## 13.3 Molecules and Carbon Compounds

Do you know which compounds you are made of? Excluding water, 91 percent of your body mass consists of compounds that are made up of only four elements: carbon, oxygen, nitrogen, and hydrogen. Of those four, carbon is the largest part at 53 percent. The molecules of some of those compounds are large and complex. In this section, you will learn more about molecules and why carbon is such an important element in the molecules of living things.

### Structural diagrams of molecules

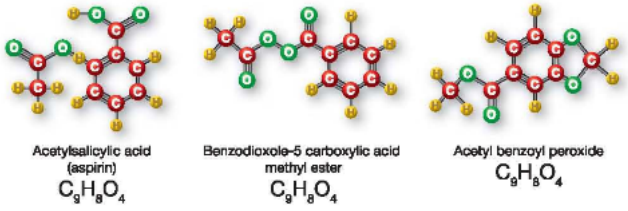
**Molecules are represented using structural diagrams**

In addition to the elements that it is made of, the shape of a molecule is also important to its function and properties. For this reason, we use *structural diagrams* to show the shape and arrangement of atoms in a molecule. Single bonds between atoms are shown with solid lines connecting the element symbols. Double and triple bonds are shown with double and triple lines. Figure 13.18 shows the chemical formula and structural diagram for some compounds.

**Properties come from the molecule**

Both the chemical formula and the structure of the molecules determine the properties of a compound. For example, aspirin, a pain reducer, is a molecule made of carbon, hydrogen, and oxygen according to the chemical formula $C_9H_8O_4$. The same 21 atoms in aspirin can be combined in other structures with the same chemical formula. But the resulting molecules do not have the pain-relieving properties of aspirin.

**Three Different Molecules, Same Chemical Formula**



Acetylsalicylic acid (aspirin) $C_9H_8O_4$

Benzodioxole-5 carboxylic acid methyl ester $C_9H_8O_4$

Acetyl benzoyl peroxide $C_9H_8O_4$

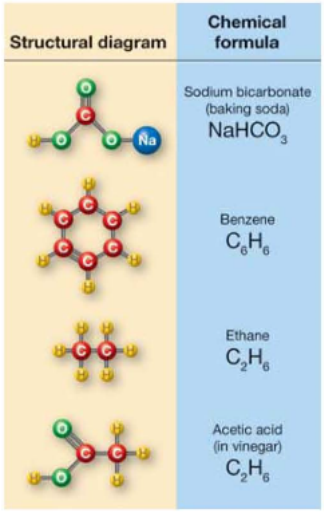



**Figure 13.18:** *Chemical formulas and structural diagrams.*

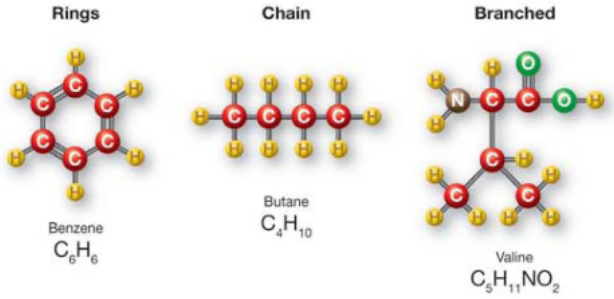
## Carbon molecules

**Many compounds contain carbon**

Most of the compounds you are made of contain the element carbon. **Organic chemistry** is the branch of chemistry that specializes in carbon compounds, also known as *organic molecules*. But carbon compounds are not only found in living things. Plastic, rubber, and gasoline are carbon compounds. In fact, there are over 12 million known carbon compounds! Carbon is unique among the elements because a carbon atom can form chemical bonds with other carbon atoms in long chains or rings. Some carbon compounds contain several thousand carbon atoms.

**Carbon forms ring and chain molecules**

Carbon atoms have four valence electrons and can share one or more of these electrons to make covalent bonds with other carbon atoms or as many as four other elements. Carbon molecules come in three basic forms: straight chains, branching chains, and rings. The three basic shapes can be combined in the same molecule.




