The Science of Gardening

Growing a garden is hard work for both you and the plants. Like you, plants need water and food for energy. How plants get food and water is different from you. Understanding how living things get the energy they need to survive will make a garden seem like much more than just plants and dirt.

Describe two ways in which you think plants get food for energy.
Why does water enter and leave plant cells?
If you forget to water a plant, it will wilt. After you water the plant, it probably will straighten up and look healthier. In the following lab, find out how water causes a plant to wilt and straighten.

1. Label a small bowl *Salt Water*. Pour 250 mL of water into the bowl. Then add 15 g of salt to the water and stir.
2. Pour 250 mL of water into another small bowl.
3. Place two carrot sticks into each bowl. Also, place two carrot sticks on the lab table.
4. After 30 min, remove the carrot sticks from the bowls and keep them next to the bowl they came from. Examine all six carrot sticks, then describe them in your Science Journal.
5. **Think Critically** Write a paragraph in your Science Journal that describes what would happen if you moved the carrot sticks from the plain water to the lab table, the ones from the salt water into the plain water, and the ones from the lab table into the salt water for 30 min. Now move the carrot sticks as described and write the results in your Science Journal.
Think about everything that surrounds you—chairs, books, clothing, other students, and air. What are all these things made up of? You’re right if you answer “matter and energy.” Matter is anything that has mass and takes up space. Energy is anything that brings about change. Everything in your environment, including you, is made of matter. Energy can hold matter together or break it apart. For example, the food you eat is matter that is held together by chemical energy. When food is cooked, energy in the form of heat can break some of the bonds holding the matter in food together.

Atoms

Whether it is solid, liquid, or gas, matter is made of atoms. Figure 1 shows a model of an oxygen atom. At the center of an atom is a nucleus that contains protons and neutrons. Although they have nearly equal masses, a proton has a positive charge and a neutron has no charge. Outside the nucleus are electrons, each of which has a negative charge. It takes about 1,837 electrons to equal the mass of one proton. Electrons are important because they are the part of the atom that is involved in chemical reactions. Look at Figure 1 again and you will see that an atom is mostly empty space. Energy holds the parts of an atom together.

Figure 1 An oxygen atom model shows the placement of electrons, protons, and neutrons.
Elements  When something is made up of only one kind of atom, it is called an element. An element can’t be broken down into a simpler form by chemical reactions. The element oxygen is made up of only oxygen atoms, and hydrogen is made up of only hydrogen atoms. Scientists have given each element its own one- or two-letter symbol.

All elements are arranged in a chart known as the periodic table of elements. You can find this table at the back of this book. The table provides information about each element including its mass, how many protons it has, and its symbol.

Everything is made up of elements. Most things, including all living things, are made up of a combination of elements. Few things exist as pure elements. **Table 1** lists elements that are in the human body. What two elements make up most of your body?

Six of the elements listed in the table are important because they make up about 99 percent of living matter. The symbols for these elements are S, P, O, N, C, and H. Use **Table 1** to find the names of these elements.

**Reading Check**  What types of things are made up of elements?
Compounds and Molecules

Suppose you make a pitcher of lemonade using a powdered mix and water. The water and the lemonade mix, which is mostly sugar, contain the elements oxygen and hydrogen. Yet, in one, they are part of a nearly tasteless liquid—water. In the other they are part of a sweet solid—sugar. How can the same elements be part of two materials that are so different? Water and sugar are compounds. Compounds are made up of two or more elements in exact proportions. For example, pure water, whether one milliliter of it or one million liters, is always made up of hydrogen atoms bonded to oxygen atoms in a ratio of two hydrogen atoms to one oxygen atom. Compounds have properties different from the elements they are made of. There are two types of compounds—molecular compounds and ionic compounds.

Molecular Compounds

The smallest part of a molecular compound is a molecule. A molecule is a group of atoms held together by the energy of chemical bonds, as shown in Figure 2. When chemical reactions occur, chemical bonds break, atoms are rearranged, and new bonds form. The molecules produced are different from those that began the chemical reaction.

Molecular compounds form when different atoms share their outermost electrons. For example, two atoms of hydrogen each can share one electron on one atom of oxygen to form one molecule of water, as shown in Figure 2B. Water does not have the same properties as oxygen and hydrogen. Under normal conditions on Earth, oxygen and hydrogen are gases. Yet, water can be a liquid, a solid, or a gas. When hydrogen and oxygen combine, changes occur and a new substance forms.

Ions

Atoms also combine because they’ve become positively or negatively charged. Atoms are usually neutral—they have no overall electric charge. When an atom loses an electron, it has more protons than electrons, so it becomes positively charged. When an atom gains an electron, it has more electrons than protons, so it becomes negatively charged. Electrically charged atoms—positive or negative—are called ions.
**Ionic Compounds** Ions of opposite charges attract one another to form electrically neutral compounds called ionic compounds. Table salt is made of sodium (Na) and chlorine (Cl) ions, as shown in Figure 3B. When they combine, a chlorine atom gains an electron from a sodium atom. The chlorine atom becomes a negatively charged ion, and the sodium atom becomes a positively charged ion. These oppositely charged ions then are attracted to each other and form the ionic compound sodium chloride, NaCl.

Ions are important in many life processes that take place in your body and in other organisms. For example, messages are sent along your nerves as potassium and sodium ions move in and out of nerve cells. Calcium ions are important in causing your muscles to contract. Ions also are involved in the transport of oxygen by your blood. The movement of some substances into and out of a cell would not be possible without ions.

