

Plant Processes

chapter preview

sections

1 Photosynthesis and Respiration

Lab Stomata in Leaves

2 Plant Responses

Lab Tropism in Plants



Virtual Lab Which colors of the light spectrum are most important for plant growth?

How did it get so big?




From crabgrass to giant sequoias, many plants start as small seeds. Some trees may grow to be more than 20 m tall. One tree can produce enough lumber to build a house. Where does all that wood come from? Did you know that plants are essential to the survival of all animals on Earth?

Science Journal Describe what would happen to life on Earth if all the green plants disappeared.

Start-Up Activities



Do plants lose water?

Plants, like all other living organisms, are made of cells, reproduce, and need water to live. What would happen if you forgot to water a houseplant? From your own experiences, you probably know that the houseplant would wilt. Do the following lab to discover one way plants lose water.   

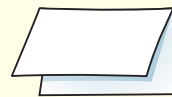


1. Obtain a self-sealing plastic bag, some aluminum foil, and a small potted plant from your teacher.
2. Using the foil, carefully cover the soil around the plant in the pot. Place the potted plant in the plastic bag.
3. Seal the bag and place it in a sunny window. Wash your hands.
4. Observe the plant at the same time every day for a few days.
5. **Think Critically** Write a paragraph that describes what happened in the bag. If enough water is lost by a plant and not replaced, predict what will happen to the plant.

FOLDABLES™ Study Organizer

Photosynthesis and Respiration Make the following Foldable to help you distinguish between photosynthesis and respiration.

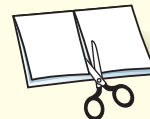
STEP 1 **Fold** a vertical sheet of paper in half from top to bottom.



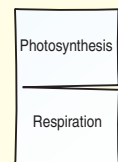
STEP 2 **Fold** in half from side to side with the fold at the top.



STEP 3 **Unfold** the paper once. **Cut** only the fold of the top flap to make two tabs.



STEP 4 **Turn** the paper vertically and **label** the front tabs as shown.



Compare and Contrast As you read the chapter, write the characteristics of respiration and photosynthesis under the appropriate tab.



Preview this chapter's content and activities at bookb.msscience.com

Photosynthesis and Respiration

as you read

What You'll Learn

- **Explain** how plants take in and give off gases.
- **Compare and contrast** photosynthesis and respiration.
- **Discuss** why photosynthesis and respiration are important.

Why It's Important

Understanding photosynthesis and respiration in plants will help you understand how life exists on Earth.

Review Vocabulary

cellulose: chemical compound made of sugar; forms tangled fibers in plant cell walls and provides structure and support

New Vocabulary

- stomata
- photosynthesis
- chlorophyll
- respiration

Taking in Raw Materials

Sitting in the cool shade under a tree, you eat lunch. Food is one of the raw materials you need to grow. Oxygen is another. It enters your lungs and eventually reaches every cell in your body. Your cells use oxygen to help release energy from the food that you eat. The process that uses oxygen to release energy from food produces carbon dioxide and water as wastes. These wastes move in your blood to your lungs, where they are removed as gases when you exhale. You look up at the tree and wonder, “Does a tree need to eat? Does it use oxygen? How does it get rid of wastes?”

Movement of Materials in Plants Trees and other plants don't take in foods the way you do. Plants make their own foods using the raw materials water, carbon dioxide, and inorganic chemicals in the soil. Just like you, plants also produce waste products.

Most of the water used by plants is taken in through roots, as shown in **Figure 1**. Water moves into root cells and then up through the plant to where it is used. When you pull up a plant,

its roots are damaged and some are lost. If you replant it, the plant will need extra water until new roots grow to replace those that were lost.

Leaves, instead of lungs, are where most gas exchange occurs in plants. Most of the water taken in through the roots exits through the leaves of a plant. Carbon dioxide, oxygen, and water vapor exit and enter the plant through openings in the leaf. The leaf's structure helps explain how it functions in gas exchange.

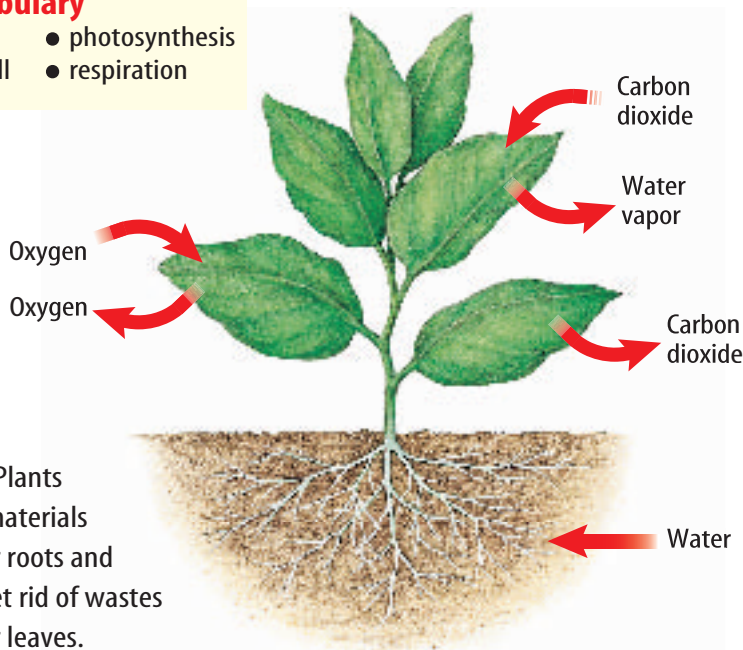
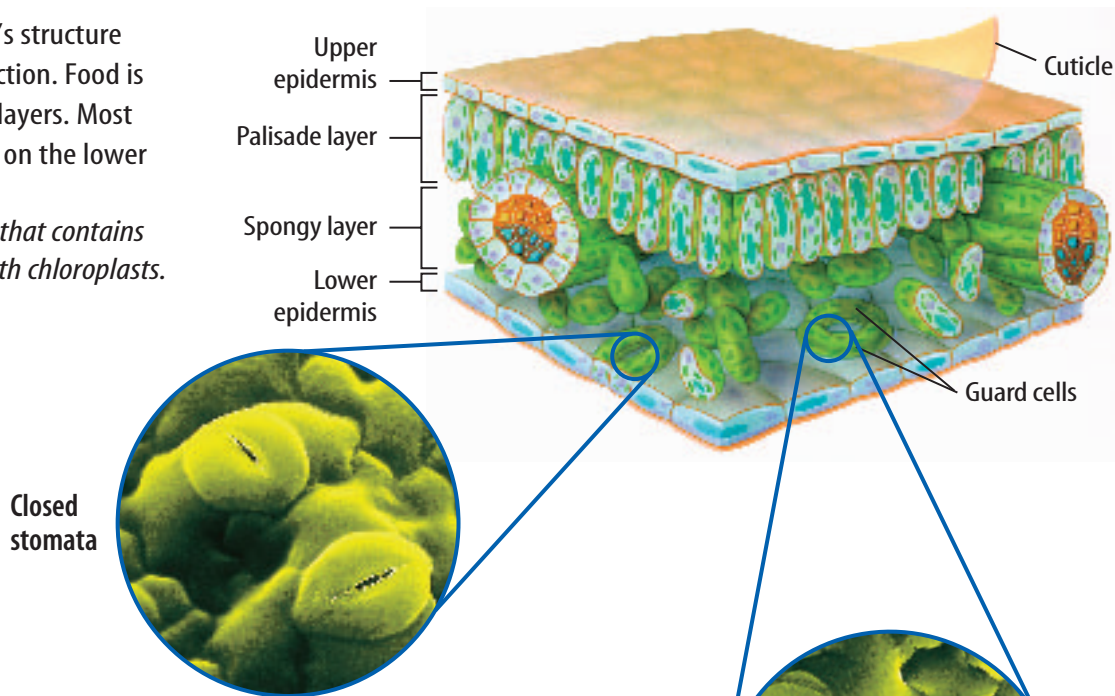


Figure 1 Plants take in raw materials through their roots and leaves and get rid of wastes through their leaves.

Figure 2 A leaf's structure determines its function. Food is made in the inner layers. Most stomata are found on the lower epidermis.

Identify the layer that contains most of the cells with chloroplasts.

