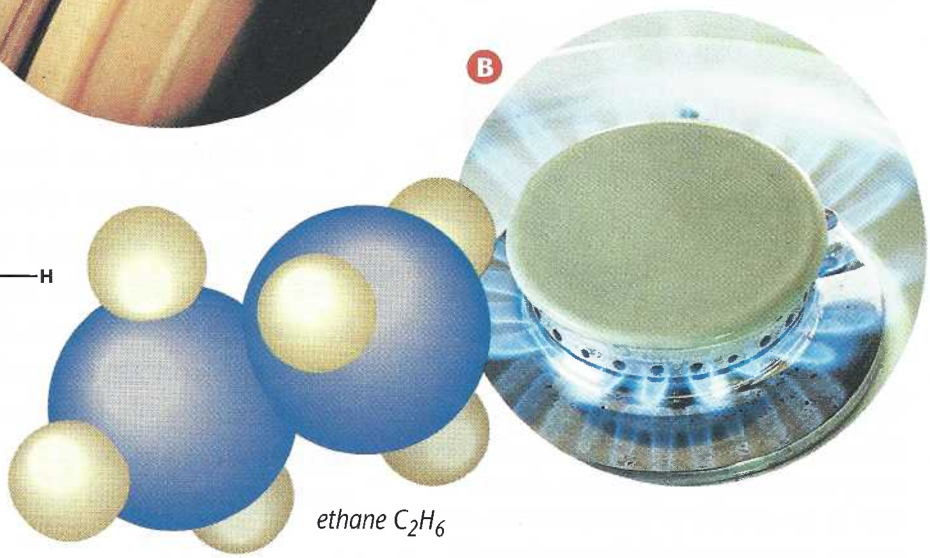


methane CH_4

Figure 10-3

Methane has been discovered on distant planets such as Saturn (A). On Earth, natural gas (B) is a fuel that is mostly methane, CH_4.





ethane C_2H_6

Figure 10-4

Ethane is formed by adding a $-CH_2$ group to methane. Compare the structural formulas of methane and ethane. In what ways are they similar?

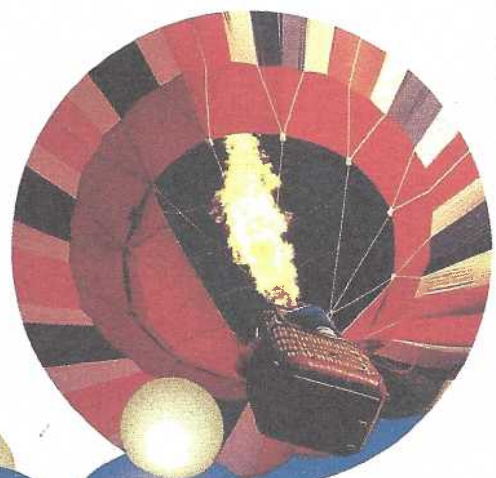
Saturated Hydrocarbons

Methane, ethane, propane, and their cousins make up a family of molecules known as saturated hydrocarbons. A hydrocarbon that is saturated contains only single covalent bonds. What would be the chemical and structural formulas for the next members of the methane family? **Table 10-1** shows formulas for some saturated hydrocarbons.

Have you ever opened your refrigerator and wondered why some foods seem to spoil quickly? How can you find out how this process works?

Figure 10-5

Propane is another popular fuel that is often used to generate the heat that enables hot air balloons to rise. Propane is the third member of the methane family and has the chemical formula C_3H_8. How does propane differ from ethane?



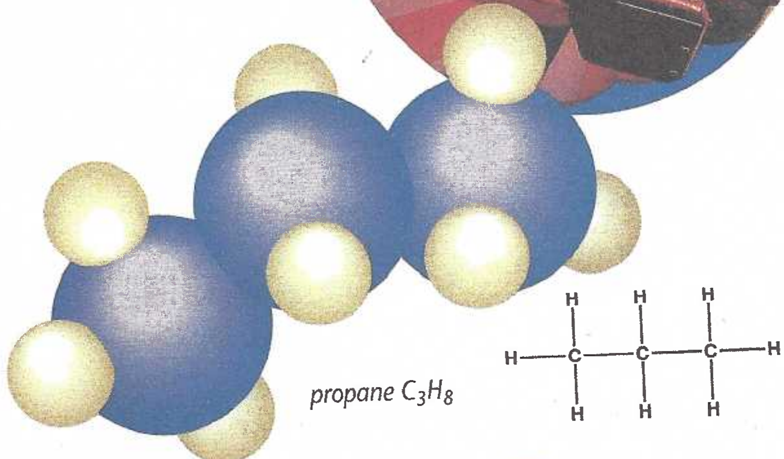
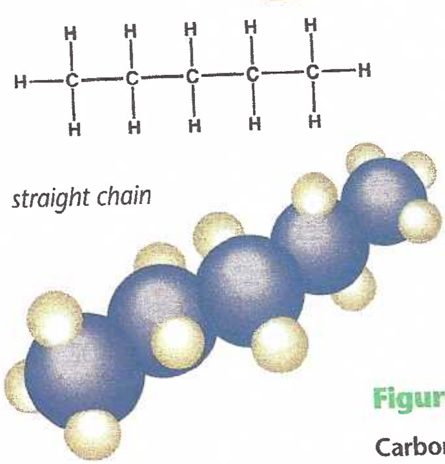
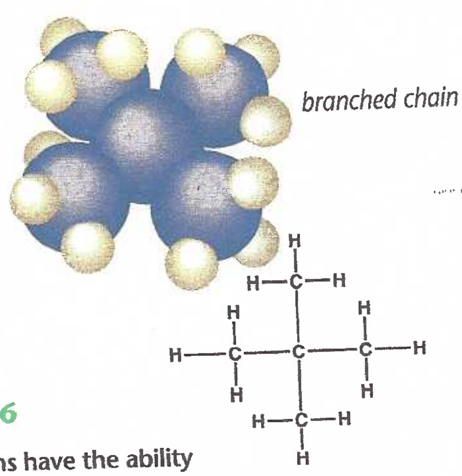


Table 10-1

Hydrocarbon Series	
NAME	**FORMULA**
Methane	CH_4
Ethane	C_2H_6
Propane	C_3H_8
Butane	C_4H_{10}
Octane	C_8H_{18}

A saturated hydrocarbon can be described as one in which all carbon atoms are bonded to the maximum number of hydrogen atoms. Think about the structural formulas of these hydrocarbons. Are all of their carbon atoms bonded to the maximum number of hydrogen atoms?





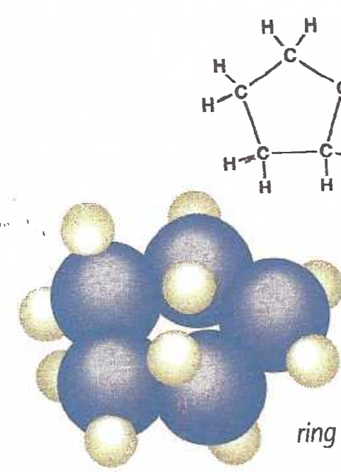


Figure 10-6

Carbon atoms have the ability to bond in a variety of ways.