**Mixtures**

Some substances, such as a combination of sugar and salt, can’t change each other or combine chemically. A mixture is a combination of substances in which individual substances retain their own properties. Mixtures can be solids, liquids, gases, or any combination of them.

*Why is a combination of sugar and salt said to be a mixture?*

Most chemical reactions in living organisms take place in mixtures called solutions. You’ve probably noticed the taste of salt when you perspire. Sweat is a solution of salt and water. In a solution, two or more substances are mixed evenly. A cell’s cytoplasm is a solution of dissolved molecules and ions.

Living things also contain mixtures called suspensions. A suspension is formed when a liquid or a gas has another substance evenly spread throughout it. Unlike solutions, the substances in a suspension eventually sink to the bottom. If blood, shown in Figure 4, is left undisturbed, the red blood cells and white blood cells will sink gradually to the bottom. However, the pumping action of your heart constantly moves your blood and the blood cells remain suspended.

Figure 3  Table salt crystals are held together by ionic bonds.

Figure 4  When a test tube of whole blood is left standing, the blood cells sink in the watery plasma.
Organic Compounds

You and all living things are made up of compounds that are classified as organic or inorganic. Rocks and other nonliving things contain inorganic compounds, but most do not contain large amounts of organic compounds. Organic compounds always contain carbon and hydrogen and usually are associated with living things. One exception would be nonliving things that are products of living things. For example, coal contains organic compounds because it was formed from dead and decaying plants. Organic molecules can contain hundreds or even thousands of atoms that can be arranged in many ways. Table 2 compares the four groups of organic compounds that make up all living things—carbohydrates, lipids, proteins, and nucleic acids.

### Table 2 Organic Compounds Found in Living Things

<table>
<thead>
<tr>
<th></th>
<th>Carbohydrates</th>
<th>Lipids</th>
<th>Proteins</th>
<th>Nucleic Acids</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elements</strong></td>
<td>carbon, hydrogen, and oxygen</td>
<td>carbon, oxygen, hydrogen, and phosphorus</td>
<td>carbon, oxygen, hydrogen, nitrogen, and sulfur</td>
<td>carbon, oxygen, hydrogen, nitrogen, and sulfur</td>
</tr>
<tr>
<td><strong>Examples</strong></td>
<td>sugars, starch, and cellulose</td>
<td>fats, oils, waxes, phospholipids, and cholesterol</td>
<td>enzymes, skin, and hair</td>
<td>DNA and RNA</td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td>supply energy for cell processes; form plant structures; short-term energy storage</td>
<td>store large amounts of energy long term; form boundaries around cells</td>
<td>regulate cell processes and build cell structures</td>
<td>carry hereditary information; used to make proteins</td>
</tr>
</tbody>
</table>

**Organic Compounds**

Carbohydrates are organic molecules that supply energy for cell processes. Sugars and starches are carbohydrates that cells use for energy. Some carbohydrates also are important parts of cell structures. For example, a carbohydrate called cellulose is an important part of plant cells.

Lipids Another type of organic compound found in living things is a lipid. Lipids do not mix with water. Lipids such as fats and oils store and release even larger amounts of energy than carbohydrates do. One type of lipid, the phospholipid, is a major part of cell membranes.

Reading Check What are three types of lipids?
Proteins  Organic compounds called proteins have many important functions in living organisms. They are made up of smaller molecules called amino acids. Proteins are the building blocks of many structures in organisms. Your muscles contain large amounts of protein. Proteins are scattered throughout cell membranes. Certain proteins called enzymes regulate nearly all chemical reactions in cells.

Nucleic Acids  Large organic molecules that store important coded information in cells are called nucleic acids. One nucleic acid, deoxyribonucleic acid, or DNA—genetic material—is found in all cells at some point in their lives. It carries information that directs each cell’s activities. Another nucleic acid, ribonucleic acid, or RNA, is needed to make enzymes and other proteins.

Inorganic Compounds  Most inorganic compounds are made from elements other than carbon. Generally, inorganic molecules contain fewer atoms than organic molecules. Inorganic compounds are the source for many elements needed by living things. For example, plants take up inorganic compounds from the soil. These inorganic compounds can contain the elements nitrogen, phosphorus, and sulfur. Many foods that you eat contain inorganic compounds. Table 3 shows some of the inorganic compounds that are important to you. One of the most important inorganic compounds for living things is water.

Table 3  Some Inorganic Compounds Important in Humans

<table>
<thead>
<tr>
<th>Compound</th>
<th>Use in Body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>makes up most of the blood; most chemical reactions occur in water</td>
</tr>
<tr>
<td>Calcium phosphate</td>
<td>gives strength to bones</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>breaks down foods in the stomach</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>helps the digestion of food to occur</td>
</tr>
<tr>
<td>Salts containing sodium, chlorine, and potassium</td>
<td>important in sending messages along nerves</td>
</tr>
</tbody>
</table>

Observing How Enzymes Work

Procedure
1. Get two small cups of prepared gelatin from your teacher. Do not eat or drink anything in lab.
2. On the gelatin in one of the cups, place a piece of fresh pineapple.
3. Let both cups stand undisturbed overnight.
4. Observe what happens to the gelatin.