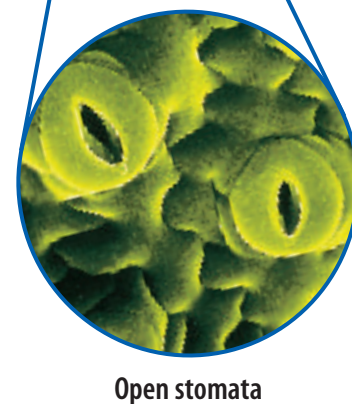


Leaf Structure and Function A leaf is made up of many different layers, as shown in **Figure 2**. The outer cell layer of the leaf is the epidermis. A waxy cuticle that helps keep the leaf from drying out covers the epidermis. Because the epidermis is nearly transparent, sunlight—which is used to make food—reaches the cells inside the leaf. If you examine the epidermis under a microscope, you will see that it contains many small openings. These openings, called **stomata** (stoh MAH tuh) (singular, *stoma*), act as doorways for raw materials such as carbon dioxide, water vapor, and waste gases to enter and exit the leaf. Stomata also are found on the stems of many plants. More than 90 percent of the water plants take in through their roots is lost through the stomata. In one day, a growing tomato plant can lose up to 1 L of water.

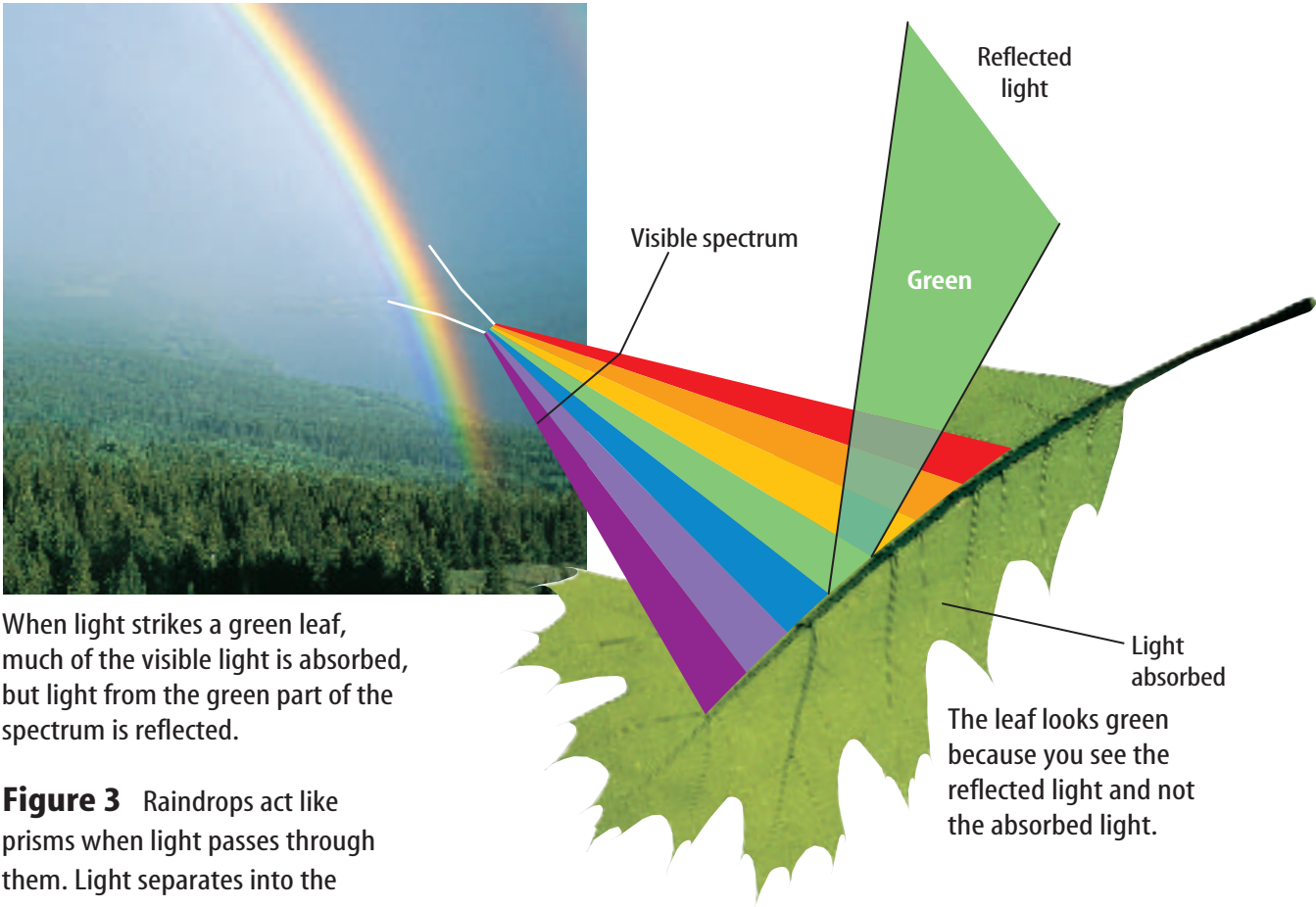
Two cells called guard cells surround each stoma and control its size. As water moves into the guard cells, they swell and bend apart, opening a stoma. When guard cells lose water, they deflate and close the stoma. **Figure 2** shows closed and open stomata.

Stomata usually are open during the day, when most plants need to take in raw materials to make food. They usually are closed at night when food making slows down. Stomata also close when a plant is losing too much water. This adaptation conserves water, because less water vapor escapes from the leaf.

Inside the leaf are two layers of cells, the spongy layer and the palisade layer. Carbon dioxide and water vapor, which are needed in the food-making process, fill the spaces of the spongy layer. Most of the plant's food is made in the palisade layer.



Nutritionist Vitamins are substances needed for good health. Nutritionists promote healthy eating habits. Research to learn about other roles that nutritionists fulfill. Create a pamphlet to promote the career of nutritionist.



When light strikes a green leaf, much of the visible light is absorbed, but light from the green part of the spectrum is reflected.

Figure 3 Raindrops act like prisms when light passes through them. Light separates into the colors of the visible spectrum. You see a rainbow when this happens.

Chloroplasts and Plant Pigments If you look closely at the leaf in **Figure 2**, you'll see that some of the cells contain small, green structures called chloroplasts. Most leaves look green because some of their cells contain so many chloroplasts. Chloroplasts are green because they contain a green pigment called **chlorophyll** (KLOR uh fihl).

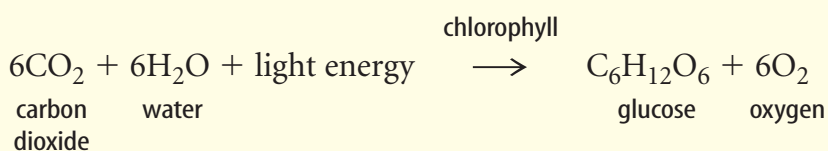
Reading Check *Why are chloroplasts green?*

As shown in **Figure 3**, light from the Sun contains all colors of the visible spectrum. A pigment is a substance that reflects a particular part of the visible spectrum and absorbs the rest. When you see a green leaf, you are seeing green light energy reflected from chlorophyll. Most of the other colors of the spectrum, especially red and blue, are absorbed by chlorophyll. In the spring and summer, most leaves have so much chlorophyll that it hides all other pigments. In fall, the chlorophyll in some leaves breaks down and the leaves change color as other pigments become visible. Pigments, especially chlorophyll, are important to plants because the light energy that they absorb is used to make food. For plants, this food-making process—photosynthesis—happens in the chloroplasts.

