**KEY CONCEPT**

Carbon-based molecules are life’s building blocks.

**BEFORE, you learned**
- Carbon is the basis of life on Earth
- Carbon atoms can form multiple bonds
- Carbon can form molecules shaped like chains or rings

**NOW, you will learn**
- About the functions of carbohydrates and lipids in living things
- About structures and functions of proteins
- How nucleic acids carry instructions for building proteins

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**EXPLORE Carbon in Food**

**How can you see the carbon in food?**

**PROCEDURE**
1. Place the candle in the pie plate and light the candle.
2. Use the tongs to hold each food sample in the candle flame for 20 seconds. Record your observations.

**WHAT DO YOU THINK?**
- What changes did you observe in the samples?
- What type of chemical reaction might have caused these changes?

**MATERIALS**
- aluminum pie plate
- candle
- wooden matches
- tongs
- small marshmallow
- piece of carrot

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**Carbon-based molecules have many functions in living things.**

You depend on carbon-based molecules for all of the activities in your life. For example, when you play softball, you need energy to swing the bat and run the bases. Carbon-based molecules are the source of the chemical energy needed by your muscle cells. Carbon-based molecules make up your muscle cells and provide those cells with the ability to contract and relax. Carbon-based molecules carry oxygen to your muscle cells so that your muscles can function properly. Carbon-based molecules even provide the information for building new molecules.

The many carbon-based molecules in all living things have certain similarities. They all contain carbon and elements such as hydrogen, oxygen, nitrogen, sulfur, and phosphorus. Many of the molecules are also very large molecules called macromolecules. However, these molecules have different structures and different functions.
Living things contain four major types of carbon-based molecules.

The organic molecules found in living things are classified into four major groups—carbohydrates, lipids, proteins, and nucleic acids. You may already be familiar with these types of molecules and their functions in living things.

Carbohydrates include sugars and starches found in foods such as bread and pasta. Many lipids are fats or oils. Proteins are necessary for many functions in the body, including the formation of muscle tissue. Nucleic acids are the molecules that carry the genetic code for all living things. As you read about each of these types of molecules, look for ways in which the molecule’s function depends on its structure.

Carbohydrates

Carbohydrates (kahr-boh-HY-DRAYTZ) include sugars, starches, and cellulose, and contain atoms of three elements—carbon, hydrogen, and oxygen. They serve two main functions. Carbohydrates are a source of chemical energy for cells in many living things. They are also part of the structural materials of plants.

One important carbohydrate is the sugar glucose, which has the chemical formula $C_6H_{12}O_6$. Cells in both plants and animals break down glucose for energy. In plants glucose molecules also can be joined together to form more complex carbohydrates, such as starch and cellulose. Starch is a macromolecule that consists of many glucose molecules, or units, bonded together. Many foods, such as pasta, contain starch. When starch is broken back down into individual glucose molecules, those glucose molecules can be used as an energy source by cells.
Plants make their own glucose through a process called photosynthesis, which you read about in Chapter 7. Some of the glucose made during photosynthesis is used to make the complex carbohydrate molecules that form a plant’s structure.

Unlike animal cells, plant cells have a tough, protective layer outside the cell membrane called the cell wall. Cellulose (SEHL-yuh-LOHS) is a macromolecule found in plant cell walls, and it is a large part of vegetables such as lettuce and celery. The illustration shows moss leaf cells with their cell walls, and a diagram of part of a cellulose molecule.

Cellulose and starch are both carbohydrates composed of glucose molecules, but the glucose molecules that make up these larger macromolecules are linked in different ways. Because of their different structures, starch and cellulose have different functions. In fact, this structural difference also prevents your body from breaking down and using cellulose as it would starch.

**Lipids**

Lipids include fats and oils and are used mainly for energy and as structural materials in living things. Like carbohydrates, most lipids are made of carbon, hydrogen, and oxygen. Even though lipids and carbohydrates have many similarities, they have different structures and properties.

Animals store chemical energy in fat. Plants store chemical energy in oils, such as olive oil and peanut oil. Fats and oils store energy very efficiently—one gram of fat contains about twice as much energy as one gram of carbohydrate or protein. Fats and oils contain three carbon chains called fatty acids. The illustration below shows the general structure of a fatty acid.

**VOCABULARY**

Make a magnet word diagram for lipid and for other vocabulary terms.

**Modeling Fatty Acids**

\[ \text{CH}_3\text{CH}_2\text{CH}_2\{\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH} = \text{O} \text{C} \text{OH} \]

The carbon chains in lipids are called fatty acids. A carbon atom is at each bend of the zig-zag model above. The break in the middle of the chain shows that some carbon atoms have been left out.
You may have heard the terms *saturated* and *unsaturated* in relation to fats. If all of the bonds between carbon atoms in the fatty acids are single bonds, the lipid is a saturated fat. If one or more of these bonds is a double bond, the lipid is an unsaturated fat. Most animal fats are saturated, and most oils from plants are unsaturated. Diets high in saturated fats have been linked to heart disease. Lipids in the butter in the photograph on the right are saturated fats.

![Fat Structure](image)

**What is the difference between a saturated fat and an unsaturated fat?**

Some lipids are important parts of cell structure. Structural lipids often contain the element phosphorus and are called phospholipids. Phospholipids are a significant part of cell membranes such as the one shown in the photograph of the nerve cell on the right.

![Phospholipid Structure](image)

Another lipid involved in cell structure is cholesterol, which is a part of cell membranes. Cholesterol has other functions as well. It is necessary to make substances called hormones. Hormones, such as adrenaline, are chemical messengers in your body.