Analysis
1. What effect did the piece of fresh pineapple have on the gelatin?
2. What does fresh pineapple contain that caused it to have the effect on the gelatin you observed?
3. Why do the preparation directions on a box of gelatin dessert tell you not to mix it with fresh pineapple?
Importance of Water  Some scientists hypothesize that life began in the water of Earth’s ancient oceans. Chemical reactions might have occurred that produced organic molecules. Similar chemical reactions can take place in cells in your body.

Living things are composed of more than 50 percent water and depend on water to survive. You can live for weeks without food but only for a few days without water. Figure 5 shows where water is found in your body. Although seeds and spores of plants, fungi, and bacteria can exist without water, they must have water if they are to grow and reproduce. All the chemical reactions in living things take place in water solutions, and most organisms use water to transport materials through their bodies. For example, many animals have blood that is mostly water and moves materials. Plants use water to move minerals and sugars between the roots and leaves.

**Applying Math**

### Solve an Equation

**CALCULATE THE IMPORTANCE OF WATER**  All life on Earth depends on water for survival. Water is the most vital part of humans and other animals. It is required for all of the chemical processes that keep us alive. At least 60 percent of an adult human body consists of water. If an adult man weighs 90 kg, how many kilograms of water does his body contain?

**Solution**

1. **This is what you know:**
   - adult human body = 60% water
   - man = 90 kg

2. **This is what you need to find:**
   - How many kilograms of water does the adult man have?

3. **This is the procedure you need to use:**
   - Set up the ratio: $\frac{60}{100} = \frac{x}{90}$.
   - Solve the equation for $x$: $(60 \times 90)/100$.
   - The adult man has 54 kg of water.

4. **Check your answer:**
   - Divide your answer by 90, then multiply by 100. You should get 60%.

**Practice Problems**

1. A human body at birth consists of 78 percent water. This gradually decreases to 60 percent in an adult. Assume a baby weighed 3.2 kg at birth and grew into an adult weighing 95 kg. Calculate the approximate number of kilograms of water the human gained.

2. Assume an adult woman weighs 65 kg and an adult man weighs 90 kg. Calculate how much more water, in kilograms, the man has compared to the woman.

For more practice, visit [green.msscience.com/math_practice](green.msscience.com/math_practice)
Characteristics of Water  The atoms of a water molecule are arranged in such a way that the molecule has areas with different charges. Water molecules are like magnets. The negative part of a water molecule is attracted to the positive part of another water molecule just like the north pole of a magnet is attracted to the south pole of another magnet. This attraction, or force, between water molecules is why a film forms on the surface of water. The film is strong enough to support small insects because the forces between water molecules are stronger than the force of gravity on the insect.

When heat is added to any substance, its molecules begin to move faster. Because water molecules are so strongly attracted to each other, the temperature of water changes slowly. The large percentage of water in living things acts like an insulator. The water in a cell helps keep its temperature constant, which allows life-sustaining chemical reactions to take place.

You’ve seen ice floating on water. When water freezes, ice crystals form. In the crystals, each water molecule is spaced at a certain distance from all the others. Because this distance is greater in frozen water than in liquid water, ice floats on water. Bodies of water freeze from the top down. The floating ice provides insulation from extremely cold temperatures and allows living things to survive in the cold water under the ice.

Figure 5  About two-thirds of your body’s water is located within your body’s cells. Water helps maintain the cells’ shapes and sizes. One-third of your body’s water is outside of your body’s cells.
“Close that window. Do you want to let in all the bugs and leaves?” How do you prevent unwanted things from coming through the window? As seen in Figure 6, a window screen provides the protection needed to keep unwanted things outside. It also allows some things to pass into or out of the room like air, unpleasant odors, or smoke.

Cells take in food, oxygen, and other substances from their environments. They also release waste materials into their environments. A cell has a membrane around it that works for a cell like a window screen does for a room. A cell’s membrane is selectively permeable (PUR mee uh bul). It allows some things to enter or leave the cell while keeping other things outside or inside the cell. The window screen also is selectively permeable based on the size of its openings.

Things can move through a cell membrane in several ways. Which way things move depends on the size of the molecules or particles, the path taken through the membrane, and whether or not energy is used. The movement of substances through the cell membrane without the input of energy is called **passive transport**. Three types of passive transport can occur. The type depends on what is moving through the cell membrane.
Diffusion  Molecules in solids, liquids, and gases move constantly and randomly. You might smell perfume when you sit near or as you walk past someone who is wearing it. This is because perfume molecules randomly move throughout the air. This random movement of molecules from an area where there is relatively more of them into an area where there is relatively fewer of them is called diffusion. Diffusion is one type of cellular passive transport. Molecules of a substance will continue to move from one area into another until the relative number of these molecules is equal in the two areas. When this occurs, equilibrium is reached and diffusion stops. After equilibrium occurs, it is maintained because molecules continue to move.

Describe  What is equilibrium?

Every cell in your body uses oxygen. When you breathe, how does oxygen get from your lungs to cells in your big toe? Oxygen is carried throughout your body in your blood by the red blood cells. When your blood is pumped from your heart to your lungs, your red blood cells do not contain much oxygen. However, your lungs have more oxygen molecules than your red blood cells do, so the oxygen molecules diffuse into your red blood cells from your lungs, as shown in Figure 7. When the blood reaches your big toe, there are more oxygen molecules in your red blood cells than in your big toe cells. The oxygen diffuses from your red blood cells and into your big toe cells, as shown also in Figure 7.

