SECTION 1

Photosynthesis

Plants don't have lungs. But like you, plants need air. Air contains oxygen, carbon dioxide, and other gases. Your body needs oxygen, and plants need oxygen. But what other gas is important to plants?

If you guessed *carbon dioxide*, you are correct. Plants use carbon dioxide for photosynthesis (FOHT oh SIN thuh sis). **Photosynthesis** is the process by which plants make their own food. Plants capture energy from sunlight during photosynthesis. This energy is used to make the sugar glucose ($C_6H_{12}O_6$) from carbon dioxide (CO_2) and water (H_2O).

What You Will Learn

- Describe photosynthesis.
- Compare photosynthesis and cellular respiration.
- Describe how gas is exchanged in the leaves of plants.
- Describe two ways in which photosynthesis is important.

Vocabulary

photosynthesis
chlorophyll
cellular respiration
stoma
transpiration

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Capturing Light Energy

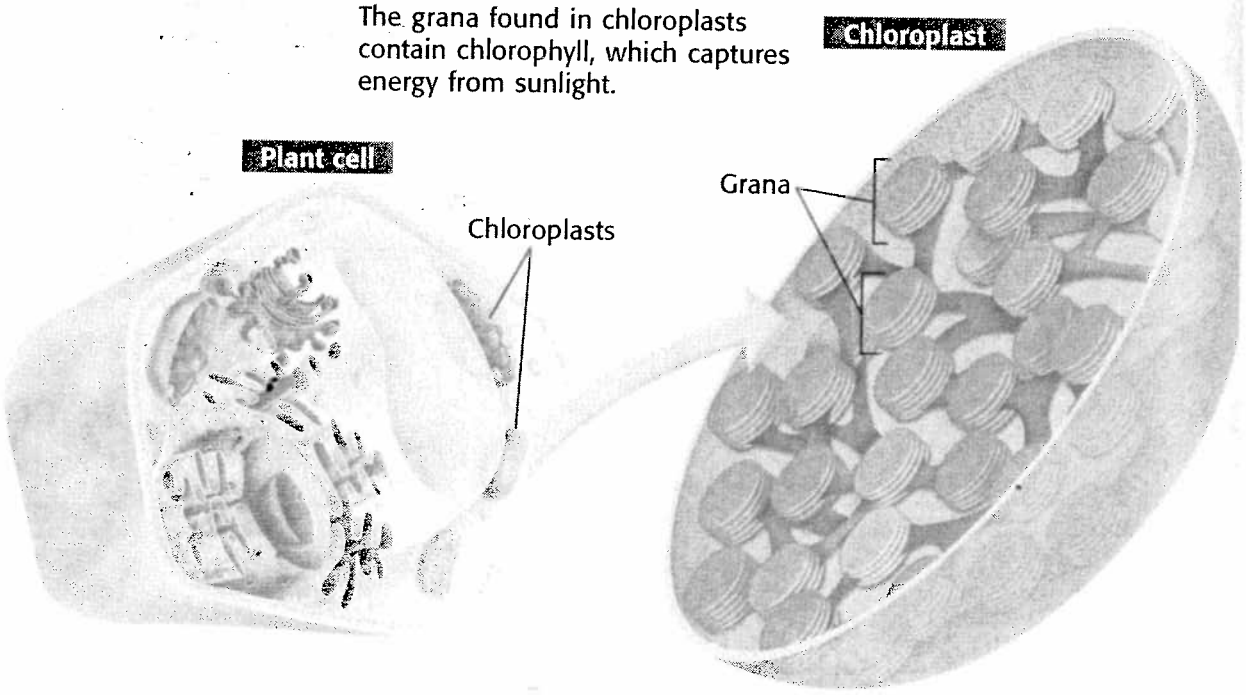
Plant cells have organelles called *chloroplasts* (KLAWR uh PLASTS), shown in **Figure 1.** Chloroplasts are surrounded by two membranes. Inside the chloroplast, another membrane forms stacks called *grana* (GRAY nuh). Grana contain a green pigment, called **chlorophyll** (KLAWR uh FIL), that absorbs light energy.

Sunlight is made up of many different wavelengths of light. Chlorophyll absorbs many of these wavelengths. But it reflects more wavelengths of green light than wavelengths of other colors of light. So, most plants look green.

Reading Check **Why are most plants green?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 Chloroplast Structure

The grana found in chloroplasts contain chlorophyll, which captures energy from sunlight.