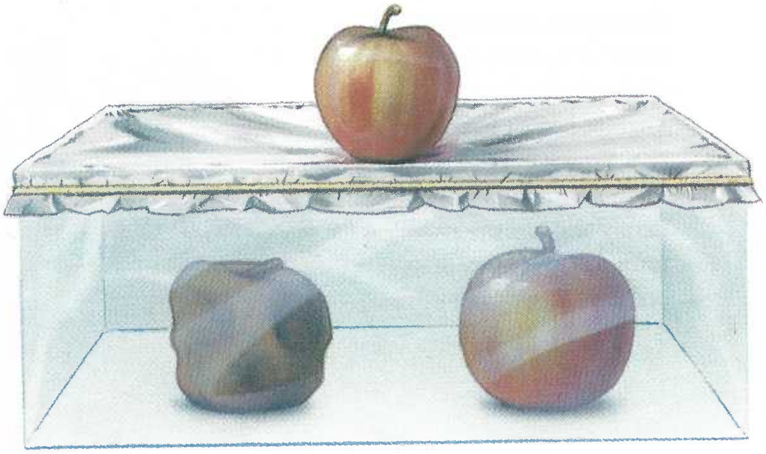
Find Out! ACTIVITY

What causes fruits and vegetables to ripen?

Fruits and vegetables change as they ripen although the cause of the change is not readily apparent.

What To Do

1. Place a rotten apple in a clear plastic box along with a fresh unripe apple.
2. Seal the lid of the box with aluminum foil and a rubber band.
3. Set another unripe apple on top of the box.
4. Observe the changes in each apple over the course of a week.
5. Repeat this experiment with two green tomatoes instead of apples.

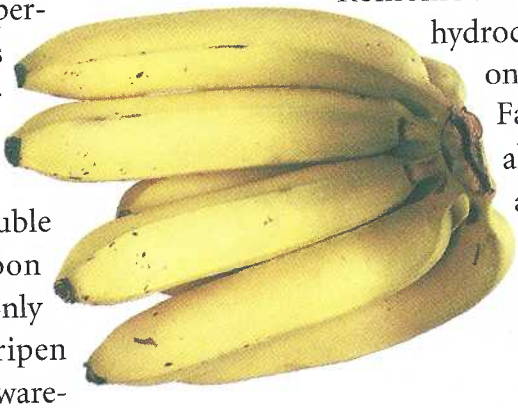


Conclude and Apply

1. Which apple ripens faster?
2. Does the same thing occur when you use tomatoes instead of apples?

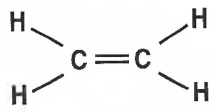
Unsaturated Hydrocarbons

In some of the hydrocarbons, some of the carbon atoms form double or triple covalent bonds with other carbon atoms. These new molecules have different properties from the molecules that have a single carbon-carbon bond.



The hydrocarbon ethene, C_2H_4, has a double bond between the carbon atoms. This gas, commonly called ethylene, helps ripen fruits and vegetables at warehouses before they are sold. Foods that spoil in your refrigerator produce this gas, which causes other foods to spoil. You saw this happen in the Find Out activity.

Hydrocarbons that contain double or triple bonds between carbon atoms are called unsaturated hydrocarbons. Remember that saturated hydrocarbons contain only single bonds. Fats and oils can also be classified as saturated or unsaturated.



ethene C_2H_4

Figure 10-7

This is the structural formula for ethene, showing the double bond.

Isomers

Imagine that you could move the desks around in your classroom. You might place them all in two long rows or in six short rows. How many combinations can you think of?

Just as you could move your desks into different arrangements, the atoms in a hydrocarbon can form several different molecular structures, all having identical chemical formulas. Each carbon atom will still have four covalent bonds, but the overall shape of the molecule may vary. **Isomers** are compounds that have identical chemical formulas but different molecular structures, or shapes. Can you make isomers from any other hydrocarbons?

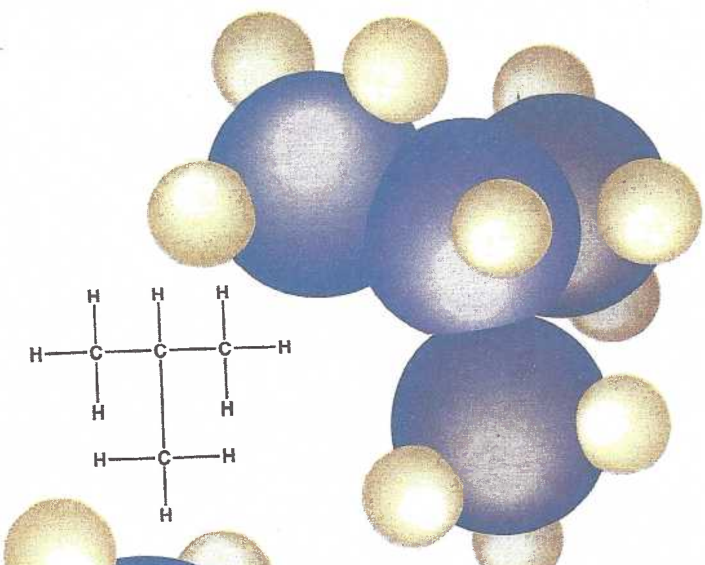
Properties of Isomers

The properties of isomers of a substance may not be identical, even though the chemical formulas are the same. The shape of the molecule seems to determine some of the properties. **Figure 10-8** shows the structures of butane and isobutane.

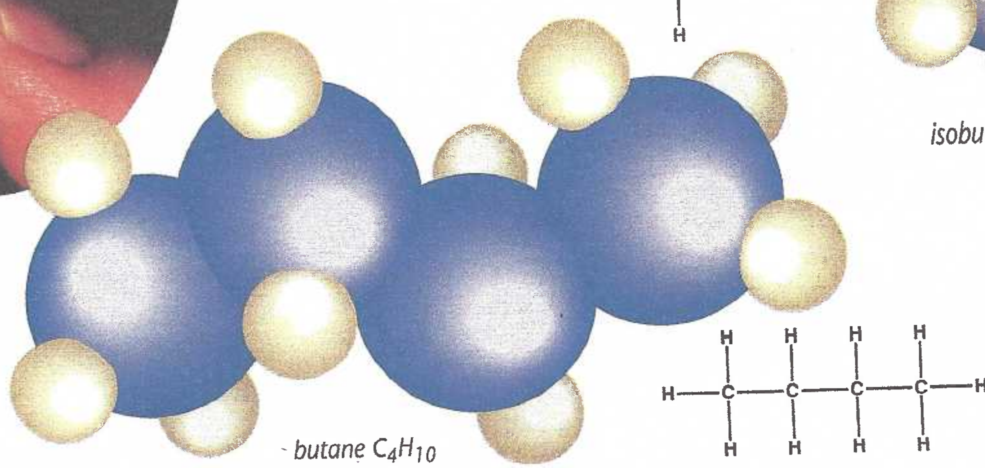
Isomers, such as those you will make for pentane and hexane, are still members of the methane family. They are all formed by adding more carbon and hydrogen atoms to methane. A double or triple covalent bond in a compound, instead of a single bond, makes an entirely new hydrocarbon, each with its own unique properties.

Figure 10-8

Butane, a gas sometimes burned in lighters, has a straight carbon chain. Isobutane has the same chemical formula as butane, C_4H_{10}, but its carbon chain is branched. Butane and isobutane are isomers.



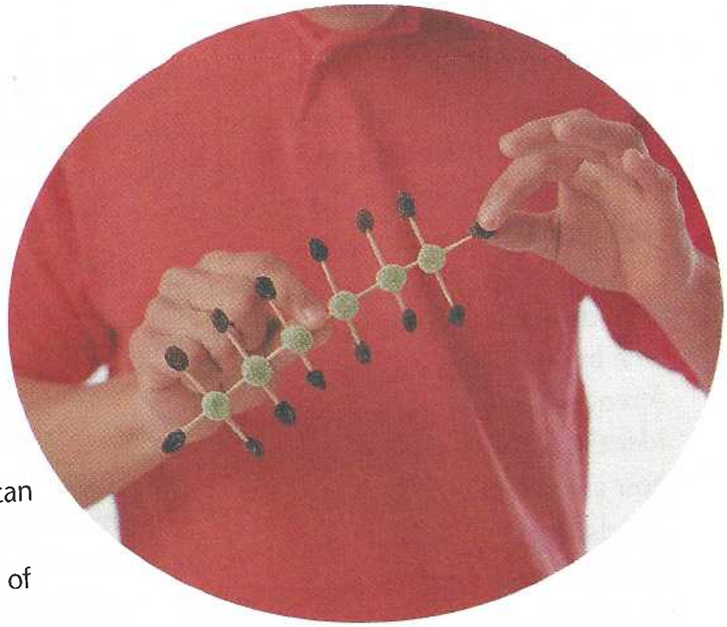
isobutane C_4H_{10}



butane C_4H_{10}

Explore! ACTIVITY

Do pentane and hexane have isomers?