**Polymers**

A **polymer** is a compound that is composed of long chains of smaller, repeating molecules. Plastic (polyethylene) is a polymer that is composed of long chains of a smaller molecule called ethylene. You can think of a plastic molecule as a chain of paperclips. Each paperclip represents an ethylene molecule (Figure 13.19).

**VOCABULARY**

**organic chemistry** - a branch of chemistry that specializes in the study of carbon compounds, also known as organic molecules.

**polymer** - a compound that is composed of long chains of smaller molecules.

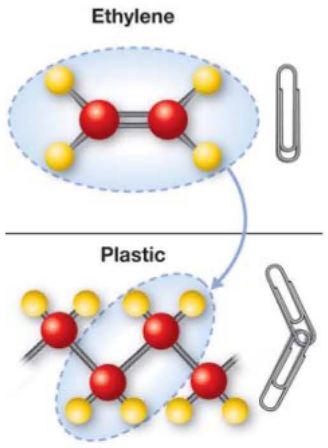



**Figure 13.19:** *Plastic is a polymer made of long chains of ethylene molecules.*

## Carbohydrates

**The four types of biological molecules**

Scientists classify the organic molecules in living things into four basic groups: carbohydrates, proteins, fats, and nucleic acids. All living things contain *all four types* of molecules. And each type of molecule includes thousands of different compounds, some specific to plants, some to animals. In the past few decades, biotechnology has revealed much more about the rich chemistry of living things.

**VOCABULARY**

**carbohydrates** - a group of energy-rich compounds that are made of carbon, hydrogen, and oxygen; they include sugars and starches.

**What are carbohydrates?**

**Carbohydrates** are energy-rich compounds made of carbon, hydrogen, and oxygen. Carbohydrates are classified as sugars and starches. Sugars are smaller molecules. *Glucose* is a simple sugar made of 6 carbon, 12 hydrogen, and 6 oxygen atoms (Figure 13.20). The sugar you use to sweeten food is called *sucrose*. A sucrose molecule is made of two simple sugars.

**Glucose Molecule**

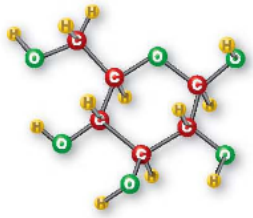


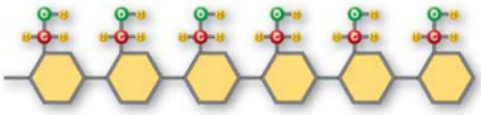
**Figure 13.20:** *A glucose molecule.*

**Starches are chains of sugar**

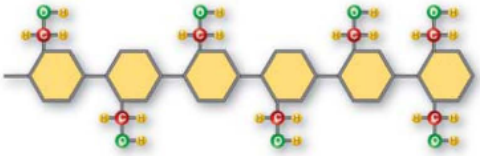
Starches are long chains of glucose molecules joined together to make natural polymers. Because starches are larger molecules, they are slower to break down in the body and therefore can provide energy for a longer period than sugars. Corn, potatoes, and wheat contain substantial amounts of starches.

**Cellulose**

Cellulose is the primary molecule in plant fibers, including wood. The long-chain molecules of cellulose are what give wood its strength. Like starch, cellulose is a polymer made of thousands of glucose molecules. However, in starch all the glucose units are the same orientation. In cellulose, alternate glucose units are inverted. This difference makes cellulose difficult for animals to digest. Trees grow so large partly because so few animals can digest wood.



**Starch**
All of the sugar molecules in the same direction.



**Cellulose**
Direction of sugar molecules alternates.

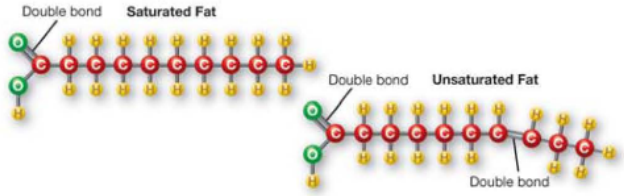
## Lipids

**Lipids** Like carbohydrates, **lipids** are energy-rich compounds made of carbon, hydrogen, and oxygen (Figure 13.21). Lipids include fats, oils, and waxes. Lipids are made by cells to store energy for long periods of time. Animals that *hibernate* (sleep through the winter) live off of the fat stored in their cells. Polar bears have a layer of fat beneath their skin to insulate them from very cold temperatures. Can you name some foods that contain lipids?