Making Sugar

The light energy captured by chlorophyll is used to help form glucose molecules. In turn, oxygen gas (O_2) is given off by plant cells. Photosynthesis is a complicated process made up of many steps. But photosynthesis can be summarized by the following chemical equation:

$$6CO_2 + 6H_2O \xrightarrow{\textit{light energy}} C_6H_{12}0_6 + 6O_2$$

Six molecules of carbon dioxide and six molecules of water are needed to form one molecule of glucose and six molecules of oxygen. **Figure 2** shows where plants get the materials for photosynthesis.

Getting Energy from Sugar

Glucose molecules store energy. Plant cells use this energy for their life processes. To get energy, plant cells break down glucose and other food molecules in a process called **cellular respiration.** During this process, plant cells use oxygen. The cells give off carbon dioxide and water. Excess glucose is converted to another sugar called *sucrose* or stored as starch.

CONNECTION TO Social Studies

WRITING **SKILL** **Sugar** Some plants make and store large amounts of sucrose, or table sugar, during photosynthesis. People harvest these plants for sucrose. Identify a plant that produces large amounts of sucrose. Then, identify how people use the plant and which countries are major growers of the plant. Write an article about your findings in your **science journal.**

photosynthesis the process by which plants, algae, and some bacteria use sunlight, carbon dioxide, and water to make food

chlorophyll a green pigment that captures light energy for photosynthesis

cellular respiration the process by which cells use oxygen to produce energy from food

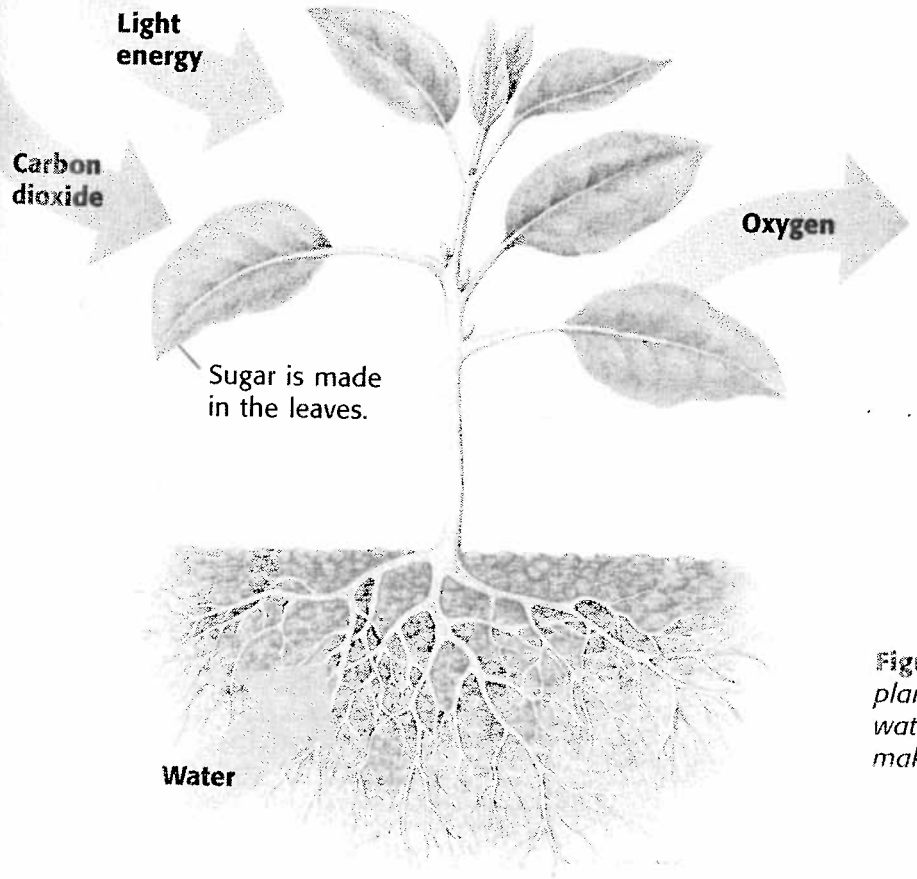
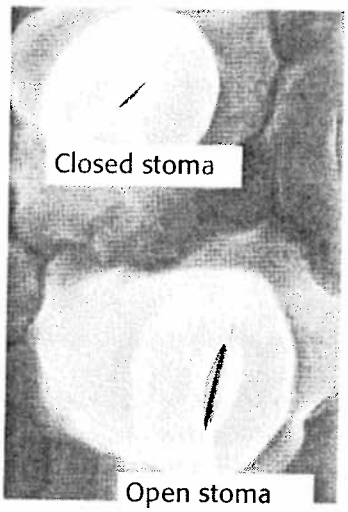
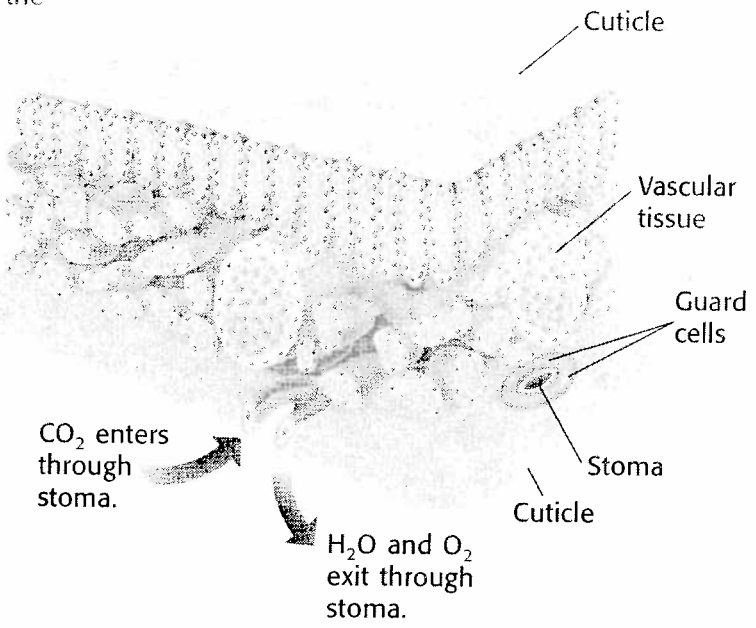