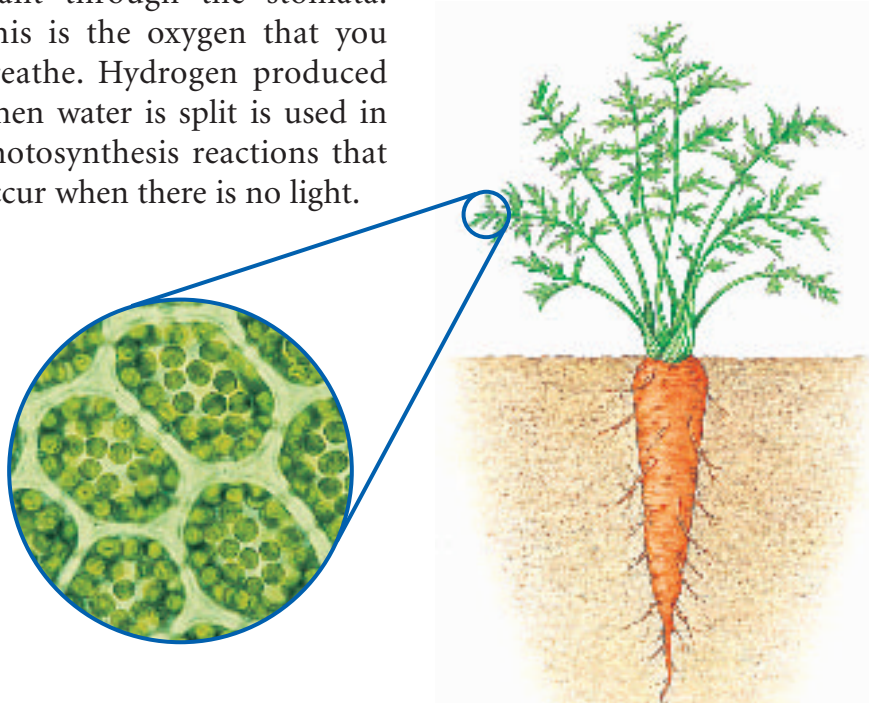
The Food-Making Process

Photosynthesis (foh toh SIHN thuh suhs) is the process during which a plant's chlorophyll traps light energy and sugars are produced. In plants, photosynthesis occurs only in cells with chloroplasts. For example, photosynthesis occurs only in a carrot plant's lacy green leaves, shown in **Figure 4**. Because a carrot's root cells lack chlorophyll and normally do not receive light, they can't perform photosynthesis. But excess sugar produced in the leaves is stored in the familiar orange root that you and many animals eat.

Besides light, plants also need the raw materials carbon dioxide and water for photosynthesis. The overall chemical equation for photosynthesis is shown below. What happens to each of the raw materials in the process?



Light-Dependent Reactions Some of the chemical reactions that take place during photosynthesis require light, but others do not. Those that need light can be called the light-dependent reactions of photosynthesis. During light-dependent reactions, chlorophyll and other pigments trap light energy that eventually will be stored in sugar molecules. Light energy causes water molecules, which were taken up by the roots, to split into oxygen and hydrogen. The oxygen leaves the plant through the stomata. This is the oxygen that you breathe. Hydrogen produced when water is split is used in photosynthesis reactions that occur when there is no light.



Mini LAB

Inferring What Plants Need to Produce Chlorophyll

Procedure

1. Cut two pieces of **black construction paper** large enough so that each one completely covers one leaf on a plant.
2. Cut a square out of the center of each piece of paper.
3. Sandwich the leaf between the two paper pieces and **tape** the pieces together along their edges.
4. Place the plant in a sunny area. Wash your hands.
5. After seven days, carefully remove the paper and observe the leaf.

Analysis

In your **Science Journal**, describe how the color of the areas covered by paper compare to the areas not covered. Infer why this happened.



Figure 4 Because they contain chloroplasts, cells in the leaf of the carrot plant are the sites for photosynthesis.

Topic: Plant Sugars

Visit bookb.msscience.com for Web links to information about sugars and related molecules produced by plants.

Activity List three sugar-containing molecules that plants produce.

Light-Independent Reactions Reactions that don't need light are called the light-independent reactions of photosynthesis. Carbon dioxide, the raw material from the air, is used in these reactions. The light energy trapped during the light-dependent reactions is used to combine carbon dioxide and hydrogen to make sugars. One important sugar that is made is glucose. The chemical bonds that hold glucose and other sugars together are stored energy. **Figure 5** compares what happens during each stage of photosynthesis.

What happens to the oxygen and glucose that were made during photosynthesis? Most of the oxygen from photosynthesis is a waste product and is released through stomata. Glucose is the main form of food for plant cells. A plant usually produces more glucose than it can use. Excess glucose is stored in plants as other sugars and starches. When you eat carrots, as well as beets, potatoes, or onions, you are eating the stored product of photosynthesis.

Glucose also is the basis of a plant's structure. You don't grow larger by breathing in and using carbon dioxide. However, that's exactly what plants do as they take in carbon dioxide gas and convert it into glucose. Cellulose, an important part of plant cell walls, is made from glucose. Leaves, stems, and roots are made of cellulose and other substances produced using glucose. The products of photosynthesis are used for plant growth.

Figure 5 Photosynthesis includes two sets of reactions, the light-dependent reactions and the light-independent reactions.

Describe what happens to the glucose produced during photosynthesis.

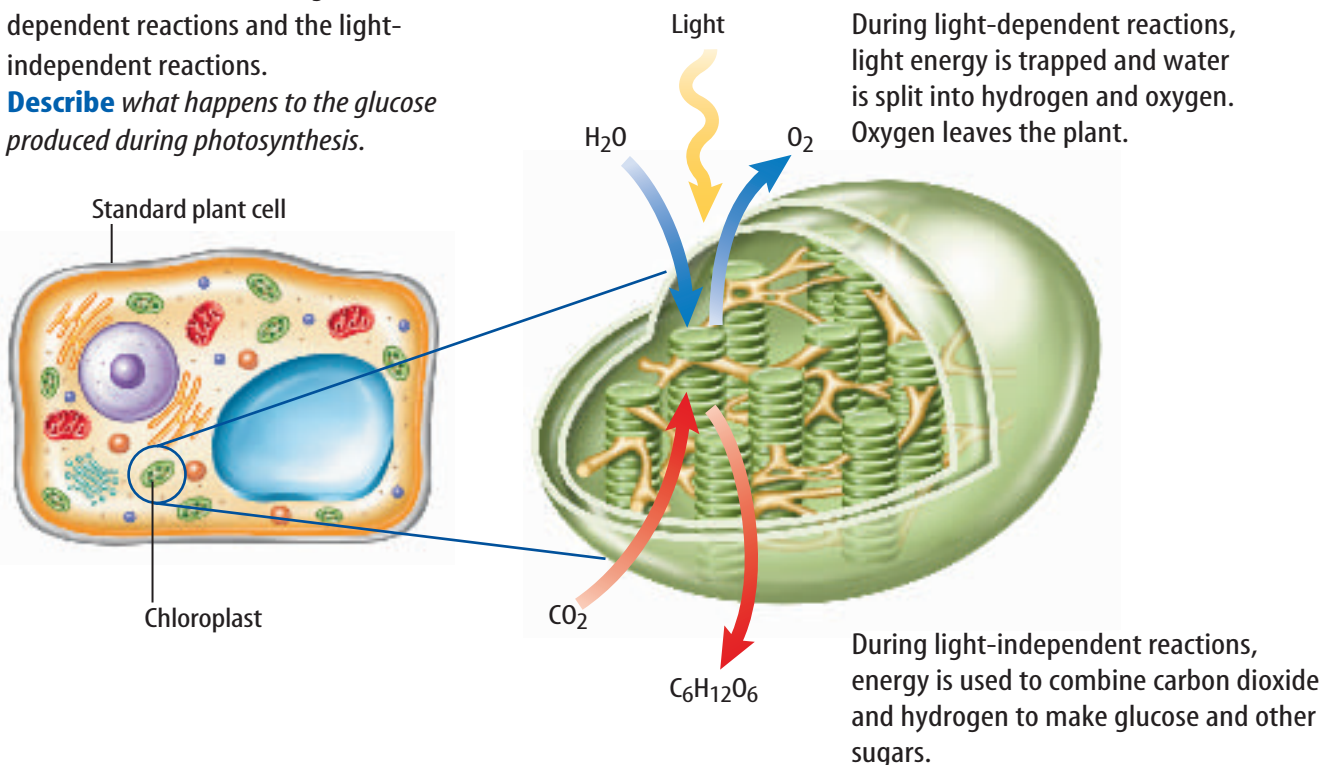




Figure 6 Tropical rain forests contain large numbers of photosynthetic plants.

Infer why tropical forests are considered an important source of oxygen.

Importance of Photosynthesis Why is photosynthesis important to living things? First, photosynthesis produces food. Organisms that carry on photosynthesis provide food directly or indirectly for nearly all the other organisms on Earth. Second, photosynthetic organisms, like the plants in **Figure 6**, use carbon dioxide and release oxygen. This removes carbon dioxide from the atmosphere and adds oxygen to it. Most organisms, including humans, need oxygen to stay alive. As much as 90 percent of the oxygen entering the atmosphere today is a result of photosynthesis.

The Breakdown of Food

Look at the photograph in **Figure 7**. Do the fox and the plants in the photograph have anything in common? They don't look alike, but the fox and the plants are made of cells that break down food and release energy in a process called respiration. How does this happen?

Respiration is a series of chemical reactions that breaks down food molecules and releases energy. Respiration occurs in cells of most organisms. The breakdown of food might or might not require oxygen. Respiration that uses oxygen to break down food chemically is called aerobic respiration. In plants and many organisms that have one or more cells, a nucleus, and other organelles, aerobic respiration occurs in the mitochondria (singular, *mitochondrion*). The overall chemical equation for aerobic respiration is shown below.