Observing Diffusion

Procedure
1. Use two clean glasses of equal size. Label one Hot, then fill it until half full with very warm water. Label the other Cold, then fill it until half full with cold water. WARNING: Do not use boiling hot water.
2. Add one drop of food coloring to each glass. Carefully release the drop just at the water’s surface to avoid splashing the water.
3. Observe the water in the glasses. Record your observations immediately and again after 15 min.

Analysis
1. Describe what happens when food coloring is added to each glass.
2. How does temperature affect the rate of diffusion?
Osmosis—The Diffusion of Water Remember that water makes up a large part of living matter. Cells contain water and are surrounded by water. Water molecules move by diffusion into and out of cells. The diffusion of water through a cell membrane is called osmosis.

If cells weren’t surrounded by water that contains few dissolved substances, water inside of cells would diffuse out of them. This is why water left the carrot cells in this chapter’s Launch Lab. Because there were relatively fewer water molecules in the salt solution around the carrot cells than in the carrot cells, water moved out of the cells and into the salt solution.

Losing water from a plant cell causes its cell membrane to come away from its cell wall, as shown on the left in Figure 8. This reduces pressure against its cell wall, and a plant cell becomes limp. If the carrot sticks were taken out of salt water and put in pure water, the water around the cells would move into them and they would fill with water. Their cell membranes would press against their cell walls, as shown on the right in Figure 8, pressure would increase, and the cells would become firm. That is why the carrot sticks would be crisp again.

Why do carrots in salt water become limp?

Osmosis also takes place in animal cells. If animal cells were placed in pure water, they too would swell up. However, animal cells are different from plant cells. Just like an overfilled water balloon, animal cells will burst if too much water enters the cell.
**Facilitated Diffusion** Cells take in many substances. Some substances pass easily through the cell membrane by diffusion. Other substances, such as glucose molecules, are so large that they can enter the cell only with the help of molecules in the cell membrane called transport proteins. This process, a type of passive transport, is known as facilitated diffusion. Have you ever used the drive through at a fast-food restaurant to get your meal? The transport proteins in the cell membrane are like the drive-through window at the restaurant. The window lets you get food out of the restaurant and put money into the restaurant. Similarly, transport proteins are used to move substances into and out of the cell.

**Active Transport**

Imagine that a football game is over and you leave the stadium. As soon as you get outside of the stadium, you remember that you left your jacket on your seat. Now you have to move against the crowd coming out of the stadium to get back in to get your jacket. Which required more energy—leaving the stadium with the crowd or going back to get your jacket? Something similar to this happens in cells.

Sometimes, a substance is needed inside a cell even though the amount of that substance inside the cell is already greater than the amount outside the cell. For example, root cells require minerals from the soil. The roots of the plant in Figure 9 already might contain more of those mineral molecules than the surrounding soil does. The tendency is for mineral molecules to move out of the root by diffusion or facilitated diffusion. But they need to move back across the cell membrane and into the cell just like you had to move back into the stadium. When an input of energy is required to move materials through a cell membrane, **active transport** takes place.

Active transport involves transport proteins, just as facilitated diffusion does. In active transport, a transport protein binds with the needed particle and cellular energy is used to move it through the cell membrane. When the particle is released, the transport protein can move another needed particle through the membrane.

**Figure 9** Some root cells have extensions called root hairs that may be 5 mm to 8 mm long. Minerals are taken in by active transport through the cell membranes of root hairs.

**Transport Proteins** Your health depends on transport proteins. Sometimes transport proteins are missing or do not function correctly. What would happen if proteins that transport cholesterol across membranes were missing? Cholesterol is an important lipid used by your cells. Write your ideas in your Science Journal.
Endocytosis and Exocytosis

Some molecules and particles are too large to move by diffusion or to use the cell membrane's transport proteins. Large protein molecules and bacteria, for example, can enter a cell when they are surrounded by the cell membrane. The cell membrane folds in on itself, enclosing the item in a sphere called a vesicle. Vesicles are transport and storage structures in a cell's cytoplasm. The sphere pinches off, and the resulting vesicle enters the cytoplasm. A similar thing happens when you poke your finger into a partially inflated balloon. Your finger is surrounded by the balloon in much the same way that the protein molecule is surrounded by the cell membrane. This process of taking substances into a cell by surrounding it with the cell membrane is called endocytosis (en duh si TOH sus). Some one-celled organisms, as shown in Figure 10, take in food this way.

The contents of a vesicle can be released by a cell using the process called exocytosis (ek soh si TOH sus). Exocytosis occurs in the opposite way that endocytosis does. A vesicle's membrane fuses with a cell's membrane, and the vesicle's contents are released. Cells in your stomach use this process to release chemicals that help digest food. The ways that materials can enter or leave a cell are summarized in Figure 11.

Summary

Passive Transport
- Cells take in substances and release waste through their cell membranes.
- Facilitated diffusion and osmosis are types of passive transport.

Active Transport
- Transport proteins are involved in active transport.
- Transport proteins can be reused many times.

Endocytosis and Exocytosis
- Vesicles are formed when a cell takes in a substance by endocytosis.
- Contents of a vesicle are released to the outside of a cell by exocytosis.

Self Check

1. Describe how cell membranes are selectively permeable.
2. Compare and contrast the processes of osmosis and diffusion.
3. Infer why endocytosis and exocytosis are important processes to cells.
4. Think Critically Why are fresh fruits and vegetables sprinkled with water at produce markets?