What To Do

1. Using gum drops for carbon atoms, raisins for hydrogen atoms, and toothpicks for covalent bonds, try to make a model of pentane, C_5H_{12}. Remember that each carbon atom must have four bonds, while each hydrogen atom can have only one bond.
2. How many different models of pentane can you build?
3. Try to make a model of hexane, C_6H_{14}. Follow the same rules as for pentane.
4. How many different models can you build now?

Most hydrocarbons form isomers. Because the larger molecules have more carbon atoms they form more isomers. Octane, C_8H_{18}, the hydrocarbon used in gasoline, has 18 possible isomers. These isomers can have straight chains or branched chains.

How Do We Know?

How are octane numbers assigned?

When fuel burns in an engine, small amounts of it will occasionally explode rather than burning evenly. These tiny explosions can be heard and are referred to as knocking. You might also notice that the car does not run as smoothly when knocking occurs. Fuels are rated on their ability to burn evenly, rather than explode. The rating is called the octane number.

Rating Fuels

Two compounds are used as standards in creating the scale for octane numbers. Isooctane, which resists knocking very well, is assigned an octane number of 100. Heptane, which knocks very badly, has an octane number of 0. The amount of knocking in a fuel is compared with a known mixture of these two compounds. For example, a sample of gasoline that knocks the same amount as a mixture of 90 percent isooctane and 10 percent heptane would have an octane number of 90. If a fuel knocks less than pure isooctane, it can have an octane number greater than 100. Gasoline pumps have an octane rating on them.

You may have heard of octane rating applied to gasoline. Octane rating does not measure the amount of octane in the fuel, but rather the tendency of fuel to knock. Knocking occurs when a fuel does not burn evenly.

Hydrocarbons directly affect you. The major source of energy in the world comes from chemicals made from organic compounds found in petroleum or natural gas. Over 90 percent of the energy used in homes, schools, industry, and transportation comes from methane and the other hydrocarbons. Products ranging from fertilizer to skateboards are manufactured from hydrocarbons. Can hydrocarbons be used to make more complicated molecules? In the next section, you will learn how three special types of organic compounds are synthesized from hydrocarbons.

SKILLBUILDER

Making and Using Graphs

Make a graph of the information in Table 10-1. For each compound, plot the number of carbon atoms on one axis and the number of hydrogen atoms on the other axis. Use this graph to predict the formula for the saturated hydrocarbon that has 11 carbon atoms. If you need help, refer to the **Skill Handbook** on page 681.

Figure 10-9

Each of the different kinds of gasoline is given an octane rating. You can see the octane ratings, 92, 87, and 89, in this photo.

check your UNDERSTANDING

1. Why can carbon form so many different organic compounds?
2. How is an unsaturated hydrocarbon different from a saturated hydrocarbon?
3. How many isomers can you make from heptane, C_7H_{16}?
4. **Apply** Cyclopropane is a saturated hydrocarbon containing three carbon atoms. In this compound, each carbon atom is bonded to two other carbon atoms. Draw its structural formula. Are cyclopropane and propane isomers? Explain.

10-2 Other Organic Compounds

Section Objectives

- Classify substituted hydrocarbons as belonging to the alcohol, carboxylic acid, or amine family.
- Describe the structure of an alcohol, a carboxylic acid, and an amine.
- Draw the structural formula for the simplest alcohol, carboxylic acid, and amine.

Key Terms

alcohol
carboxylic acid
amines

Substituted Hydrocarbons

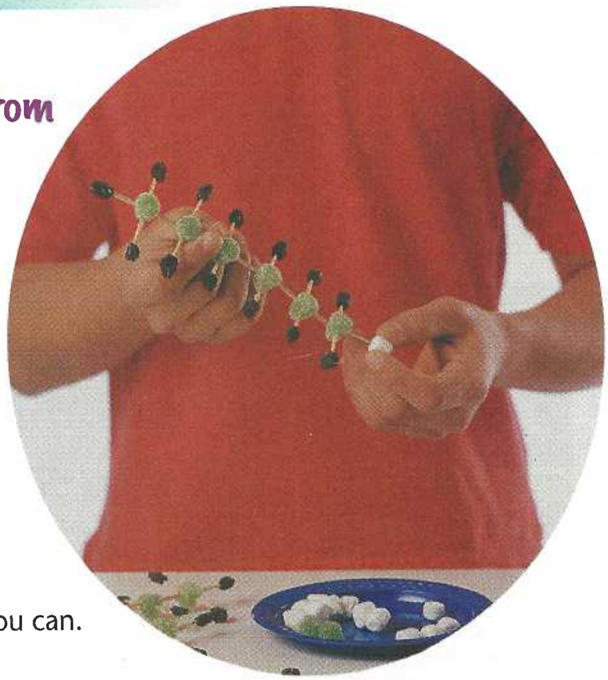
Usually a cheeseburger is a hamburger covered with American cheese and served on a bun. However, you can make a cheeseburger with Swiss cheese and serve it on slices of rye bread. If you ate this cheeseburger, you would notice that the substitutions affected the taste.

Explore! ACTIVITY

Can you make new models from your hexane structures?

What To Do

1. Make a gumdrop/raisin/toothpick model for hexane.
2. Remove a hydrogen raisin and replace it with a mini marshmallow.
3. Then exchange the marshmallow with a raisin already on your model.
4. Replace another raisin with a gummy candy.
5. Make as many different models as you can.



Chemists make similar changes to organic compounds. These changes produce compounds called substituted hydrocarbons. A substituted hydrocarbon has had one or more of its hydrogen atoms replaced by atoms or groups of atoms of other elements.

In the Explore activity, you substituted marshmallows and gummy candy for the raisin/hydrogen in the gumdrop/hexane model. Substituting even one new chemical group on a hydrocarbon forms an entirely new class of compounds with chemical properties different from those of the original compound. Sometimes two or more chemical groups can replace hydrogen atoms. You can imagine how complicated these new molecules can become. This is why millions of organic compounds exist in our world.

Alcohols

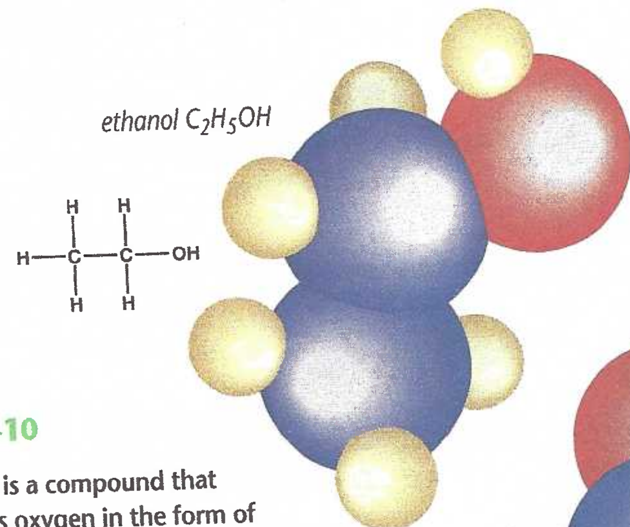
Ethanol, shown in **Figure 10-10A**, is an example of an alcohol. **Alcohol** is the name of a family of compounds formed when a hydroxyl (-OH) group replaces one or more hydrogen atoms in a hydrocarbon. Ethanol is produced naturally by sugar fermenting in corn, grains, and fruits. You will learn more about mixing ethanol with gasoline to fuel cars.