Figure 1 *During photosynthesis, plants take in carbon dioxide and water and absorb light energy. They make sugar and release oxygen.*

Figure 3 Gas Exchange in Leaves

When light is available for photosynthesis, the stomata are usually open. At nighttime, the stomata close to conserve water.





Gas Exchange

Many above-ground plant surfaces are covered by a waxy cuticle. The cuticle protects the plant from water loss. How does a plant get carbon dioxide through this barrier? Carbon dioxide enters the plant's leaves through stomata (singular, *stoma*). A **stoma** is an opening in the leaf's epidermis and cuticle. Each stoma is surrounded by two *guard cells*. The guard cells act like double doors, opening and closing the stoma. You can see stomata in **Figure 3.**

stoma one of many openings in a leaf or a stem of a plant that enable gas exchange to occur (plural, *stomata*)

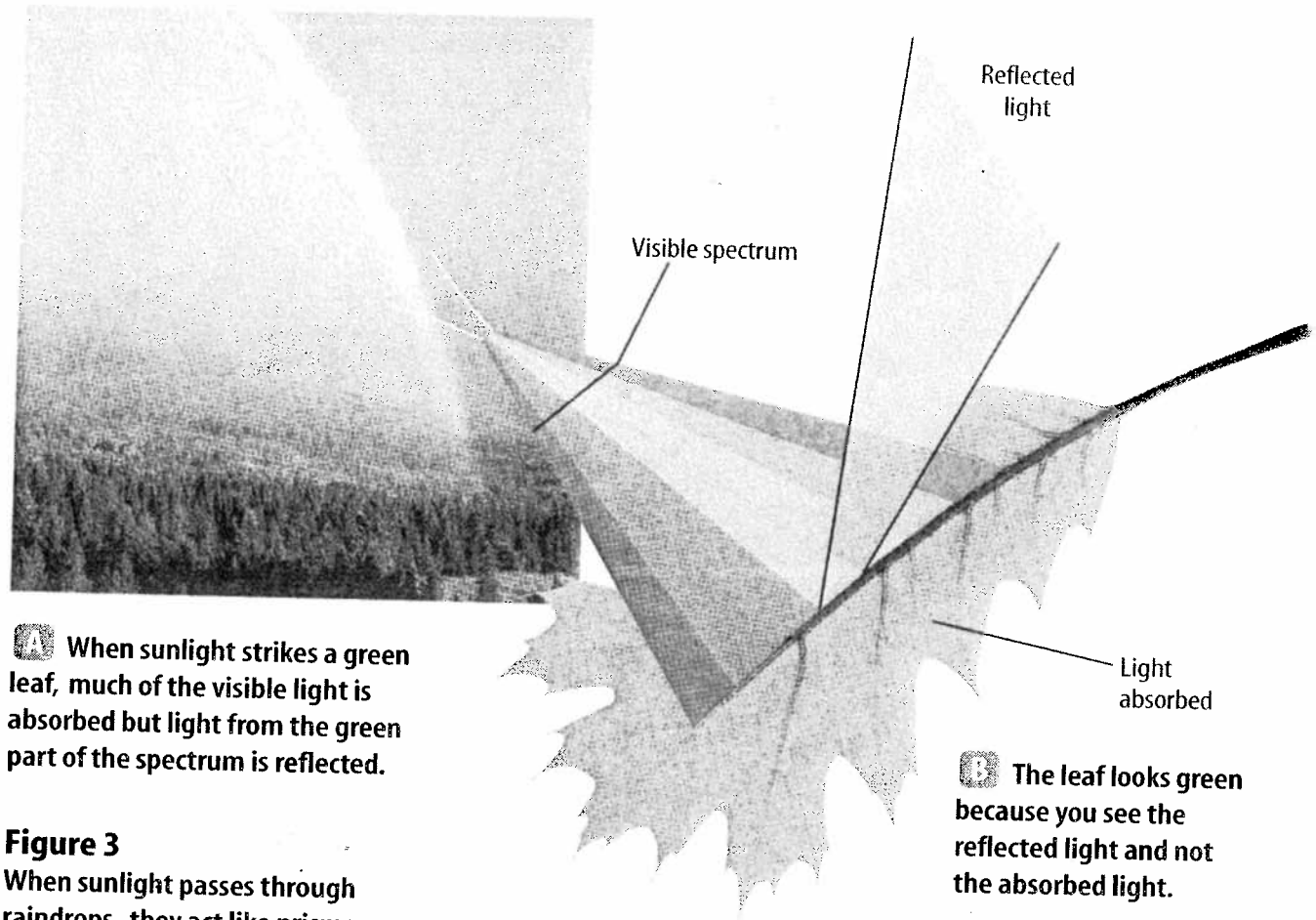
transpiration the process by which plants release water vapor into the air through stomata