Applying Skills

5. Communicate Seawater is saltier than tap water. Explain why drinking large amounts of seawater would be dangerous for humans.
A flexible yet strong layer, the cell membrane is built of two layers of lipids (gold) pierced by protein “passageways” (purple). Molecules can enter or exit the cell by slipping between the lipids or through the protein passageways. Substances that cannot enter or exit the cell in these ways may be surrounded by the membrane and drawn into or expelled from the cell.

**DIFFUSION AND OSMOSIS**
Small molecules such as oxygen, carbon dioxide, and water can move between the lipids into or out of the cell.

**ACTIVE TRANSPORT**
Cellular energy is used to move some molecules through protein passageways. The protein binds to the molecule on one side of the membrane and then releases the molecule on the other side.

**FACILITATED DIFFUSION**
Larger molecules such as glucose also diffuse through the membrane—but only with the help of transport proteins.

**ENDOCYTOSIS AND EXOCYTOSIS**
In endocytosis, part of the cell membrane wraps around a particle and engulfs it in a vesicle. During exocytosis, a vesicle filled with molecules bound for export moves to the cell membrane, fuses with it, and the contents are released to the outside.
It is difficult to observe osmosis in cells because most cells are so small. However, a few cells can be seen without the aid of a microscope. Try this lab to observe osmosis.

**Real-World Question**
How does osmosis occur in an egg cell?

**Materials**
- unshelled egg*
- distilled water (250 mL)
- balance
- light corn syrup (250 mL)
- spoon
- 500-mL container

*an egg whose shell has been dissolved by vinegar

**Goals**
- **Observe** osmosis in an egg cell.
- **Determine** what affects osmosis.

**Safety Precautions**

WARNING: Eggs may contain bacteria. Avoid touching your face.

**Procedure**

1. Copy the table below into your Science Journal and use it to record your data.

2. Obtain an unshelled egg from your teacher. Handle the egg gently. Use a balance to find the egg’s mass and record it in the table.

3. Place the egg in the container and add enough distilled water to cover it.

4. **Observe** the egg after 30 min, one day, and two days. After each observation, record the egg’s appearance in your Science Journal.

5. After day two, remove the egg with a spoon and allow it to drain. Find the egg’s mass and record it in the table.

6. Empty the container, then put the egg back in. Now add enough corn syrup to cover it. Repeat steps 4 and 5.

**Conclude and Apply**

1. **Explain** the difference between what happened to the egg in water and in corn syrup.

2. **Calculate** the mass of water that moved into and out of the egg.

3. **Hypothesize** why you used an unshelled egg for this investigation.

4. **Infer** what part of the egg controlled water’s movement into and out of the egg.

**Egg Mass Data**

<table>
<thead>
<tr>
<th>Egg Mass</th>
<th>Beginning Egg Mass</th>
<th>Egg Mass After Two Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distilled water</td>
<td>Do not write in this book.</td>
<td></td>
</tr>
<tr>
<td>Corn syrup</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Communicating Your Data**

Compare your conclusions with those of other students in your class. For more help, refer to the Science Skill Handbook.
Enzymes are needed for most chemical reactions that take place in cells. Determine What is the sum of all chemical reactions in an organism called?

**What You’ll Learn**
- List the differences between producers and consumers.
- Explain how the processes of photosynthesis and respiration store and release energy.
- Describe how cells get energy from glucose through fermentation.

**Why It’s Important**
Because of photosynthesis and respiration, you use the Sun’s energy.

**Review Vocabulary**
- mitochondrion: cell organelle that breaks down lipids and carbohydrates and releases energy

**New Vocabulary**
- metabolism
- photosynthesis
- respiration
- fermentation

**Figure 12**
Enzymes are needed for most chemical reactions that take place in cells.

**Trapping and Using Energy**
Think of all the energy that players use in a basketball game. Where does the energy come from? The simplest answer is “from the food they eat.” The chemical energy stored in food molecules is changed inside of cells into forms needed to perform all the activities necessary for life. In every cell, these changes involve chemical reactions. All of the activities of an organism involve chemical reactions in some way. The total of all chemical reactions in an organism is called metabolism.

The chemical reactions of metabolism need enzymes. What do enzymes do? Suppose you are hungry and decide to open a can of spaghetti. You use a can opener to open the can. Without a can opener, the spaghetti is unusable. The can of spaghetti changes because of the can opener, but the can opener does not change. The can opener can be used again later to open more cans of spaghetti. Enzymes in cells work something like can openers. The enzyme, like the can opener, causes a change, but the enzyme is not changed and can be used again, as shown in Figure 12. Unlike the can opener, which can only cause things to come apart, enzymes also can cause molecules to join. Without the right enzyme, a chemical reaction in a cell cannot take place. Each chemical reaction in a cell requires a specific enzyme.

The enzyme attaches to the large molecule it will help change. The enzyme causes the larger molecule to break down into two smaller molecules. The enzyme is not changed and can be used again.
Photosynthesis

Living things are divided into two groups—producers and consumers—based on how they obtain their food. Organisms that make their own food, such as plants, are called producers. Organisms that cannot make their own food are called consumers.

If you have ever walked barefoot across a sidewalk on a sunny summer day, you probably moved quickly because the sidewalk was hot. Sunlight energy was converted into thermal energy and heated the sidewalk. Plants and many other producers can convert light energy into another kind of energy—chemical energy. The process they use is called photosynthesis. During photosynthesis, producers use light energy to make sugars, which can be used as food.

**Producing Carbohydrates**

Producers that use photosynthesis are usually green because they contain a green pigment called chlorophyll (KLOR uh fihl). Chlorophyll and other pigments are used in photosynthesis to capture light energy. In plant cells, these pigments are found in chloroplasts.