Table 10-2 lists some common alcohols and their uses.

Table 10-2

Some Common Alcohols

Uses	METHANOL H H–C–OH H	ETHANOL H H H–C–C–OH H H	ISOPROPYL ALCOHOL H OH H H–C–C–C–H H H H
Fuel	√	√	
Cleaner	√	√	√
Disinfectant		√	√
Manufacturing chemicals	√		√



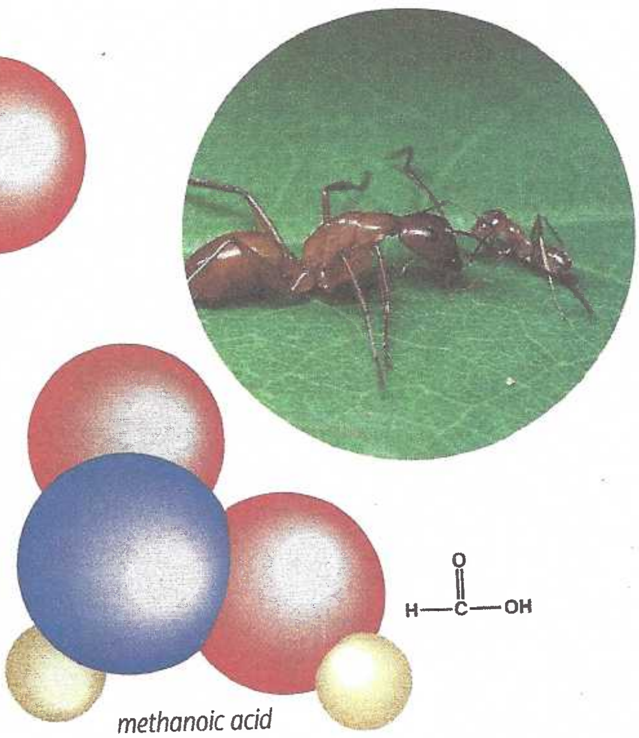


Figure 10-10

A Alcohol is a compound that contains oxygen in the form of hydroxyl groups. Some alcohols contain more than one hydroxyl group. Is ethanol an alcohol that contains more than one hydroxyl group?

B Methanoic acid is an example of a carboxylic acid. The carbon has a double bond to the oxygen atom, a single bond to the hydroxyl (-OH) group, and a single bond to what remains of the original hydrocarbon molecule. Some ants have a gland that makes formic acid, which is connected to a powerful stinger at the end of their abdomen.

Carboxylic Acid

If you have ever tasted salad dressing made with too much vinegar, you probably made a face because of the sour taste. Acetic acid in vinegar causes that sour taste.

A **carboxylic acid** is formed when a $-CH_3$ group is displaced by a carboxyl (-COOH) group. The simplest carboxylic acid is methanoic acid or formic acid, as seen in **Figure 10-10B.** This acid is made by ants and is injected into your skin and causes pain when an ant bites you.

Amines

In another group of substituted hydrocarbons, nitrogen forms covalent bonds with the carbon and hydrogen in the molecule. When the amine group, $-NH_2$, replaces the hydrogen in a hydrocarbon, organic compounds called **amines** are formed. Methylamine, CH_3NH_2, shown in **Figure 10-11**, is the simplest amine. Have you ever been given novocaine at a dentist's office? Do you take vitamins that include niacin? Does your soft drink contain caffeine? These are all hydrocarbons substituted with nitrogen.

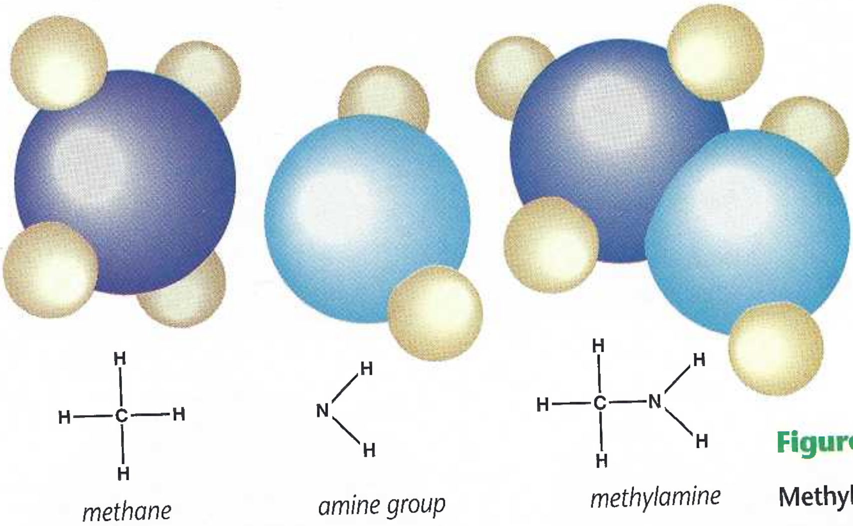


Figure 10-11

Methylamine, CH_3NH_2, is formed when an amine group ($-NH_2$) replaces a hydrogen in methane.

a CLOSER LOOK

Organic Motor Fuels

Did you know that about 90 percent of the total United States energy needs are met by fossil fuels, such as oil and natural gas?

Oil, of course, is used for a variety of purposes, from plastics production to the food manufacturing industry. One of the most important uses of oil is as a fuel to power the engines of automobiles and other forms of transportation.

Fossil Fuels

As you know, fossil fuels are considered to be nonrenewable energy sources. In other words, once they have been used up, they're gone forever. Right now, we are using up fossil fuels much faster than can be replaced by Earth. What fuels will power the engines of the transportation vehicles of the future?

Since the energy crisis of the 1970s, scientists have been working on the development of new sources of energy, especially ones that can be used to power engines.

Gasohol

Did you ever see a sign like the one pictured here? Gasohol is a combination of the alcohol ethanol and gasoline. The gasohol used currently contains about 90 percent gasoline and

Amino Acids

As well as being in novocaine, niacin, and caffeine, amines occur in many other biological compounds. A special type of amine-substituted hydrocarbon forms when both the $-NH_2$ group and the $-COOH$ group replace hydrogens on the same molecule. This type of compound is called an amino acid, which is a building block for the formation of proteins. You may have eaten an amino acid lately if you like gelatin desserts.

Many organic compounds are composed of different combinations of carbon, hydrogen, oxygen, and nitrogen atoms. You have already learned about alcohols, carboxylic acids, and amines. Can one of these types of hydrocarbons be converted into another?

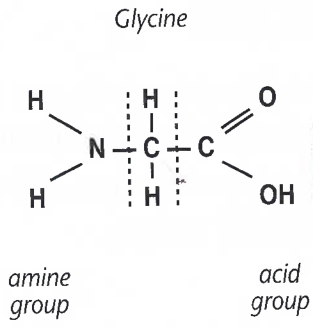


Figure 10-12

Gelatin desserts contain glycine, an amino acid. Amino acids are a key ingredient of proteins. Why are proteins important to you?

10 percent ethanol. As you recall, ethanol is the substituted hydrocarbon found in all alcoholic beverages.

Gasohol has many advantages over gasoline. Ethanol is produced commercially by the fermentation of potatoes, sugar cane, and grains, such as corn and wheat. Because it is produced from plant materials, ethanol is considered to be a renewable energy source.