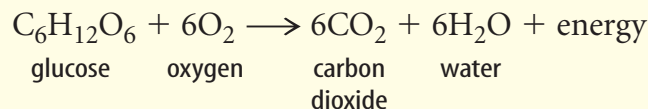
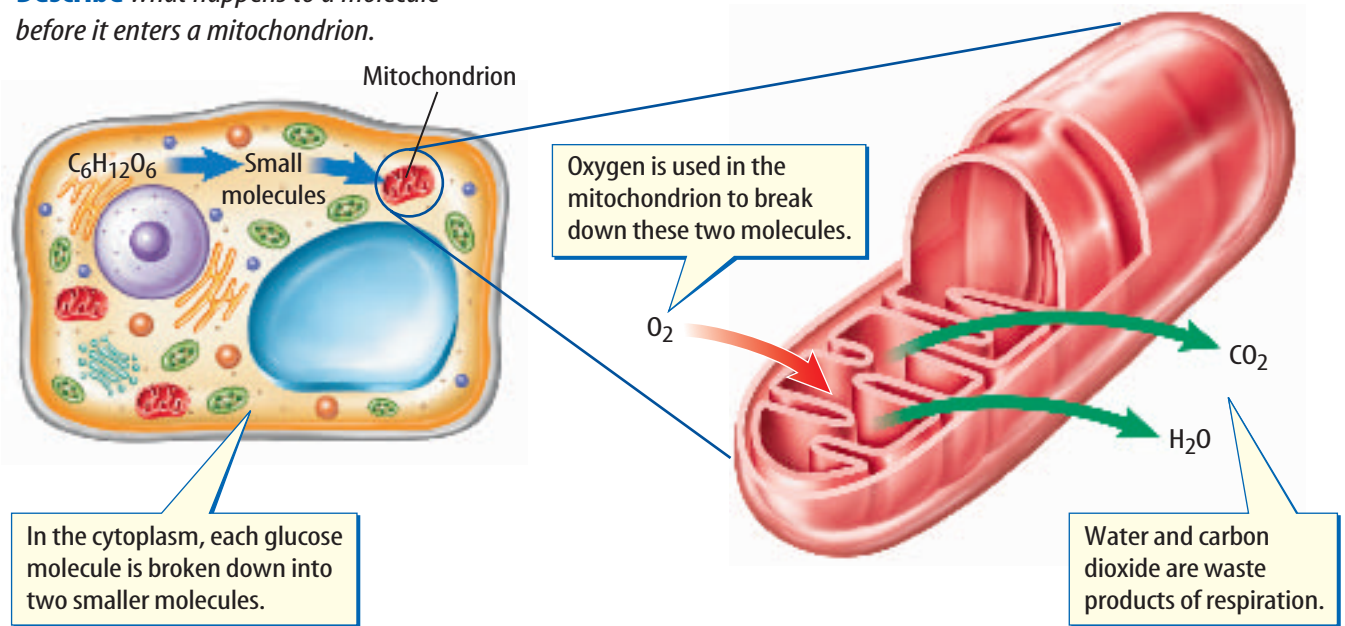


Figure 7 You know that animals such as this red fox carry on respiration, but so do all the plants that surround the fox.



Figure 8 Aerobic respiration takes place in the mitochondria of plant cells. **Describe** what happens to a molecule before it enters a mitochondrion.



Aerobic Respiration Before aerobic respiration begins, glucose molecules are broken down into two smaller molecules. This happens in the cytoplasm. The smaller molecules then enter a mitochondrion, where aerobic respiration takes place. Oxygen is used in the chemical reactions that break down the small molecules into water and carbon dioxide. The reactions also release energy. Every cell in the organism needs this energy. **Figure 8** shows aerobic respiration in a plant cell.

Figure 9 Plants use the energy released during respiration to carry out many functions.



Importance of Respiration Although food contains energy, it is not in a form that can be used by cells. Respiration changes food energy into a form all cells can use. This energy drives the life processes of almost all organisms on Earth.

Reading Check *What organisms use respiration?*

Plants use energy produced by respiration to transport sugars and to open and close stomata. Some of the energy is used to produce substances needed for photosynthesis, such as chlorophyll. When seeds sprout, they use energy from the respiration of stored food in the seed. **Figure 9** shows some uses of energy in plants.

The waste product carbon dioxide is also important. Aerobic respiration returns carbon dioxide to the atmosphere, where it can be used again by plants and some other organisms for photosynthesis.

Table 1 Comparing Photosynthesis and Aerobic Respiration

	Energy	Raw Materials	End Products	Where
Photosynthesis	stored	water and carbon dioxide	glucose and oxygen	cells with chlorophyll
Aerobic respiration	released	glucose and oxygen	water and carbon dioxide	cells with mitochondria

Comparison of Photosynthesis and Respiration

Look back in the section to find the equations for photosynthesis and aerobic respiration. You can see that aerobic respiration is almost the reverse of photosynthesis. Photosynthesis combines carbon dioxide and water by using light energy. The end products are glucose (food) and oxygen. During photosynthesis, energy is stored in food. Photosynthesis occurs only in cells that contain chlorophyll, such as those in the leaves of plants. Aerobic respiration combines oxygen and food to release the energy in the chemical bonds of the food. The end products of aerobic respiration are energy, carbon dioxide, and water. All plant cells contain mitochondria. Any cell with mitochondria can use the process of aerobic respiration. **Table 1** compares photosynthesis and aerobic respiration.

section 1 review

Summary

Taking in Raw Materials

- Leaves take in carbon dioxide that is used in photosynthesis.
- Oxygen and carbon dioxide are waste products of photosynthesis and respiration.

The Food-Making Process

- Photosynthesis takes place in chloroplasts.
- Photosynthesis is a series of chemical reactions that transforms energy from light into energy stored in the chemical bonds of sugar molecules.

The Breakdown of Food

- Aerobic respiration uses oxygen to release energy from food.
- Aerobic respiration takes place in mitochondria.

Self Check

1. **Describe** how gases enter and exit a leaf.
2. **Explain** why photosynthesis and respiration are important.
3. **Identify** what must happen to glucose molecules before respiration begins.
4. **Compare and contrast** the number of organisms that respire and the number that photosynthesize.
5. **Think Critically** Humidity is water vapor in the air. Infer how plants contribute to humidity.

Applying Math

6. **Solve One-Step Equations** How many CO_2 molecules result from the respiration of a glucose molecule ($\text{C}_6\text{H}_{12}\text{O}_6$)? Refer to the equation in this section.

LAB

Stomata in Leaves

Stomata open and close, which allows gases into and out of a leaf. These openings are usually invisible without the use of a microscope. Do this lab to see some stomata.

Real-World Question

Where are stomata in lettuce leaves?

Goals

- **Describe** guard cells and stomata.
- **Infer** the conditions that make stomata open and close.

Materials

lettuce in dish of water microscope slide
coverslip salt solution
microscope forceps

Safety Precautions



WARNING: *Never eat or taste any materials used in the laboratory.*

Procedure

1. Copy the Stomata Data table into your Science Journal.
2. From a head of lettuce, tear off a piece of an outer, crisp, green leaf.
3. Bend the piece of leaf in half and carefully use a pair of forceps to peel off some of the epidermis, the transparent tissue that covers a leaf. Prepare a wet mount of this tissue.
4. Examine your prepared slide under low and high power on the microscope.
5. Count the total number of stomata in your field of view and then count the number of

Stomata Data (Sample data only)

	Wet Mount	Salt-Solution Mount
Total Number of Stomata		
Number of Open Stomata	Do not write in this book.	
Percent Open		

open stomata. Enter these numbers in the data table.

6. Make a second slide of the lettuce leaf epidermis. This time place a few drops of salt solution on the leaf instead of water.
7. Repeat steps 4 and 5.
8. **Calculate** the percent of open stomata using the following equation:

$$\frac{\text{number of open stomata}}{\text{total number of stomata}} \times 100 = \text{percent open}$$

Conclude and Apply

1. **Determine** which slide preparation had a greater percentage of open stomata.
2. **Infer** why fewer stomata were open in the salt-solution mount.
3. What can you infer about the function of stomata in a leaf?

Communicating Your Data

Collect data from your classmates and compare it to your data. Discuss any differences you find and why they occurred. **For more help, refer to the Science Skill Handbook.**

Plant Responses

What are plant responses?