Your body makes some of the cholesterol that it needs, but it also uses cholesterol from foods you eat. Cholesterol is found in many foods that come from animals, such as meat and eggs. Even some plant products, such as coconut oil, can increase the amount of cholesterol in your body. Although you need cholesterol, eating too much of it—just like eating too much saturated fat—can lead to heart disease.

![Fat Structure](image)

Fats in butter contain three fatty acids and are used for energy. Butter contains saturated fats.

![Phospholipid Structure](image)

Some lipids in this nerve cell's membrane have two fatty acids and one phosphate group. These lipids are called phospholipids.
Where can you find organic molecules?

PROCEDURE

1. Place a dropper of cornstarch solution into one jar lid and a dropper of liquid gelatin into a second jar lid.
2. Add a drop of iodine solution to the cornstarch sample and to the gelatin sample.
3. Examine the jar lids after 1 minute. Record your observations.
4. Using the remaining two jar lids, repeat steps 2 and 3 with the bread and the tofu instead of the cornstarch and gelatin.

WHAT DO YOU THINK?

- What changes occurred after the addition of iodine to the cornstarch and to the gelatin?
- Iodine can be used to detect the presence of starches. What carbon-based molecules might be in the bread and tofu? How do you know?

CHALLENGE Suppose you tested a piece of pepperoni pizza with iodine. Which ingredients (crust, sauce, cheese, pepperoni) would likely contain starch?

Proteins

Proteins are macromolecules that are made of smaller molecules called amino acids. Proteins, like carbohydrates and lipids, contain carbon, hydrogen, and oxygen. However, proteins differ from carbohydrates and lipids in that they also contain nitrogen, sulfur, and other elements. Unlike carbohydrates and lipids, which are used primarily for energy and structure, proteins have many different functions.

Think of a protein as being like a word, with amino acids as the letters in that word. The meaning of a word depends on the order of letters in the word. For example, rearranging the letters in the word “eat” makes different words with different meanings. Similarly, proteins depend on the order of their amino acids.

Linked Amino Acids

- tyrosine
- lysine
- cysteine
- serine
- leucine

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Just as 26 letters of the alphabet make up all words in the English language, 20 amino acids make up all of the proteins in your body. The structure of a protein is determined by the order of its amino acids. If two amino acids change places, the entire protein changes.

The function of a protein depends on its structure. There are at least 100,000 proteins in your body, each with a different structure that gives it a specific function. Some proteins are structural materials, some control chemical reactions, and others transport substances within cells and through the body. Still others are a part of the immune system, which protects you from infections.

CHECK YOUR READING How does the function of a protein depend on its structure?

Proteins that are part of the structure of living things are often shaped like coils. One coil-shaped protein, keratin, is part of human hair as shown on the left below. Proteins called actin and myosin are coil-shaped proteins that help your muscles contract.

Other types of proteins have coiled regions but curl up into shapes like balls. One example is hemoglobin, shown on the right below. Hemoglobin is a transport protein that carries oxygen in the blood.

Some proteins that curl up into a shape like a ball are enzymes. An enzyme (EHN-zym) is a catalyst for a chemical reaction in living things. Catalysts increase the rate of chemical reactions. Enzymes are necessary for many chemical reactions in your body. Without enzymes, these reactions would occur too slowly to keep you alive.

It is important to have proteins in your diet so that your body can make its own proteins. Proteins in foods such as meats, soybeans, and nuts are broken down into amino acids by your body. These amino acids are then used by your cells to make new proteins.
DNA contains the genetic code, which is the information needed to build proteins.

1. The “backbone” of DNA is made of alternating sugar molecules and phosphate groups.

2. The “rungs” of DNA are made of four molecules called bases.

   - Cytosine (C) always pairs with Guanine (G).
   - Adenine (A) always pairs with Thymine (T).

3. A sequence of three bases codes for a specific amino acid. T-A-C is a code for tyrosine; T-C-G is a code for serine.

4. The amino acids coded for by DNA are linked together to make proteins.

5. This mouse’s appearance, from eye color to hair color to the shape of its ears, is the result of the proteins coded for by its DNA.
Nucleic Acids

Nucleic acids (noo-KLEE-ihk AS-ihdz) are huge, complex carbon-based molecules that contain the information that cells use to make proteins. These macromolecules are made of carbon, hydrogen, and oxygen, as well as nitrogen and phosphorus. Each of the cells in your body contains a complete set of nucleic acids. This means that each cell has all of the instructions necessary for making any protein in your body.

The illustration on page 288 shows part of a nucleic acid molecule called DNA, which looks like a twisted ladder. The sides of the ladder are made of sugar molecules and phosphate groups. Each rung of the ladder is composed of two nitrogen-containing molecules called bases. DNA has four types of bases, represented by the letters A, C, T, and G. The order of the bases in a DNA molecule is the way in which DNA stores the instructions for making proteins. How do just four molecules—A, C, T, and G—carry all of this important information?

Recall that a protein is composed of amino acids that have to be linked in a certain order. Each of the 20 amino acids is represented by a particular series of three DNA bases. For example, the sequence T–A–C corresponds to—or is a code for—the amino acid tyrosine. There are 64 different three-base sequences in DNA, all of which have a specific meaning. This genetic code works in the same way in every living thing on Earth. It provides a complete set of instructions for linking amino acids in the right order to make each specific protein molecule. The DNA code is only one part of making proteins, though. Other types of nucleic acids, called RNA, are responsible for reading the code and assembling a protein with the correct amino acids.

How many different types of bases make up the genetic code in DNA?