Another advantage of using gasohol is that most car engines do not have to be modified to burn the gasohol manufactured today. In fact, car engines can be made to burn pure ethanol, and engineers are working hard to design engines that can use ethanol efficiently.

What Do You Think?

Clearly, we need to develop new sources of fuel for our transportation vehicles. Gasohol shows some promise as an alternative fuel, but there are some disadvantages to gasohol as well. Commercial production of ethanol results in numerous environmental problems. Among these are disruption of the ecosystem, fertilizer runoff, and erosion. Do you think gasohol is an answer to our fossil fuel problems? Explain your answers.

Figure 10-13

Substituted hydrocarbons have had one or more of the hydrogen atoms replaced by atoms or groups of atoms of other elements. Some examples of substituted hydrocarbons are shown here.

Many organic compounds are composed of different combinations of carbon, hydrogen, oxygen, and other elements. Organic compounds occur naturally in your body and can also be found in the foods you eat. As you saw in the Investigate, some substituted hydrocarbons can be changed into other substituted hydrocarbons. You used potassium permanganate and sodium hydroxide to change ethanol to vinegar (acetic acid). There are many other types of substituted hydrocarbons. They are found in such varied products as refrigerants, fire extinguishers, pesticides, anesthetics, and moth repellents. Freon and DDT are two commonly known substituted hydrocarbons.

In the following section of this chapter, you will find out more about the complicated hydrocarbons that make up your body and why you need to eat foods to rebuild yourself.

check your UNDERSTANDING

1. What major chemical group is characteristic of an alcohol? A carboxylic acid? An amine?
2. Can a substituted hydrocarbon have more than one chemical group replacing its hydrogen atoms at one time? Give an example.
3. Ethylmethylamine is a compound in which one hydrogen in ammonia has been replaced with a $-CH_3$ group, another hydrogen has been replaced with a $-CH_2CH_3$ group, and a third hydrogen remains. Draw its structural formula.
4. **Apply** Rubbing alcohol is isopropyl alcohol. How does its structure differ from propyl alcohol?

10-3 Biological Compounds

Polymers

Milk, muscle, blood, cassette tapes, and athletic shoes are made of organic compounds which are made of very large molecules. In the Explore activity, you will see one way that large molecules can be formed from many different molecules. **Polymers** are huge molecules made up of many smaller organic molecules that are linked together to form new bonds. The smaller molecules, called monomers, are usually similar in size and structure.

Polymers are also found in the biological compounds that make up living things. There are three major groups of biological compounds: proteins, carbohydrates, and lipids.

Section Objectives

- Describe polymers and examine their importance as biological compounds.
- Compare and contrast proteins, carbohydrates, and lipids.

Key Terms

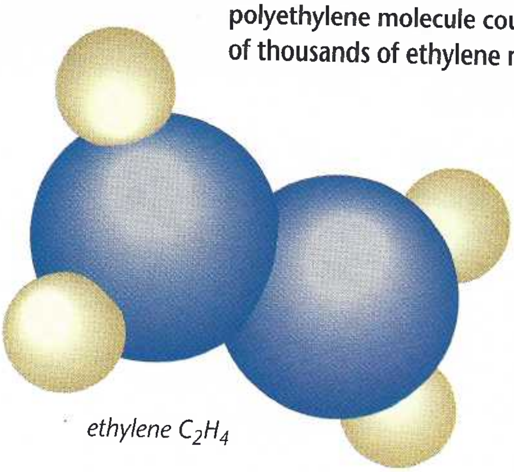
polymers
proteins
carbohydrates
lipids

Explore! ACTIVITY

Can you build a complex molecule?

What To Do

1. Loop together different colored strips of paper into a chain, or string colored paper clips together.
2. How many different combinations can be made?



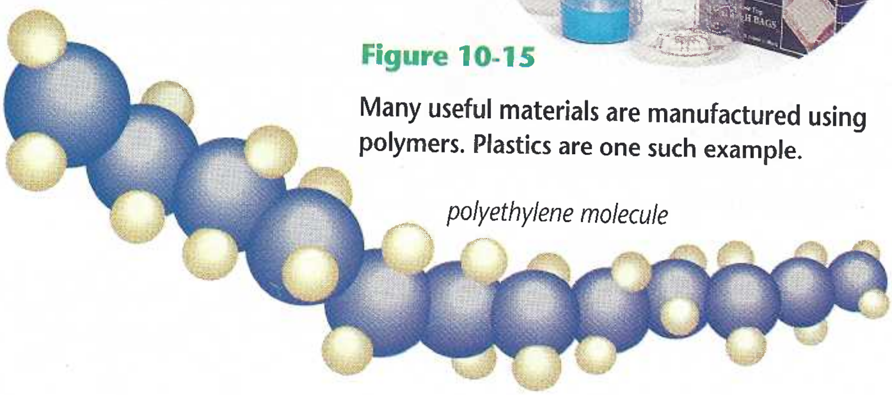


Figure 10-14

The polyethylene polymer is synthesized by linking together ethylene molecules, C_2H_4. The resulting polyethylene molecule could have a continuous chain of thousands of ethylene molecules linked as one.

Figure 10-15

Many useful materials are manufactured using polymers. Plastics are one such example.

Proteins

Milk and fish contain protein, a particular kind of hydrocarbon polymer that is a necessary part of all living cells. **Proteins** are polymers formed by linking together various amino acids.

Proteins are in your muscles, hair, bones, fingernails–in every living cell. Eight of the twenty-two or more amino acids used by the body are absolutely essential for your body to function properly, but your body cannot make them. You need to eat protein-rich foods every day for your body to get adequate protein so it can grow and renew itself. How can you tell whether a certain food contains proteins or not?

Explore! ACTIVITY

How can you test for protein in food?

What To Do

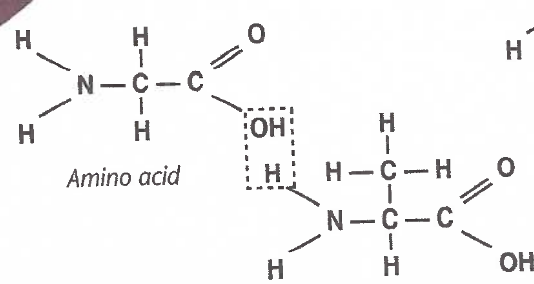
1. Add 5 g of sodium hydrogen sulfate and 5 g of potassium nitrate to a large test tube.
2. Add one drop of milk to the test tube and heat the contents gently over a burner.
3. Describe what happens inside the test tube. Yellow indicates the presence of protein in your milk sample. Record your results *in your Journal.*
4. Repeat this test with samples of egg white, meat, and chocolate.
5. Do all of these foods contain protein? Record your answer *in your Journal.*

Figure 10-16

Eggs, meat, tofu, and milk are examples of foods that are rich in proteins.

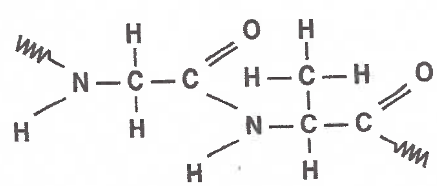
Figure 10-17

Amino acids combine to make a protein segment. Even though there are only about 200 different amino acids, millions of different proteins can be made from them. Proteins account for 15% of your total weight.



Amino acid

Amino acid



Protein segment

Carbohydrates

What do you think of when you hear the word carbohydrate? Do you think of pasta or bread? Maybe you think of your diet and good nutrition. Sugars and starches are known as **carbohydrates**; this class of food provides energy for your body.

Glucose ($C_6H_{12}O_6$) and sucrose ($C_{12}H_{22}O_{11}$) are common sugars. Glucose is found in many sweet foods such as grapes and honey. In your body, glucose is broken down into simpler substances that enter the mitochondria to provide energy to all of your cells. Another sugar found in foods is sucrose, the white table sugar produced from sugarcane. Sucrose breaks down into glucose and other simple sugars during digestion.