**Cholesterol is a lipid** Like fat, cholesterol is listed on food labels. *Cholesterol* is a lipid that makes up part of the outer membrane of your cells. Your liver normally produces enough cholesterol for your cells to use. Too much cholesterol in some people's diet might cause fat deposits on their blood vessels. This might lead to coronary artery disease. Foods that come from animals are often high in cholesterol.

**Saturated fats** A lipid molecule has a two-part structure. The first part is called *glycerol*. Attached to the glycerol are 3 carbon chains. In a **saturated fat**, the carbon atoms are surrounded by as many hydrogens as possible. (See graphic below, left.)

**Unsaturated fats** An **unsaturated fat** has fewer hydrogen atoms than it could have, because double bonds exist between some of the carbon atoms. (See graphic below, right.) Chemical processing of food adds some hydrogen to unsaturated fats in a process called *hydrogenation*. While *partially hydrogenated* fats have a longer shelf life, research is showing that consuming them might be unhealthy.




**VOCABULARY**

**lipids** - a group of energy-rich compounds that are made of carbon, hydrogen, and oxygen; they include fats, waxes, and oils.

**saturated fat** - a fat in which the carbon atoms are surrounded by as many hydrogen atoms as possible.

**unsaturated fat** - a fat that has fewer hydrogen atoms because double bonds exist among some of the carbon atoms.

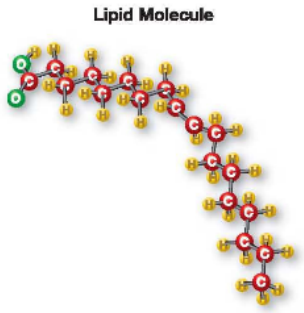


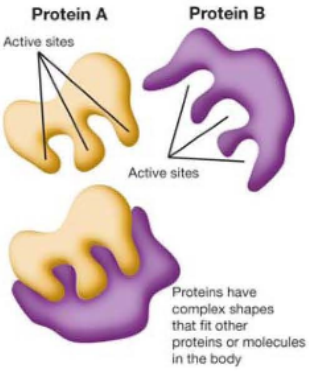

**Figure 13.21:** *A lipid molecule.*

## Proteins

**Proteins** **Proteins** are very large molecules made of carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur. Many animal parts such as hair, fingernails, muscle, and skin contain proteins. *Hemoglobin* is a protein in your blood that carries oxygen to your cells. Enzymes are also proteins. An **enzyme** is a type of protein that cells use to speed up chemical reactions in living things.

**Proteins are made of amino acids** Protein molecules are made of smaller molecules called **amino acids**. Your cells combine different amino acids in various ways to make different proteins. There are 20 amino acids used by cells to make proteins. You can compare amino acids to letters in the alphabet. Just as you can spell thousands of words with just 26 letters, you can make thousands of different proteins from just 20 amino acids (Figure 13.22).

**Shape and function** Only certain parts of a protein are chemically active. The shape of a protein determines which active sites are exposed. Many proteins work together by fitting into each other like a lock and key. This is one reason why proteins that perform a function in one organism cannot perform the same function in another organism. For example, a skin protein from an animal cannot replace a skin protein from a human.




**Amino acids from food are used to build proteins** Food supplies new proteins that a body needs to live and grow. However, proteins from one organism cannot be directly used by another. Fortunately, the same 20 amino acids are found in proteins from almost all living things. In your body, digestion breaks down food protein into its component amino acids. Cells reassemble the amino acids into new proteins suitable for your body's needs.