The captured light energy powers chemical reactions that produce sugar and oxygen from the raw materials, carbon dioxide and water. For plants, the raw materials come from air and soil. Some of the captured light energy is stored in the chemical bonds that hold the sugar molecules together. **Figure 13** shows what happens during photosynthesis in a plant. Enzymes also are needed before these reactions can occur.

**Storing Carbohydrates**

Plants make more sugar during photosynthesis than they need for survival. Excess sugar is changed and stored as starches or used to make other carbohydrates. Plants use these carbohydrates as food for growth, maintenance, and reproduction.

Why is photosynthesis important to consumers? Do you eat apples? Apple trees use photosynthesis to produce apples. Do you like cheese? Some cheese comes from milk, which is produced by cows that eat plants. Consumers take in food by eating producers or other consumers. No matter what you eat, photosynthesis was involved directly or indirectly in its production.
Respiration Imagine that you get up late for school. You dress quickly, then run three blocks to school. When you get to school, you feel hot and are breathing fast. Why? Your muscle cells use a lot of energy when you run. To get this energy, muscle cells break down food. Some of the energy from the food is used when you move and some of it becomes thermal energy, which is why you feel warm or hot. Most cells also need oxygen to break down food. You were breathing fast because your body was working to get oxygen to your muscles. Your muscle cells were using the oxygen for the process of respiration. During respiration, chemical reactions occur that break down food molecules into simpler substances and release their stored energy. Just as in photosynthesis, enzymes are needed for the chemical reactions of respiration.

What must happen to food molecules for respiration to take place?

Breaking Down Carbohydrates The food molecules most easily broken down by cells are carbohydrates. Respiration of carbohydrates begins in the cytoplasm of the cell. The carbohydrates are broken down into glucose molecules. Each glucose molecule is broken down further into two simpler molecules. As the glucose molecules are broken down, energy is released.

The two simpler molecules are broken down again. This breakdown occurs in the mitochondria of the cells of plants, animals, fungi, and many other organisms. This process uses oxygen, releases much more energy, and produces carbon dioxide and water as wastes. When you exhale, you breathe out carbon dioxide and some of the water.

Respiration occurs in the cells of all living things. Figure 14 shows how respiration occurs in one consumer. As you are reading this section of the chapter, millions of cells in your body are breaking down glucose, releasing energy, and producing carbon dioxide and water.
Fermentation  Remember imagining you were late and had to run to school? During your run, your muscle cells might not have received enough oxygen, even though you were breathing rapidly. When cells do not have enough oxygen for respiration, they use a process called **fermentation** to release some of the energy stored in glucose molecules.

Like respiration, fermentation begins in the cytoplasm. Again, as the glucose molecules are broken down, energy is released. But the simple molecules from the breakdown of glucose do not move into the mitochondria. Instead, more chemical reactions occur in the cytoplasm. These reactions release some energy and produce wastes. Depending on the type of cell, the wastes may be lactic acid or alcohol and carbon dioxide, as shown in **Figure 15**. Your muscle cells can use fermentation to change the simple molecules into lactic acid while releasing energy. The presence of lactic acid is why your muscle cells might feel stiff and sore after you run to school.

**Reading Check**  Where in a cell does fermentation take place?

Some microscopic organisms, such as bacteria, carry out fermentation and make lactic acid. Some of these organisms are used to produce yogurt and some cheeses. These organisms break down a sugar in milk and release energy. The lactic acid produced causes the milk to become more solid and gives these foods some of their flavor.

Have you ever used yeast to make bread? Yeasts are one-celled living organisms. Yeast cells use fermentation and break down sugar in bread dough. They produce alcohol and carbon dioxide as wastes. The carbon dioxide waste is a gas that makes bread dough rise before it is baked. The alcohol is lost as the bread bakes.

**ScienceOnline**

**Topic: Beneficial Microorganisms**

Visit [green.msscience.com](http://green.msscience.com) for Web links to information about how microorganisms are used to produce many useful products.

**Activity**  Find three other ways that microorganisms are beneficial.

**Figure 15**  Organisms that use fermentation produce several different wastes.

Yeast cells produce carbon dioxide and alcohol as wastes when they undergo fermentation.

Your muscle cells produce lactic acid as a waste when they undergo fermentation.
Related Processes  How are photosynthesis, respiration, and fermentation related? Some producers use photosynthesis to make food. All living things use respiration or fermentation to release energy stored in food. If you think carefully about what happens during photosynthesis and respiration, you will see that what is produced in one is used in the other, as shown in Figure 16. These two processes are almost the opposite of each other. Photosynthesis produces sugars and oxygen, and respiration uses these products. The carbon dioxide and water produced during respiration are used during photosynthesis. Most life would not be possible without these important chemical reactions.

Summary
Trapping and Using Energy
- Metabolism is the total of all chemical reactions in an organism.
- During photosynthesis, light energy is used to make sugars.
- Chlorophyll and other pigments capture light energy.
- Consumers take in energy by eating producers and other consumers.
- Living cells break down glucose and release energy. This is called respiration.
- Fermentation changes simple molecules and releases energy.
- Without photosynthesis and respiration, most life would not be possible.