It's dark. You're alone in a room watching a horror film on television. Suddenly, the telephone near you rings. You jump, and your heart begins to beat faster. You've just responded to a stimulus. A stimulus is anything in the environment that causes a response in an organism. The response often involves movement either toward the stimulus or away from the stimulus. A stimulus may come from outside (external) or inside (internal) the organism. The ringing telephone is an example of an external stimulus. It caused you to jump, which is a response. Your beating heart is a response to an internal stimulus. Internal stimuli are usually chemicals produced by organisms. Many of these chemicals are hormones. Hormones are substances made in one part of an organism for use somewhere else in the organism.

All living organisms, including plants, respond to stimuli. Many different chemicals are known to act as hormones in plants. These internal stimuli have a variety of effects on plant growth and function. Plants respond to external stimuli such as touch, light, and gravity. Some responses, such as the response of the Venus's-flytrap plant in **Figure 10**, are rapid. Other plant responses are slower because they involve changes in growth.



as you read

What You'll Learn

- **Identify** the relationship between a stimulus and a tropism in plants.
- **Compare and contrast** long-day and short-day plants.
- **Explain** how plant hormones and responses are related.

Why It's Important

You will be able to grow healthier plants if you understand how they respond to certain stimuli.

Review Vocabulary

behavior: the way in which an organism interacts with other organisms and its environment

New Vocabulary

- tropism
- auxin
- photoperiodism
- long-day plant
- short-day plant
- day-neutral plant

Figure 10 A Venus's-flytrap has three small trigger hairs on the surface of its toothed leaves. When two hairs are touched at the same time, the plant responds by closing its trap in less than 1 second.

Figure 11 Tropisms are responses to external stimuli.
Identify the part of a plant that shows negative gravitropism.



The pea plant's tendrils respond to touch by coiling around things.



This plant is growing toward the light, an example of positive phototropism.



This plant was turned on its side. With the roots visible, you can see that they are showing positive gravitropism.

Tropisms

Some responses of a plant to an external stimuli are called tropisms. A **tropism** (TROH pih zum) can be seen as movement caused by a change in growth and can be positive or negative. For example, plants might grow toward a stimulus—a positive tropism—or away from a stimulus—a negative tropism.

Touch One stimulus that can result in a change in a plant's growth is touch. When the pea plant, as shown in **Figure 11**, touches a solid object, it responds by growing faster on one side of its stem than on the other side. As a result the stem bends and twists around any object it touches.

Light Did you ever see a plant leaning toward a window? Light is an important stimulus to plants. When a plant responds to light, the cells on the side of the plant opposite the light get longer than the cells facing the light. Because of this uneven growth, the plant bends toward the light. This response causes the leaves to turn in such a way that they can absorb more light. When a plant grows toward light it is called a positive response to light, or positive phototropism, shown in **Figure 11**.

Gravity Plants respond to gravity. The downward growth of plant roots, as shown in **Figure 11**, is a positive response to gravity. A stem growing upward is a negative response to gravity. Plants also may respond to electricity, temperature, and darkness.



Gravity and Plants

Gravity is a stimulus that affects how plants grow. Can plants grow without gravity? In space the force of gravity is low. Write a paragraph in your Science Journal that describes your idea for an experiment aboard a space shuttle to test how low gravity affects plant growth.

Plant Hormones

Hormones control the changes in growth that result from tropisms and affect other plant growth. Plants often need only millionths of a gram of a hormone to stimulate a response.

Ethylene Many plants produce the hormone ethylene (EH thuh leen) gas and release it into the air around them. Ethylene is produced in cells of ripening fruit, which stimulates the ripening process. Commercially, fruits such as oranges and bananas are picked when they are unripe and the green fruits are exposed to ethylene during shipping so they will ripen. Another plant response to ethylene causes a layer of cells to form between a leaf and the stem. The cell layer causes the leaf to fall from the stem.

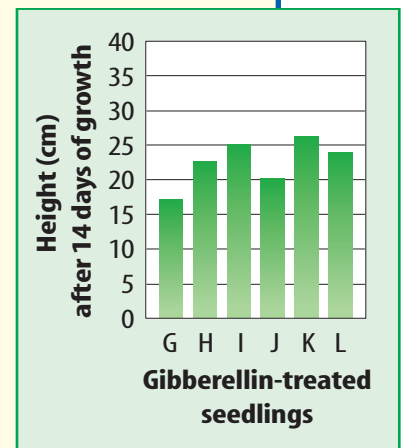
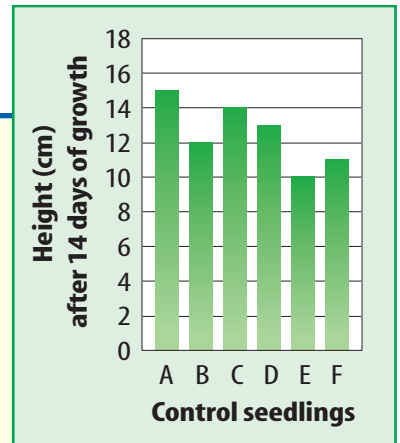
Applying Math Calculate Averages

GROWTH HORMONES Gibberellins are plant hormones that increase growth rate. The graphs on the right show data from an experiment to determine how gibberellins affect the growth of bean seedlings. What is the average height of control bean seedlings after 14 days?

Solution

- This is what you know:*
 - height of control seedlings after 14 days
 - number of control seedlings
- This is what you need to find out:*

What is the average height of control seedlings after 14 days?
- This is the procedure you need to use:*
 - Find the total of the seedling heights. $15 + 12 + 14 + 13 + 10 + 11 = 75$ cm
 - Divide the height total by the number of control seedlings to find the average height. $75 \text{ cm} / 6 = 12.5$ cm
- Check your answer:* Multiply 12.5 cm by 6 and you should get 75 cm.



Practice Problems

- Calculate the average height of seedlings treated with gibberellin.
- In an experiment, the heights of gibberellin-treated rose stems were 20, 26, 23, 24, 23, 25, and 26 cm. The average height of the controls was 23 cm. Did gibberellin have an effect?



For more practice, visit
[bookb.msscience.com/
math_practice](http://bookb.msscience.com/math_practice)

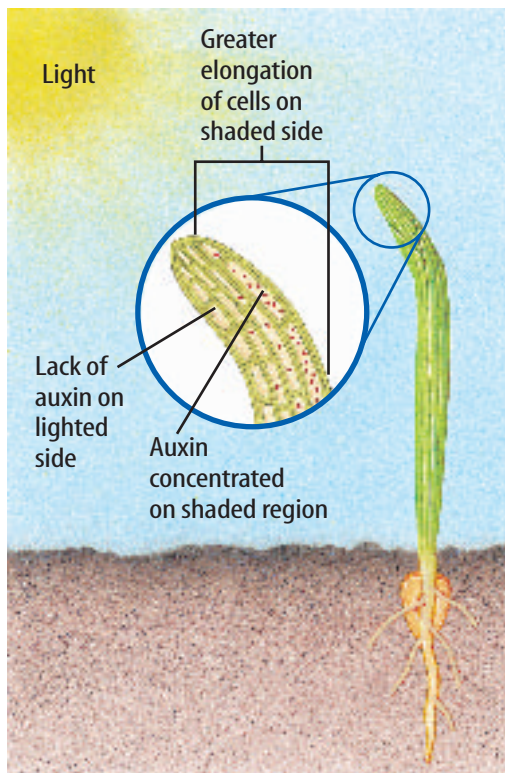


Figure 12 The concentration of auxin on the shaded side of a plant causes cells on that side to lengthen.

Auxin Scientists identified the plant hormone, **auxin** (AWK sun) more than 100 years ago. Auxin is a type of plant hormone that causes plant stems and leaves to exhibit positive response to light. When light shines on a plant from one side, the auxin moves to the shaded side of the stem where it causes a change in growth, as shown in **Figure 12**. Auxins also control the production of other plant hormones, including ethylene.

Reading Check

How are auxins and positive response to light related?

Development of many parts of the plant, including flowers, roots, and fruit, is stimulated by auxins. Because auxins are so important in plant development, synthetic auxins have been developed for use in agriculture. Some of these synthetic auxins are used in orchards so that all plants produce flowers and fruit at the same time. Other synthetic auxins damage plants when they are applied in high doses and are used as weed killers.

Mini LAB

Observing Ripening

Procedure

1. Place a **green banana** in a **paper bag**. Roll the top shut.
2. Place another green banana on a counter or table.
3. After two days check the bananas to see how they have ripened. **WARNING:** *Do not eat the materials used in the lab.*

Analysis

Which banana ripened more quickly? Why?