Starches are larger molecule carbohydrates that occur naturally in plants like wheat, rice, and corn.

Carbohydrates are organic compounds in which there are twice as many hydrogen atoms as oxygen atoms. Count the hydrogen and oxygen atoms in the formulas for yourself to prove that this is true. The simple sugars are straight-chain compounds, but the larger molecule sugars and starches can be branched and are more complex.

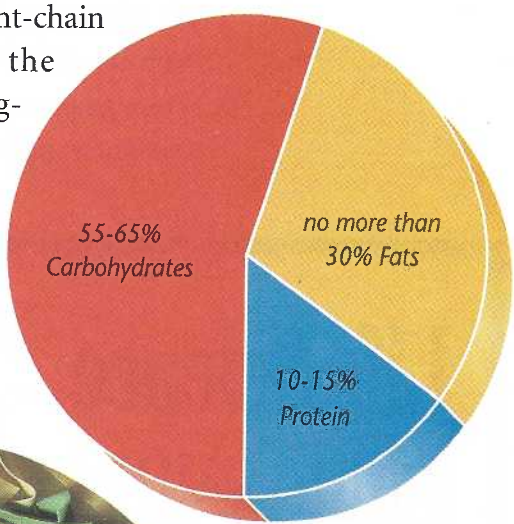


Figure 10-19

This graph shows the recommended percentage of calories that come from carbohydrates, protein, and fats. Why is a balanced diet important?

Figure 10-18

Starch is the major component of pasta.

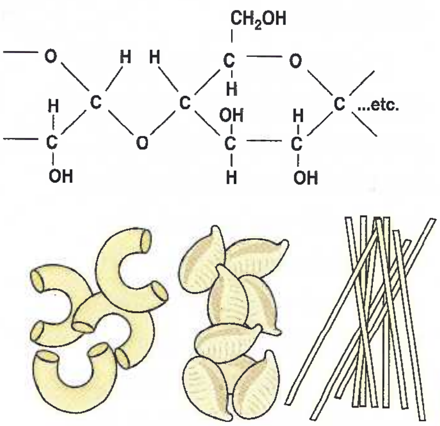


Figure 10-20

Pasta, rice, corn, and potatoes are examples of foods that contain a high concentration of carbohydrates. Why does your body need carbohydrates?

Lipids

What do butter, margarine, the oil part of salad dressings, and some vitamins have in common? They are all included in the third major type of biological compound called a lipid. **Lipids** are organic compounds that

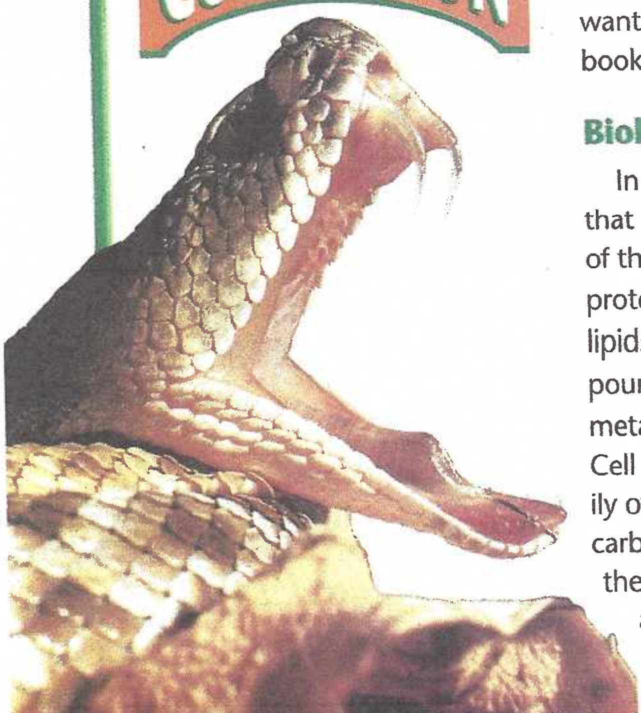
Explore! ACTIVITY

How can you tell a fat from an oil?

What To Do

1. Obtain small samples of butter, soybean oil, margarine, olive oil, and solid shortening. Observe them at room temperature.
2. *In your Journal*, list which ones have similar properties.

Life Science CONNECTION



Poisonous Proteins

The next time you visit the zoo to learn about the exotic animals, you just might want to bring along a chemistry book! Why?

Biological Compounds

In this chapter, you learned that living organisms are made of the biological compounds—proteins, carbohydrates, and lipids. As you know, these compounds are important for the metabolic processes of cells. Cell structures are made primarily of proteins, and lipids and carbohydrates are important for the functioning of cells. Lipids and carbohydrates provide energy for cells.

Biotoxins

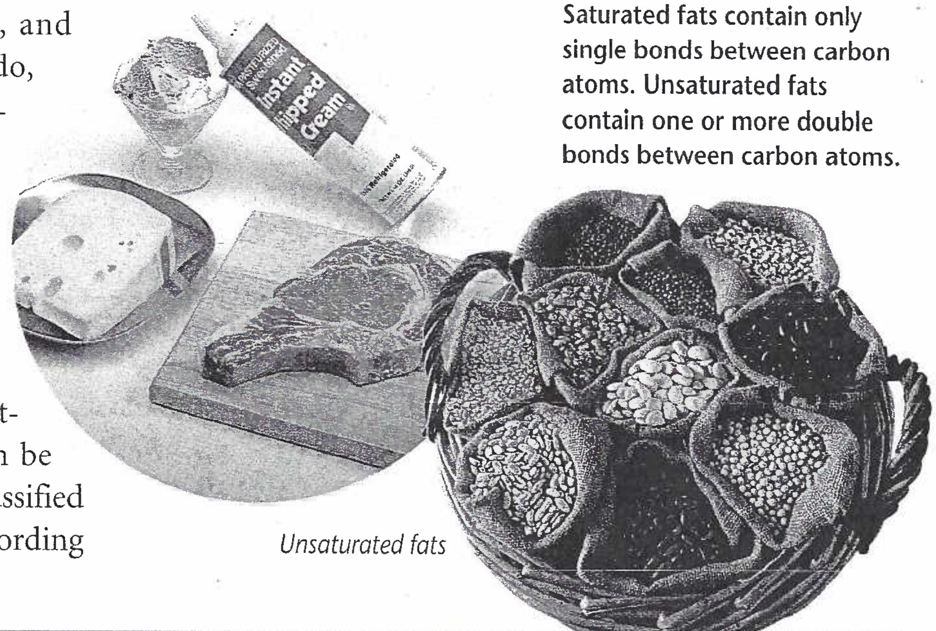
It's clear that if the cells of organisms did not manufacture proteins from amino acids, organisms couldn't stay alive. But would you believe that there are many animals and plants that produce proteins that can mean immediate death for other organisms? Such proteins are organic poisons that are known as biotoxins, and they are produced and used by animals, plants, fungi, and bacteria for defense against predators and for obtaining food.

The reptile house at the zoo is a great place to learn about animals that produce biotoxins. Many species of snakes, includfeel greasy and will not dissolve in water. Fats, oils, waxes, and related compounds make up this group of biological compounds.

Although lipids contain the same elements—carbon, hydrogen, and oxygen—that carbohydrates do, they are put together in different proportions. Lipids are a more concentrated source of energy for the body than carbohydrates. They provide twice as much energy per gram as carbohydrates.

Have you ever heard that eating too much saturated fat can be unhealthy? Fats and oils are classified as saturated or unsaturated according to the types of bonds in their carbon chains. Let's test for the presence of fats and starches in various foods.