Self Check
1. Explain the difference between producers and consumers and give three examples of each.
2. Infer how the energy used by many living things on Earth can be traced back to sunlight.
3. Compare and contrast respiration and fermentation.
4. Think Critically How can some indoor plants help to improve the quality of air in a room?
5. Solve Refer to the chemical equation for photosynthesis. Calculate then compare the number of carbon, hydrogen, and oxygen atoms before and after photosynthesis.

Figure 16  The chemical reactions of photosynthesis and respiration could not take place without each other.

green.msscience.com/self_check_quiz
Real-World Question

Every living cell carries on many chemical processes. Two important chemical processes are respiration and photosynthesis. All cells, including the ones in your body, carry on respiration. However, some plant cells can carry on both processes. In this experiment you will investigate when these processes occur in plant cells. How could you find out when plants were using these processes? Are the products of photosynthesis and respiration the same? When do plants carry on photosynthesis and respiration?

Procedure

1. In your Science Journal, copy and complete the test-tube data table as you perform this lab.

<table>
<thead>
<tr>
<th>Test-Tube Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Tube</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

Goals

- **Observe** green water plants in the light and dark.
- **Determine** whether plants carry on photosynthesis and respiration.

Materials

- 16-mm test tubes (3)
- 150-mm test tubes with stoppers (4)
- *small, clear-glass baby food jars with lids (4)*
- test-tube rack
- stirring rod
- scissors
- carbonated water (5 mL)
- bromthymol blue solution in dropper bottle
- aged tap water (20 mL)
- *distilled water (20 mL)*
- sprigs of Elodea (2)
- *other water plants*
- *Alternate materials*

Safety Precautions

**WARNING:** Wear splash-proof safety goggles to protect eyes from hazardous chemicals.
2. Label each test tube using the numbers 1, 2, 3, and 4. Pour 5 mL of aged tap water into each test tube.

3. Add 10 drops of carbonated water to test tubes 1 and 2.

4. Add 10 drops of bromthymol blue to all of the test tubes. Bromthymol blue turns green to yellow in the presence of an acid.

5. Cut two 10-cm sprigs of Elodea. Place one sprig in test tube 1 and one sprig in test tube 3. Stopper all test tubes.

6. Place test tubes 1 and 2 in bright light. Place tubes 3 and 4 in the dark. Observe the test tubes for 30 min or until the color changes. Record the color of each of the four test tubes.

**Analyze Your Data**

1. **Identify** what is indicated by the color of the water in all four test tubes at the start of the activity.

2. **Infer** what process occurred in the test tube or tubes that changed color after 30 min.

**Conclude and Apply**

1. **Describe** the purpose of test tubes 2 and 4 in this experiment.

2. **Explain** whether or not the results of this experiment show that photosynthesis and respiration occur in plants.

**Communicating Your Data**

Choose one of the following activities to communicate your data. Prepare an oral presentation that explains how the experiment showed the differences between products of photosynthesis and respiration. Draw a cartoon strip to explain what you did in this experiment. Use each panel to show a different step. For more help, refer to the Science Skill Handbook.
I watched its first green push through bare dirt, where the builders had dropped boards, shingles, plaster—killing everything.

I could not recall what grew there, what returned each spring, but the leaves looked tulip, and one morning it arrived, a scarlet slash against the aluminum siding.

Mornings, on the way to my car, I bow to the still bell of its closed petals; evenings, it greets me, light ringing at the end of my driveway.

Sometimes I kneel to stare into the yellow throat... It opens and closes my days. It has made me weak with love....

**Respond to the Reading**

1. Why do you suppose the tulip survived the builders’ abuse?
2. What is the yellow throat that the narrator is staring into?
3. **Linking Science and Writing** Keep a gardener’s journal of a plant for a month, describing weekly the plant’s condition, size, health, color, and other physical qualities.

Because most chemical reactions in plants take place in water, plants must have water in order to grow. The water carries nutrients and minerals from the soil into the plant. The process of active transport allows needed nutrients to enter the roots. The cell membranes of root cells contain proteins that bind with the needed nutrients. Cellular energy is used to move these nutrients through the cell membrane.
Copy and complete the following table on energy processes.

<table>
<thead>
<tr>
<th>Energy Processes</th>
<th>Photosynthesis</th>
<th>Respiration</th>
<th>Fermentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy source</td>
<td>food (glucose)</td>
<td>food (glucose)</td>
<td>food (glucose)</td>
</tr>
<tr>
<td>In plant and animal cells, occurs in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reactants are</td>
<td></td>
<td></td>
<td>Do not write in this book.</td>
</tr>
<tr>
<td>Products are</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Use what you know about the vocabulary words to answer the following questions.

1. What is the diffusion of water called?
2. What type of protein regulates nearly all chemical reactions in cells?
3. How do large food particles enter an amoeba?
4. What type of compound is water?
5. What process is used by some producers to convert light energy into chemical energy?
6. What type of compounds always contain carbon and hydrogen?
7. What process uses oxygen to break down glucose?
8. What is the total of all chemical reactions in an organism called?

Use the photo below to answer question 10.

10. What cell process is occurring in the photo?
   A) osmosis       C) exocytosis
   B) endocytosis   D) diffusion

11. What occurs when the number of molecules of a substance is equal in two areas?
    A) equilibrium   C) fermentation
    B) metabolism    D) cellular respiration

12. Which of the following substances is an example of a carbohydrate?
    A) enzymes       C) waxes
    B) sugars        D) proteins

13. What is RNA an example of?
    A) carbon dioxide C) lipid
    B) water         D) nucleic acid

14. What organic molecule stores the greatest amount of energy?
    A) carbohydrate  C) lipid
    B) water         D) nucleic acid

15. Which of these formulas is an example of an organic compound?
    A) C₆H₁₂O₆       C) H₂O
    B) NO₂            D) O₂

16. What are organisms that cannot make their own food called?
    A) biodegradable   C) consumers
    B) producers       D) enzymes
17. **Concept Map** Copy and complete the events-chain concept map to sequence the following parts of matter from smallest to largest: *atom*, *electron*, and *compound*.