Gibberellins and Cytokinins Two other groups of plant hormones that also cause changes in plant growth are gibberellins and cytokinins. Gibberellins (jih buh REH lunz) are chemical substances that were isolated first from a fungus. The fungus caused a disease in rice plants called “foolish seedling” disease. The fungus infects the stems of plants and causes them to grow too tall. Gibberellins can be mixed with water and sprayed on plants and seeds to stimulate plant stems to grow and seeds to germinate.

Like gibberellins, cytokinins (si tuh KI nunz) also cause rapid growth. Cytokinins promote growth by causing faster cell divisions. Like ethylene, the effect of cytokinins on the plant also is controlled by auxin. Interestingly, cytokinins can be sprayed on stored vegetables to keep them fresh longer.

Abscisic Acid Because hormones that cause growth in plants were known to exist, biologists suspected that substances that have the reverse effect also must exist. Abscisic (ab SIH zihk) acid is one such substance. Many plants grow in areas that have cold winters. Normally, if seeds germinate or buds develop on plants during the winter, they will die. Abscisic acid is the substance that keeps seeds from sprouting and buds from developing during the winter. This plant hormone also causes stomata to close and helps plants respond to water loss on hot summer days. **Figure 13** summarizes how plant hormones affect plants and how hormones are used.

Figure 13

Chemical compounds called plant hormones help determine how a plant grows. There are five main types of hormones. They coordinate a plant's growth and development, as well as its responses to environmental stimuli, such as light, gravity, and changing seasons. Most changes in plant growth are a result of plant hormones working together, but exactly how hormones cause these changes is not completely understood.



▲ **ETHYLENE** By controlling the exposure of these tomatoes to ethylene, a hormone that stimulates fruit ripening, farmers are able to harvest unripe fruit and make it ripen just before it arrives at the supermarket.

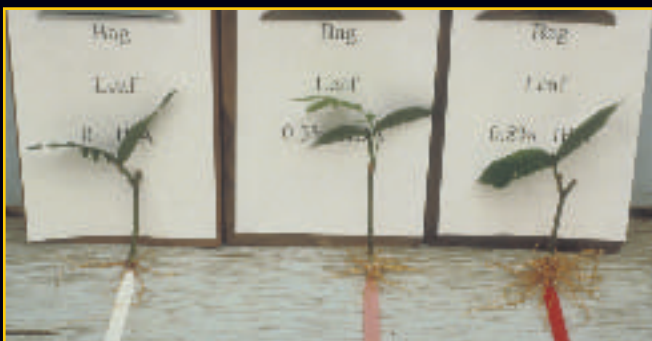


◀ **GIBBERELLINS** The larger mustard plant in the photo at left was sprayed with gibberellins, plant hormones that stimulate stem elongation and fruit development.

▼ **AUXINS** Powerful growth hormones called auxins regulate responses to light and gravity, stem elongation, and root growth. The root growth on the plant cuttings, center and right, is the result of auxin treatment.



◀ **CYTOKININS** Lateral buds do not usually develop into branches. However, if a plant's main stem is cut, as in this bean plant, naturally occurring cytokinins will stimulate the growth of lateral branches, causing the plant to grow "bushy."



▶ **ABA (ABSCISIC ACID)** In plants such as the American basswood, right, abscisic acid causes buds to remain dormant for the winter. When spring arrives, ABA stops working and the buds sprout.



Topic: Plant Pigments

Visit bookb.msscience.com for Web links to information about how plant pigments are involved in photoperiodism.

Activity Explain how day length affects a hormone that promotes flowering.

Photoperiods



Sunflowers bloom in the summer, and cherry trees flower in the spring. Some plant species produce flowers at specific times during the year. A plant's response to the number of hours of daylight and darkness it receives daily is **photoperiodism** (foh toh PIHR ee uh dih zum).

Earth revolves around the Sun once each year. As Earth moves in its orbit, it also rotates. One rotation takes about 24 h. Because Earth is tilted about 23.5° from a line perpendicular to its orbit, the hours of daylight and darkness vary with the seasons. As you probably have noticed, the Sun sets later in summer than in winter. These changes in lengths of daylight and darkness affect plant growth.

Darkness and Flowers Many plants require a specific length of darkness to begin the flowering process. Generally, plants that require less than 10 h to 12 h of darkness to flower are called **long-day plants**. You may be familiar with some long-day plants such as spinach, lettuce, and beets. Plants that need 12 or more hours of darkness to flower are called **short-day plants**. Some short-day plants are poinsettias, strawberries, and ragweed. **Figure 14** shows what happens when a short-day plant receives less darkness than it needs to flower.

 **Reading Check** *What is needed to begin the flowering process?*

Day-Neutral Plants Plants like dandelions and roses are **day-neutral plants**. They have no specific photoperiod, and the flowering process can begin within a range of hours of darkness.

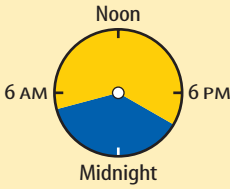



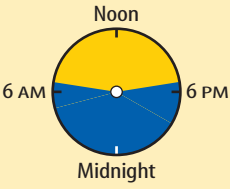



In nature, photoperiodism affects where flowering plants can grow and produce flowers and fruit. Even if a particular environment has the proper temperature and other growing conditions

for a plant, it will not flower and produce fruit without the correct photoperiod. **Table 2** shows how day length affects flowering in all three types of plants.

Sometimes the photoperiod of a plant has a narrow range. For example, some soybeans will flower with 9.5 h of darkness but will not flower with 10 h of darkness. Farmers must choose the variety of soybeans with a photoperiod that matches the hours of darkness in the section of the country where they plant their crop.

Figure 14 When short-day plants receive less darkness than required to produce flowers, they produce larger leaves instead.



Table 2 Photoperiodism			
	Long-Day Plants	Short-Day Plants	Day-Neutral Plants
Early Summer 			
Late Fall 			
	An iris is a long-day plant that is stimulated by short nights to flower in the early summer.	Goldenrod is a short-day plant that is stimulated by long nights to flower in the fall.	Roses are day-neutral plants and have no specific photoperiod.

Today, greenhouse growers are able to provide any length of artificial daylight or darkness. This means that you can buy short-day flowering plants during the summer and long-day flowering plants during the winter.

section 2 review

Summary

What are plant responses?

- Plants respond to both internal and external stimuli.

Tropisms

- Tropisms are plant responses to external stimuli, including touch, light, and gravity.

Plant Hormones

- Hormones control changes in plant growth, including changes that result from tropisms.

Photoperiods

- Long-day plants flower in late spring or summer.
- Short-day plants flower in late fall or winter.

Self Check

- List one example of an internal stimulus and one example of an external stimulus in plants.
- Compare and contrast photoperiodism and phototropism.
- Identify the term that describes the photoperiod of red raspberries that produce fruit in late spring and in the fall.
- Distinguish between abscisic acid and gibberellins.
- Think Critically Describe the relationship between hormones and tropisms.

Applying Skills

- Compare and contrast the responses of roots and stems to gravity.

Tropism in Plants

Goals

- **Describe** how roots and stems respond to gravity.
- **Observe** how changing the stimulus changes the growth of plants.

Materials

paper towel
 30-cm × 30-cm sheet of aluminum foil
 water
 mustard seeds
 marking pen
 1-L clear-glass or plastic jar

Safety Precautions



WARNING: *Some kinds of seeds are poisonous. Do not put any seed in your mouth.*

Real-World Question

Grapevines can climb on trees, fences, or other nearby structures. This growth is a response to the stimulus of touch. Tropisms are specific plant responses to stimuli outside of the plant. One part of a plant can respond positively while another part of the same plant can respond negatively to the same stimulus. Gravitropism is a response to gravity. Why might it be important for some plant parts to have a positive response to gravity while other plant parts have a negative response? Do stems and roots respond to gravity in the same way? You can design an experiment to test how some plant parts respond to the stimulus of gravity.



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Using Scientific Methods

Procedure

1. Copy the data table on the right in your Science Journal.
2. Moisten the paper towel with water so that it's damp but not dripping. Fold it in half twice.
3. Place the folded paper towel in the center of the foil and sprinkle mustard seeds in a line across the center of the towel.
4. Fold the foil around the towel and seal each end by folding the foil over. Make sure the paper towel is completely covered by the foil.
5. Use a marking pen to draw an arrow on the foil, and place the foil package in the jar with the arrow pointing upward.
6. After five days, carefully open the package and record your observations in the data table. (Note: *If no stems or roots are growing yet, reseal the package and place it back in the jar, making sure that the arrow points upward. Reopen the package in two days.*)
7. Reseal the foil package, being careful not to disturb the seedlings. Place it in the jar so that the arrow points downward instead of upward.
8. After five more days, reopen the package and observe any new growth of the seedlings' roots and stems. Record your observations in your data table.