**VOCABULARY**

**proteins** - a group of very large molecules made of carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur.

**enzyme** - a type of protein used to speed up chemical reactions in living things.

**amino acids** - a group of smaller molecules that are the building blocks of proteins.

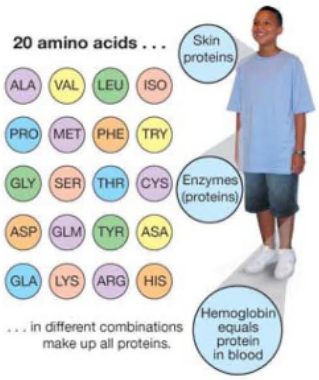
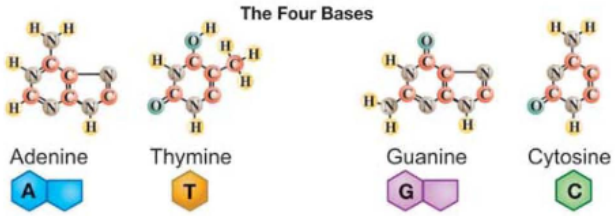



**Figure 13.22:** *Proteins are made of smaller molecules called amino acids.*

## DNA and nucleic acids

**What are nucleic acids?** **Nucleic acids** are compounds made of long, repeating chains called *nucleotides*. Nucleotides are made of carbon, hydrogen, oxygen, nitrogen, and phosphorus. Each nucleotide contains a sugar molecule, a phosphate molecule, and a base molecule, as shown in the graphic below.


**DNA** **DNA** (deoxyribonucleic acid) is a nucleic acid that contains the information cells need to make all of their proteins. A DNA molecule is put together like a twisted ladder, or *double helix*. Each rung of the DNA ladder consists of a base pair. A base on one side of the molecule always matches up with a certain base on the other side (Figure 13.23). The base adenine (**A**) only pairs with thymine (**T**), and cytosine (**C**) only pairs with guanine (**G**). This base pairing is very important to the function of DNA. A single DNA molecule contains more than one million atoms!




**VOCABULARY**

**nucleic acids** - compounds made of long, repeating chains of smaller molecules called nucleotides.

**DNA** - a type of nucleic acid that contains the genetic code for an organism.

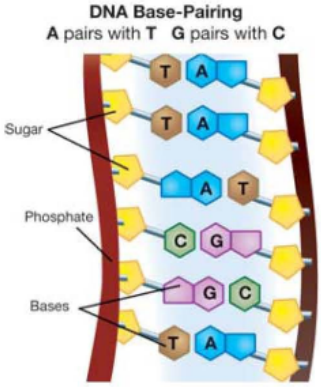



**Figure 13.23:** *The DNA molecule.*

## Section 13.3 Review

1. Explain why life is often referred to as "carbon based."
2. What are the four groups of carbon compounds found in living things?
3. You might have heard the saying, "You are what you eat." Use the information you learned in this section to explain what this statement means.
4. Classify each substance as either sugar, starch, protein, or nucleic acid.
   a. the major compound that makes up the skin
   b. glucose
   c. the major compound in potatoes
   d. DNA
5. Complete the table below.

| Carbon Compound | Elements it is Made of | Importance to Living Things | Example |
|---|---|---|---|
| Carbohydrate | | | |
| Lipid | | | |
| Protein | | | |
| Nucleic acid | | | |

6. What is the difference between saturated and unsaturated fat? Why are partially hydrogenated fats useful for making potato chips but not particularly healthy for humans to eat?
7. Simple sugars are the building blocks of carbohydrates. What are the simple units that make up proteins?
8. How many amino acids are used by cells to make proteins? How many different kinds of proteins can be made by this number of amino acids?
9. What type of biological molecule is an enzyme, and why are enzymes so important to living things?

**SOLVE IT!**

**Counting Calories**


A food calorie (kilocalorie) tells you how much energy is in different foods. Each type of carbon compound has a certain number of food calories per gram. Fat contains 9 food calories per gram. Carbohydrate and protein each contain 4 food calories per gram. Based on this information, answer the following questions.

1. How many food calories in the product above come from fat?
2. How many food calories come from carbohydrates?
3. How many food calories come from protein?
4. One serving is 130 calories or 130 kilocalories. Does this make sense?