Saturated fats



Unsaturated fats

Figure 10-21

Saturated fats contain only single bonds between carbon atoms. Unsaturated fats contain one or more double bonds between carbon atoms.

ing North American snakes, produce a substance called venom. Some types, similar to the snake shown in the photo at the left, are more poisonous to humans than others.

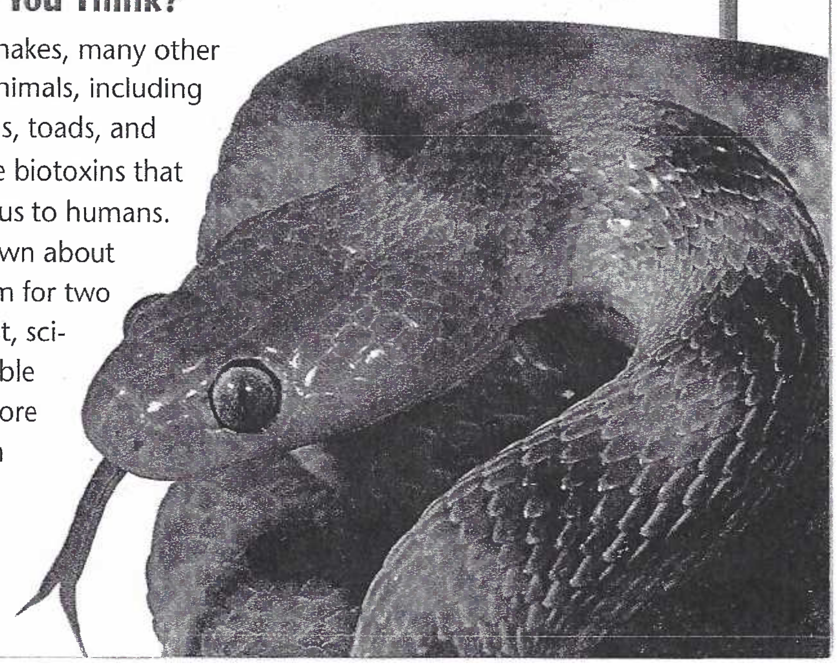
Snake Venom

Scientists know more about the chemical makeup of snake venom than any other animal biotoxin. Proteins in snake venom are of a special group called enzymes. Enzymes are large and complex protein molecules that work by breaking down other organic molecules. The most common protein in snake venom is an enzyme called cholinesterase, which disrupts the functioning of the nervous system.

The most poisonous land snake in the world is the tiger snake from Australia, shown in the photo at the right. Tiger snake venom is extremely poisonous. It only takes about one-half a milligram of tiger snake venom to kill an adult human.

What Do You Think?

Besides snakes, many other species of animals, including insects, frogs, toads, and fish produce biotoxins that are poisonous to humans. More is known about snake venom for two reasons. First, scientists are able to obtain more venom from snakes than biotoxins from other animals. More importantly, the enzymes in snake venom are important for the development of drugs to treat illness. How do you suppose studying the proteins found in snake venom can help scientists develop new types of drugs?



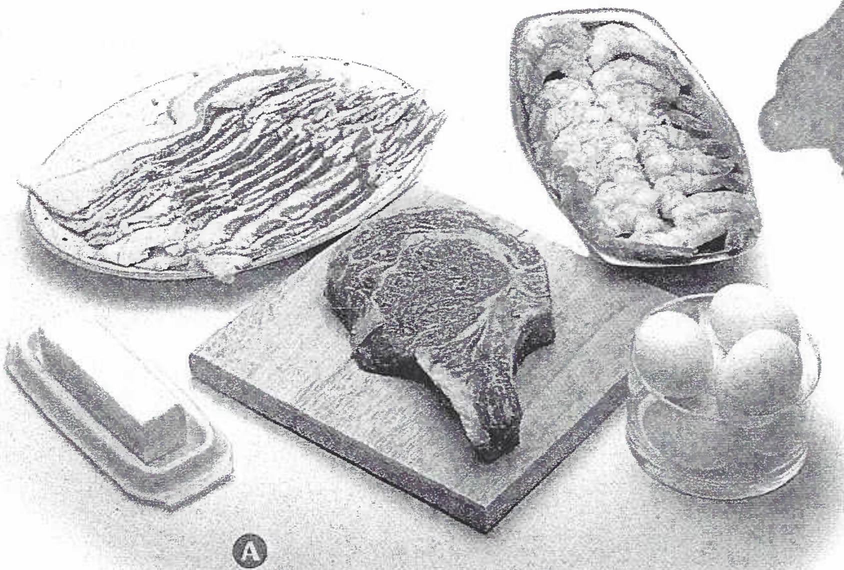
DID YOU KNOW?

Rubber is a polymer that we sometimes chew. Bubble gum is stretchy because it contains a little synthetic rubber, other synthetic polymers, flavoring, and vegetable oil for softening.

Cholesterol

Besides saturated fats, animal foods contain another lipid called cholesterol. Do you know that even if you never eat foods containing cholesterol, your body will still make its own supply? Cholesterol is needed by your body to build cell membranes and is also found in bile, a fluid made by the liver and needed for digestion. Too much cholesterol is not good and can result in a buildup of cholesterol in arteries.

We have discussed three important classes of biological compounds: proteins, carbohydrates, and lipids. Many of these compounds are very long and complicated polymers. Carbohydrates and lipids are in foods that provide energy for the body. Proteins are present in every living substance and are needed in food for growth and to renew the body. Each of these compounds exists because of carbon's ability to form covalent bonds with other atoms such as oxygen or nitrogen.



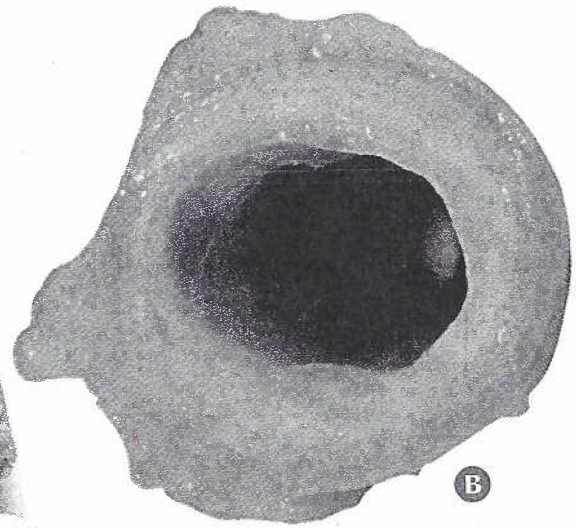


Figure 10-22

Foods high in cholesterol (A) can contribute to a buildup of cholesterol in an artery (B). What dangers are posed when cholesterol builds up and clings to walls of the arteries?

check your UNDERSTANDING

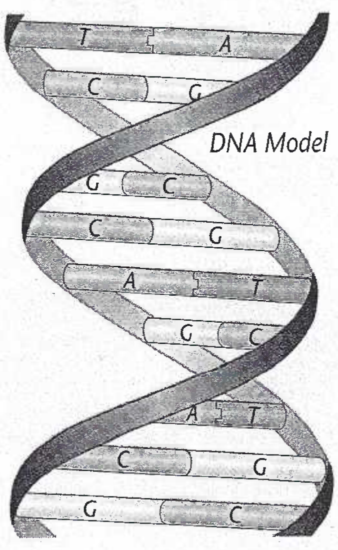
1. How are polymers formed?
2. Name some examples of biological compounds. Where are they found?
3. What do proteins, carbohydrates, and lipids in the foods you eat provide for your body?
4. **Apply** Unlike animals, plants cannot digest the foods necessary to form biological compounds. Explain how plants make the biological compounds they need.