When stomata are open, carbon dioxide enters the leaf. The oxygen produced during photosynthesis exits the leaf through the stomata. Water vapor also exits the leaf in this way. The loss of water from leaves is called **transpiration.** Most of the water absorbed by a plant's roots replaces the water lost during transpiration. Sometimes, more water is lost through a plant's leaves than is absorbed by the plant's roots. When this happens, the plant wilts.

CONNECTION TO Chemistry

Transpiration Wrap a plastic bag around the branch of a tree or a portion of a potted plant. Secure the bag closed with a piece of tape or a rubber band, but be sure not to injure the plant. Record what happens over the next few days. What happened to the bag? How does this illustrate transpiration?

ACTIVITY



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

B The leaf looks green because you see the reflected light and not the absorbed light.

Figure 3
When sunlight passes through raindrops, they act like prisms. 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 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?

$$6CO_2 + 6H_2O + \text{light energy} \xrightarrow{\text{chlorophyll}} C_6H_{12}O_6 + 6O_2$$

carbon dioxide — water — glucose — oxygen

Light-Dependent Reactions Some of the chemical reactions that take place during photosynthesis need 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. Leftover hydrogen is used in photosynthesis reactions that occur when there is no light.

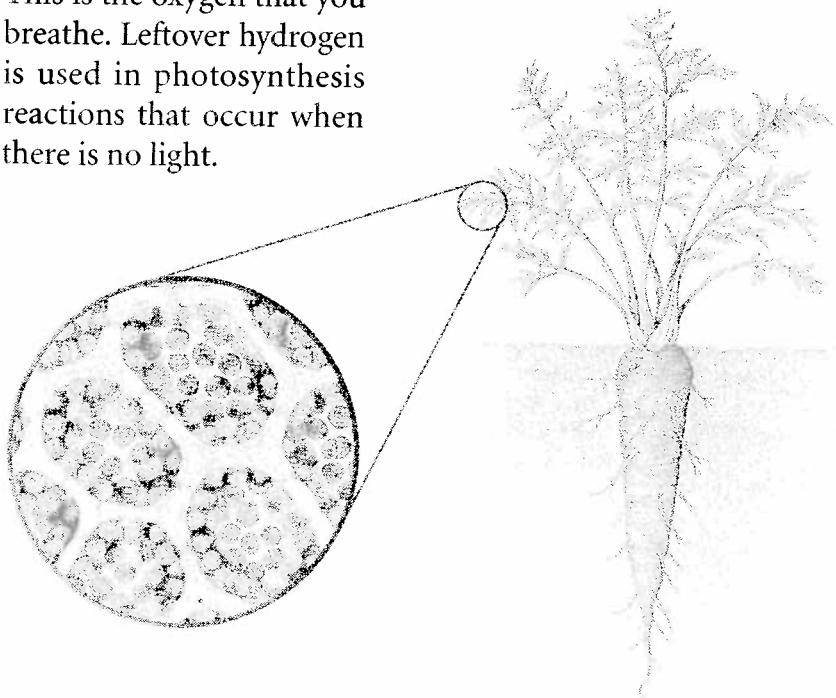


Figure 4
Because they contain chloroplasts, cells in the leaf of the carrot plant are the sites for photosynthesis.