Response to Gravity		
Position of Arrow on Foil Package	Observations of Seedling Roots	Observations of Seedling Stems
Arrow up		
Arrow down	Do not write in this book.	



Analyze Your Data

1. **Classify** the responses you observed as positive or negative tropisms.
2. **Explain** why the plants' growth changed when you placed them upside down.

Conclude and Apply

1. **Infer** why it was important that no light reach the seedlings during your experiment.
2. **Describe** some other ways you could have changed the position of the foil package to test the seedlings' response.

Communicating Your Data

Compare drawings you make of the growth of the seedlings before and after you turned the package. **Compare** your drawings with those of other students in your class. For more help, refer to the **Science Skill Handbook**.



“Sunkissed: An Indian Legend”

as told by Alberto and Patricia De La Fuente

A long time ago, deep down in the very heart of the old Mexican forests, so far away from the sea that not even the largest birds ever had time to fly that far, there was a small, beautiful valley. A long chain of snow-covered mountains stood between the valley and the sea. . . . Each day the mountains were the first ones to tell everybody that Tonatiuh, the King of Light, was coming to the valley. . . .

“Good morning, Tonatiuh!” cried a little meadow. . . .

The wild flowers always started their fresh new day with a kiss of golden sunlight from Tonatiuh, but it was necessary to first wash their sleepy baby faces with the dew that Metztli, the Moon, sprinkled for them out of her bucket onto the nearby leaves during the night. . . .

. . . All night long, then, Metztli Moon would walk her night-field making sure that by sun-up all flowers had the magic dew that made them feel beautiful all day long.

However, much as flowers love to be beautiful as long as possible, they want to be happy too. So every morning Tonatiuh himself would give each one a single golden kiss of such power that it was possible to be happy all

day long after it. As you can see, then, a flower needs to feel beautiful in the first place, but if she does not feel beautiful, she will not be ready for her morning sun-kiss. If she cannot wash her little face with the magic dew, the whole day is lost.



Understanding Literature

Legends and Oral Traditions A legend is a traditional story often told orally and believed to be based on actual people and events. Legends are believed to be true even if they cannot be proved. “Sunkissed: An Indian Legend” is a legend about a little flower that is changed forever by the Sun. This legend also is an example of an oral tradition. Oral traditions are stories or skills that are handed down by word of mouth. What in this story indicates that it is a legend?

Respond to the Reading

1. What does this passage tell you about the relationship between the Sun and plants?
2. What does this passage tell you about the relationship between water and the growth of flowers?
3. **Linking Science and Writing** Create an idea for a fictional story that explains why the sky becomes so colorful during a sunset. Then retell your story to your classmates.



The passage from “Sunkissed: An Indian Legend” does not teach us the details about photosynthesis or respiration. However, it does show how sunshine and water are important to plant life. The difference between the legend and the information contained in your textbook is this—photosynthesis and respiration can be proved scientifically, and the legend, although fun to read, cannot.

Reviewing Main Ideas

Section 1

Photosynthesis and Respiration

1. Carbon dioxide and water vapor enter and leave a plant through openings in the epidermis called stomata. Guard cells cause a stoma to open and close.
2. Photosynthesis takes place in the chloroplasts of plant cells. Light energy is used to produce glucose and oxygen from carbon dioxide and water.
3. Photosynthesis provides the food for most organisms on Earth.
4. All organisms use respiration to release the energy stored in food molecules. Oxygen is used in the mitochondria to complete respiration in plant cells and many other types of cells. Energy is released and carbon dioxide and water are produced.
5. The energy released by respiration is used for the life processes of most living organisms, including plants.

6. Photosynthesis and respiration are almost the reverse of each other. The end products of photosynthesis are the raw materials needed for aerobic respiration. The end products of aerobic respiration are the raw materials needed for photosynthesis.

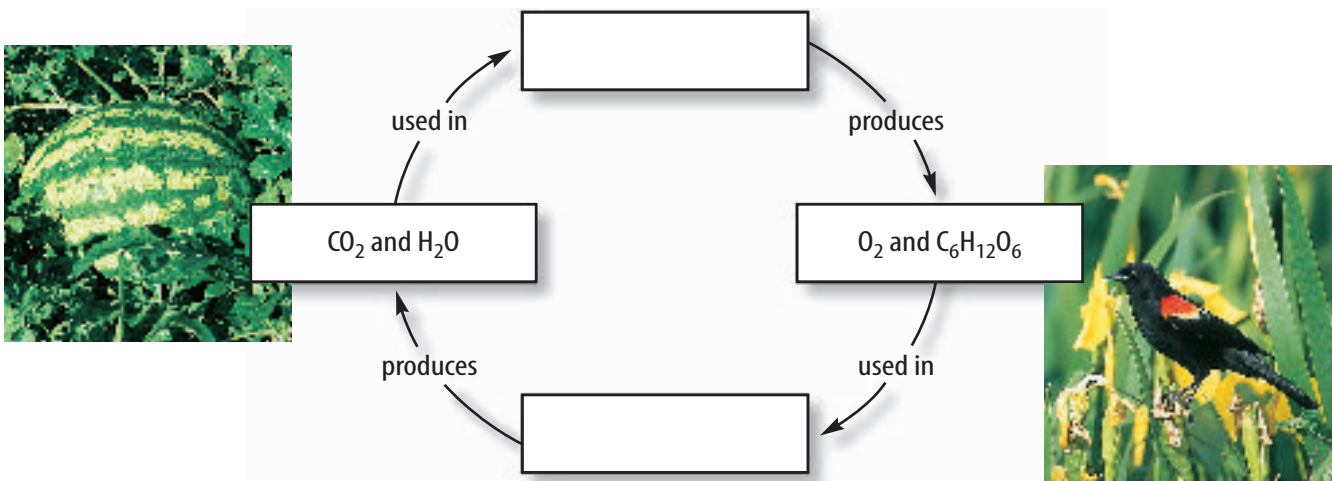
Section 2

Plant Responses

1. Plants respond positively and negatively to stimuli. The response may be a movement, a change in growth, or the beginning of some process such as flowering.
2. A stimulus from outside the plant is called a tropism. Outside stimuli include light, gravity, and touch.
3. The length of darkness each day can affect flowering times of plants.
4. Plant hormones cause responses in plants. Some hormones cause plants to exhibit tropisms. Other hormones cause changes in plant growth rates.

Visualizing Main Ideas

Copy and complete the following concept map on photosynthesis and respiration.



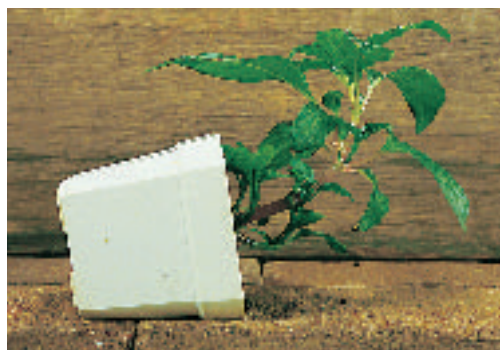
Using Vocabulary

auxin p. 136	photosynthesis p. 127
chlorophyll p. 126	respiration p. 129
day-neutral plant p. 138	short-day plant p. 138
long-day plant p. 138	stomata p. 125
photoperiodism p. 138	tropism p. 134

Fill in the blanks with the correct vocabulary word(s) from the list above.

- _____ is a hormone that causes plant stems and leaves to exhibit positive phototropism.
- _____ is a light-dependent process conducted by green plants but not by animals.
- _____ is required for photosynthesis.
- A poinsettia, often seen flowering during December holidays, is a(n) _____.
- In most living things, energy is released from food by _____.
- Spinach requires only ten hours of darkness to flower, which makes it a(n) _____.
- A(n) _____ can cause a plant to bend toward light.
- Plants usually take in carbon dioxide through _____.
- _____ controls a plant's response to day length.
- Plants that flower without regard to day length are _____.
- What is a function of stomata?
 - photosynthesis
 - to guard the interior cells
 - to allow sugar to escape
 - to permit the release of oxygen
- What plant process produces water, carbon dioxide, and energy?
 - cell division
 - photosynthesis
 - growth
 - respiration
- What are the products of photosynthesis?
 - glucose and oxygen
 - carbon dioxide and water
 - chlorophyll and glucose
 - carbon dioxide and oxygen
- What are plant substances that affect plant growth called?
 - tropisms
 - glucose
 - germination
 - hormones
- Leaves change colors because what substance breaks down?
 - hormone
 - carotenoid
 - chlorophyll
 - cytoplasm
- Which of these is a product of respiration?
 - CO₂
 - O₂
 - C₂H₄
 - H₂

Use the photo below to answer question 18.