Technology Connection: The Discovery of DNA Structure

Almost everyone has heard of DNA today, but in the 1950s, DNA structure was a mystery. In fact, one of the major scientific events of the 20th century was the discovery of the structure of DNA. Much of the research that led to this discovery was based on the work of an English scientist, Rosalind Elsie Franklin.

X-ray Crystallography

From 1947 to 1950, Franklin studied the basics of a technique called X-ray crystallography. In X-ray crystallography, X rays are sent through a substance to find out how atoms are arranged. She used this technique to research changes in the arrangement of carbon atoms when coal is heated. Her work was invaluable to the coking and atomic technology industries.

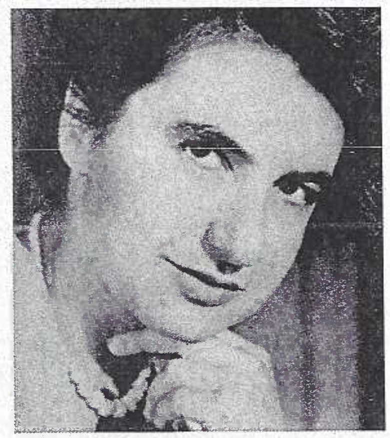


DNA Model

In 1951, Franklin applied X-ray crystallography techniques to the study of DNA. She is credited with discovering the density of DNA and its double-strand structure. She died of cancer at the age of 37.

DNA Structure

Using Franklin's invaluable discoveries, other scientists continued the study of DNA. They started their work knowing that DNA is a large molecule composed of sugar and phosphate groups linked in long chains plus nitrogen-containing compounds called bases. They did not know, however, how all these components fit together.



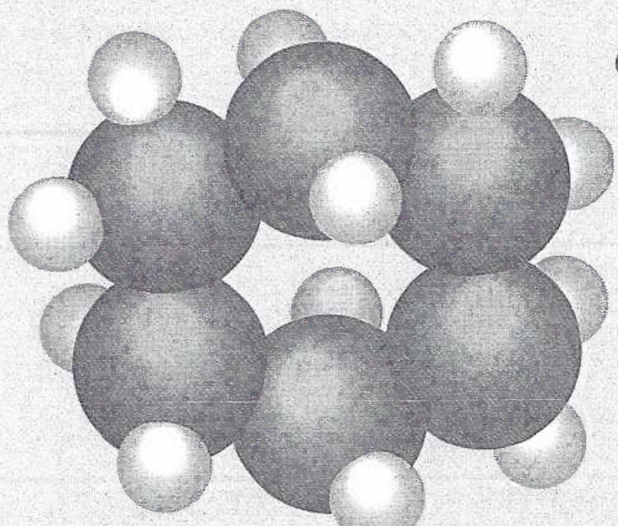
With further use of X-ray crystallography, James D. Watson, Francis Crick, and Maurice Wilkins, discovered the exact structure of DNA. Watson, Crick, and Wilkins received the Nobel Prize for this discovery in 1962. Franklin's early discoveries paved the way for the work that continues to expand our knowledge of human genetic material.

What Do You Think?

Do you always work straight through a problem from beginning to end? Did you ever wake up in the middle of the night knowing just how to solve a problem? Can you draw any conclusions from these experiences about how the mind works?

REVIEWING MAIN IDEAS

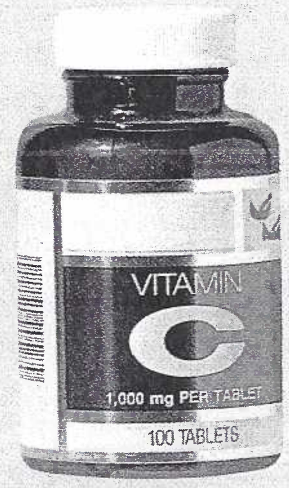
Review the statements below about the big ideas presented in this chapter, and try to answer the questions. Then, reread your answers to the Did You Ever Wonder questions at the beginning of the chapter. *In your Journal*, write a paragraph about how your understanding of the big ideas in the chapter has changed.

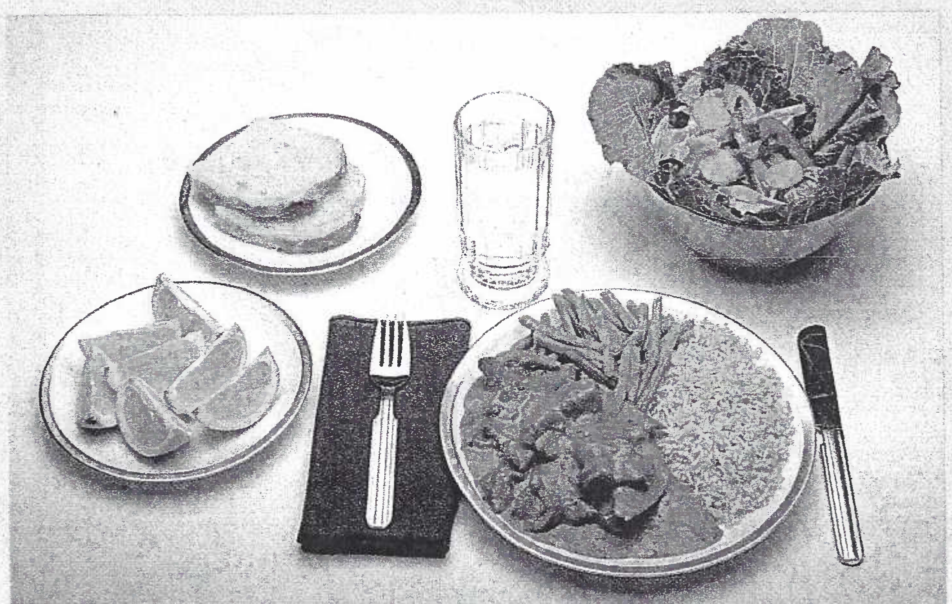


cyclohexane

1 Carbon's unique ability to form four covalent bonds with other atoms enables it to make a huge number of compounds. ***How does the structure of a compound determine its properties?***

2 Hydrocarbons can be composed of hydrogen and carbon alone, or other chemical groups may be substituted for hydrogen on the molecule to form new compounds, as with vitamin C. ***Compared and contrast the three types of substituted hydrocarbons.***

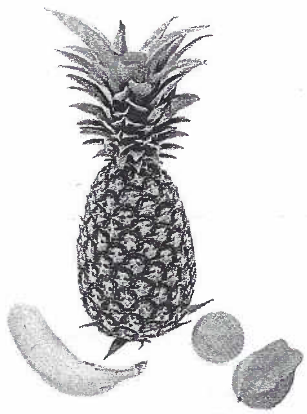




3 Biological compounds are complex compounds that make up living things. Your body needs the proteins, carbohydrates, and lipids that are found in food to provide energy and to repair or replace cells. ***What are two examples of foods that provide protein? Carbohydrates? Lipids?***

CHAPTER 11

FUELING the BODY



Did you ever wonder...

- How long someone could live without food?
- Why your stomach makes noises when you're hungry?
- How large the area of your small intestine is?

Before you begin to study about fueling the body, think about these questions and answer them *in your Journal*. When you finish the chapter, compare your Journal write-up with what you have learned.

Welcome to Blanca Hidalgo's garden. Those red-ripe tomatoes soon will find their way into a spicy salsa. The carrots and zucchini will become part of a fresh vegetable salad. And those onions and peppers will add zip to tonight's tacos.

Animals benefit from Blanca's garden too. Pesky crows swoop down to sample the ripening corn. A rabbit nibbles at the lettuce and aphids suck juices from the tomato stems.

All living things—from the largest animal to the tiniest cell—require nourishment. In this chapter you will learn about the fuel your body needs and how your body processes that fuel to keep you healthy!

▶ ***In the Explore activity you will learn about different diets that people eat.***