   ![Concept Map Diagram]

   Use the table below to answer question 18.

   **Photosynthesis in Water Plants**

<table>
<thead>
<tr>
<th>Beaker Number</th>
<th>Distance from Light (cm)</th>
<th>Bubbles per Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>19</td>
</tr>
<tr>
<td>4</td>
<td>70</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>1</td>
</tr>
</tbody>
</table>

18. **Interpret Data** Water plants were placed at different distances from a light source. Bubbles coming from the plants were counted to measure the rate of photosynthesis. What can you say about how the distance from the light affected the rate?

19. **Infer** why, in snowy places, salt is used to melt ice on the roads. Explain what could happen to many roadside plants as a result.

20. **Draw a conclusion** about why sugar dissolves faster in hot tea than in iced tea.

21. **Predict** what would happen to the consumers in a lake if all the producers died.

22. **Explain** how meat tenderizers affect meat.

23. **Form a hypothesis** about what will happen to wilted celery when placed in a glass of plain water.

24. **Puzzle** Make a crossword puzzle with words describing ways substances are transported across cell membranes. Use the following words in your puzzle: *diffusion*, *osmosis*, *facilitated diffusion*, *active transport*, *endocytosis*, and *exocytosis*. Make sure your clues give good descriptions of each transport method.

25. **Light and Photosynthesis** Using the data from question 18, make a line graph that shows the relationship between the rate of photosynthesis and the distance from light.

26. **Importance of Water** Assume the brain is 70% water. If the average adult human brain weighs 1.4 kg, how many kilograms of water does it contain?

27. **Photosynthesis** Refer to the chemical equation above. If 18 CO₂ molecules and 18 H₂O molecules are used with light energy to make sugar, how many sugar molecules will be produced? How many oxygen molecules will be produced?
1. An element cannot be broken down by chemical reactions and is made up of only one kind of
   A. electron.           C. atom.
   B. carbohydrate.      D. molecule.

2. What kind of chemical compound do salt and water form?
   A. covalent
   B. ionic
   C. solution
   D. lipid

3. Salt is very important in the human body. What kind of compound is salt?
   A. organic
   B. carbohydrate
   C. protein
   D. inorganic

4. A cell that contains 40% water is placed in a solution that is 20% water. The cell and the solution will reach equilibrium when they both contain how much water?
   A. 30%
   B. 40%
   C. 60%
   D. 20%

5. All chemical reactions in living things take place in what kind of a solution?
   A. protein
   B. water
   C. gas
   D. solid

6. The sum of all the chemical reactions in an organism is
   A. respiration.
   B. metabolism.
   C. fermentation.
   D. endocytosis.

7. What is needed for all chemical reactions in cells?
   A. enzymes
   B. lipids
   C. DNA
   D. cell membrane

8. The carbon dioxide that you exhale is a product of
   A. osmosis.
   B. DNA synthesis.
   C. photosynthesis.
   D. respiration.

9. Matter cannot be held together or broken apart without
   A. gas.
   B. liquid.
   C. energy.
   D. temperature.

10. According to this information, which organic compound is the least flexible?
    A. keratin
    B. collagen
    C. chitin
    D. cellulose
Part 2 | Short Response/Grid In

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

11. Explain the structure of an atom.

12. How does chewing food affect your body’s ability to release the chemical energy of the food?

13. Ice fishing is a popular sport in the winter. What properties of water is this sport based on?

14. Explain where the starch in a potato comes from.

15. Does fermentation or respiration release more energy for an athlete’s muscles? Which process would be responsible for making muscles sore?

Use the table below to answer question 16.

<table>
<thead>
<tr>
<th>Classification of Compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compound</strong></td>
</tr>
<tr>
<td>Salt</td>
</tr>
<tr>
<td>Fat</td>
</tr>
<tr>
<td>Skin</td>
</tr>
<tr>
<td>DNA</td>
</tr>
<tr>
<td>Sugar</td>
</tr>
<tr>
<td>Water</td>
</tr>
<tr>
<td>Potassium</td>
</tr>
</tbody>
</table>

16. Copy and complete the table above. Identify each item as inorganic or organic. If the item is an organic compound further classify it as a protein, carbohydrate, lipid or nucleic acid.

17. Define selectively permeable and discuss why it is important for the cell membrane.

18. What is the source of energy for the photosynthesis reactions and where do they take place in a cell?

Part 3 | Open Ended

Record your answers on a sheet of paper.

19. Give examples of each of the four types of organic molecules and why they are needed in a plant cell.

20. Trace the path of how oxygen molecules are produced in a plant cell to how they are used in human cells.

21. Describe four ways a large or small molecule can cross the cell membrane.

22. Discuss how water is bonded together and the unique properties that result from the bonds.

Use the illustration below to answer question 23.

23. Describe in detail what process is taking place in this diagram and its significance for a cell.

24. How do plants use carbon dioxide? Why would plants need oxygen?

Test-Taking Tip

Diagrams: Study a diagram carefully, being sure to read all labels and captions.