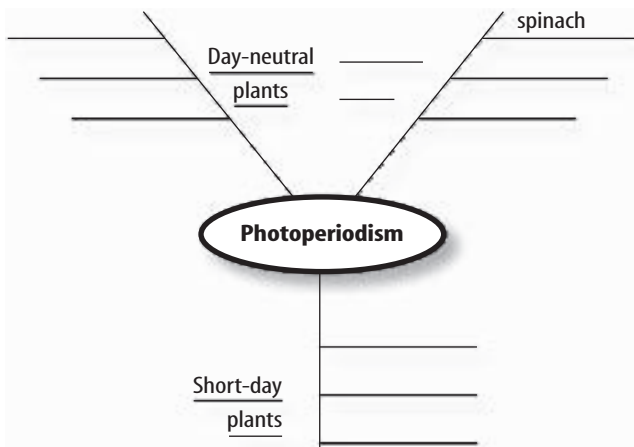
Checking Concepts

Choose the word or phrase that best answers the question.

- What raw material needed by plants enters through open stomata?
 - sugar
 - chlorophyll
 - carbon dioxide
 - cellulose
- What stimulus is this plant responding to?
 - light
 - gravity
 - touch
 - water

Thinking Critically

19. **Predict** You buy pears at the store that are not completely ripe. What could you do to help them ripen more rapidly?
20. **Name** each tropism and state whether it is positive or negative.
 - a. Stem grows up.
 - b. Roots grow down.
 - c. Plant grows toward light.
 - d. A vine grows around a pole.
21. **Infer** Scientists who study sedimentary rocks and fossils suggest that oxygen was not in Earth's atmosphere until plantlike, one-celled organisms appeared. Why?
22. **Explain** why apple trees bloom in the spring but not in the summer.
23. **Discuss** why day-neutral and long-day plants grow best in countries near the equator.
24. **Form a hypothesis** about when guard cells open and close in desert plants.
25. **Concept Map** Copy and complete the following concept map about photoperiodism using the following information: flower year-round—*corn, dandelion, tomato*; flower in the spring, fall, or winter—*chrysanthemum, rice, poinsettia*; flower in summer—*spinach, lettuce, petunia*.



26. **Compare and contrast** the action of auxin and the action of ethylene on a plant.

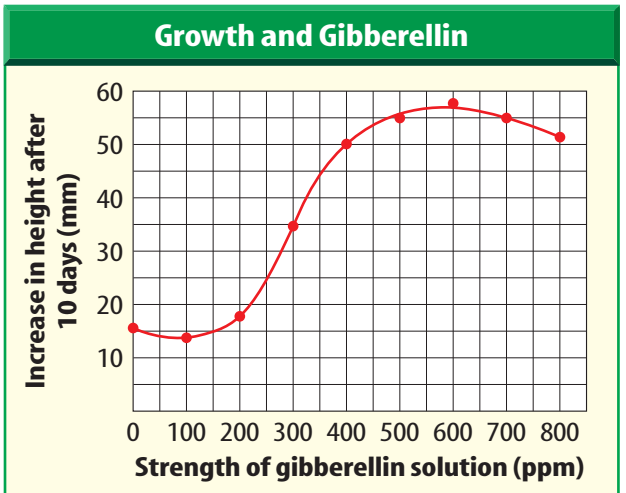
Performance Activities

27. **Coloring Book** Create a coloring book of day-neutral plants, long-day plants, and short-day plants. Use pictures from magazines and seed catalogs to get your ideas. Label the drawings with the plant's name and how it responds to darkness. Let a younger student color the flowers in your book.

Applying Math

28. **Stomata** A houseplant leaf has 1,573 stomata. During daylight hours, when the plant is well watered, about 90 percent of the stomata were open. During daylight hours when the soil was dry, about 25 percent of the stomata remained open. How many stomata were open (a) when the soil was wet and (b) when it was dry?

Use the graph below to answer question 29.



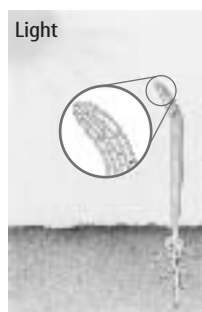
29. **Gibberellins** The graph above shows the results of applying different amounts of gibberellin to the roots of bean plants. What effect did a 100-ppm solution of gibberellin have on bean plant growth? Which gibberellin solution resulted in the tallest plants?

Part 1 Multiple Choice

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

- Which statement correctly describes the leaf epidermis?
 - This is an inner cell layer of the leaf.
 - This layer is nearly transparent.
 - Food is made in this layer.
 - Sunlight cannot penetrate this layer.
- What happens when a plant is losing too much water?
 - stomata close
 - guard cells swell
 - stomata open
 - respiration increases
- Which statement is TRUE?
 - Changes in length of daylight and darkness have no effect on plant growth.
 - Plants that need less than 10 to 12 hours of darkness to flower are called short-day plants.
 - Plants that need 12 or more hours of darkness to flower are called short-day plants.
 - Very few plants rely on a specific length of darkness to flower.

Use the illustration below to answer question 4.



- The plant above is showing a growth response that is controlled by
 - auxin.
 - gravity.
 - abscisic acid.
 - length of darkness.

Use the illustration below to answer questions 5 and 6.



- What type of response is displayed by this plant?
 - negative phototropism
 - positive gravitropism
 - positive phototropism
 - negative gravitropism
- What plant hormone is responsible for the response shown here?

A. abscisic acid	C. a gibberellin
B. auxin	D. a cytokinin
- In which plant cell structure does respiration take place?

A. nucleus	C. vacuole
B. mitochondrion	D. cell wall
- Which of these is NOT produced through aerobic respiration?

A. glucose	C. water
B. energy	D. carbon dioxide
- Which plant hormone prevents the development of buds during the winter?

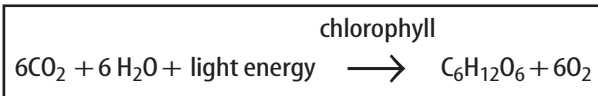
A. abscisic acid	C. gibberellin
B. auxin	D. cytokinin
- What chemical absorbs light energy which plants use in photosynthesis?

A. oxygen	C. chlorophyll
B. hydrogen	D. glucose

Part 2 Short Response/Grid In

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

Use the illustration below to answer questions 11 and 12.



11. Identify this process. How would this process change if the amount of available water was limited?
12. Based on this equation, what is the main food source for plant cells? How do animals use this food source?
13. Why is respiration necessary for plants? Describe some plant processes which require energy.
14. What advantage do growers gain by picking and shipping unripe fruit? What role does ethylene play in this commercial process?
15. Identify specific stimuli to which plants respond in the natural environment.
16. Many people who save poinsettia plants from Christmas cannot get them to flower the following Christmas. Why?
17. What effect have commercial greenhouses had on the availability of long-day and short-day plants year-round?
18. Where are stomata found on the leaf? What function do these structures perform?
19. Describe the relationship between chlorophyll and the color of leaves in spring and summer.


Part 3 Open Ended

Record your answers on a sheet of paper.

20. Cellulose is an important component of plants. Describe its relationship to glucose. Identify cell and plant structures which contain significant amounts of cellulose.
21. Organisms which make their own food generate most of the oxygen in Earth's atmosphere. Trace the path of this element from a component of water in the soil to a gas in the air.

Use the illustration below to answer questions 22 and 23.

22. Explain how the tropism shown by this plant could help a gardener incorporate a larger number of plants into a small vegetable garden plot.


23. What advantages might thigmotropism, the response shown in this picture, provide for some plants?
24. The destruction of large areas of rain forest concerns scientists on many levels. Describe the relationship between environmental conditions for plant growth in rainforest regions, their relative rate of photosynthesis, and the amount of oxygen this process adds to the atmosphere.

Test-Taking Tip

Pace Yourself If you are taking a timed test, keep track of time during the test. If you find that you're spending too much time on a multiple-choice question, mark your best guess and move on.