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.

SCIENCE Online

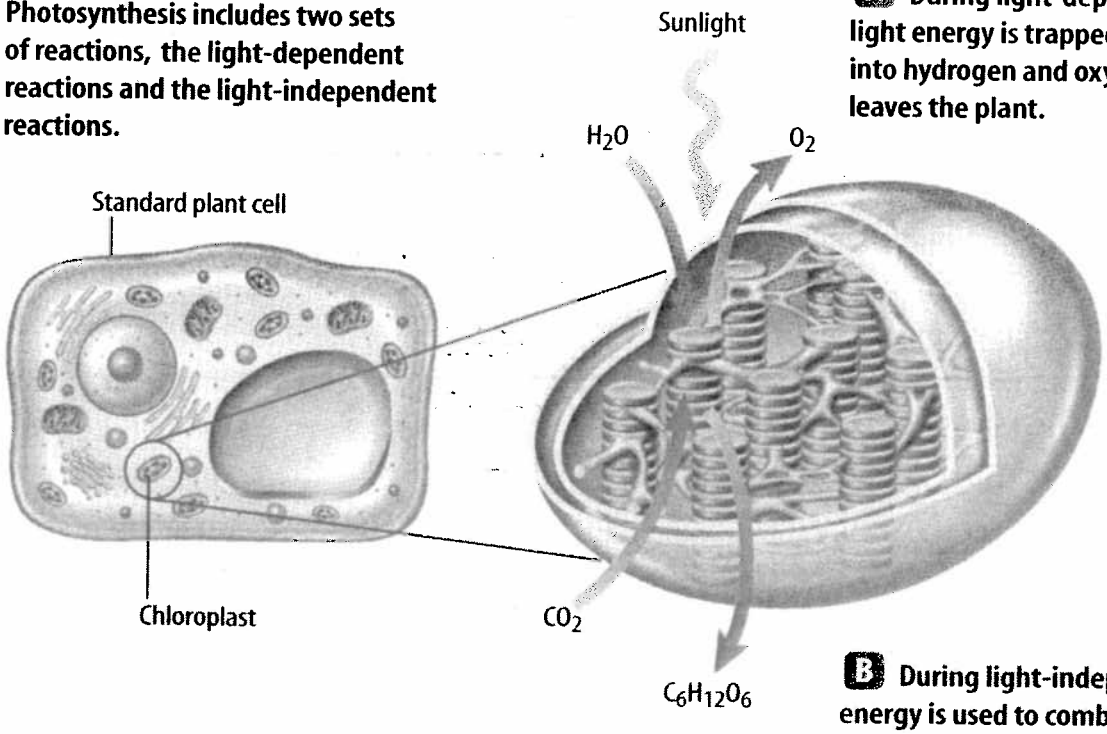
Research Besides glucose, what other sugars do plants produce? Visit the Glencoe Science Web site at **science.glencoe.com** for more information about plant sugars. In your Science Journal list three sugars produced by plants.

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 by plants to grow.

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



A **During light-dependent reactions, light energy is trapped and water is split into hydrogen and oxygen. Oxygen leaves the plant.**

B **During light-independent reactions, energy is used to combine carbon dioxide and hydrogen to make glucose and other sugars.**

The Importance of Photosynthesis

Plants and other photosynthetic organisms, such as some bacteria and many protists, form the base of nearly all food chains on Earth. An example of one food chain is shown in **Figure 4.** During photosynthesis, plants store light energy as chemical energy. Some animals use this chemical energy when they eat plants. Other animals get energy from plants indirectly. These animals eat animals that eat plants. Most organisms could not survive without photosynthetic organisms.

Plants, animals, and most other organisms rely on cellular respiration to get energy. Cellular respiration requires oxygen. Oxygen is a byproduct of photosynthesis. So, photosynthesis provides the oxygen that animals and plants need for cellular respiration.

Reading Check **What are two ways in which photosynthesis is important?**

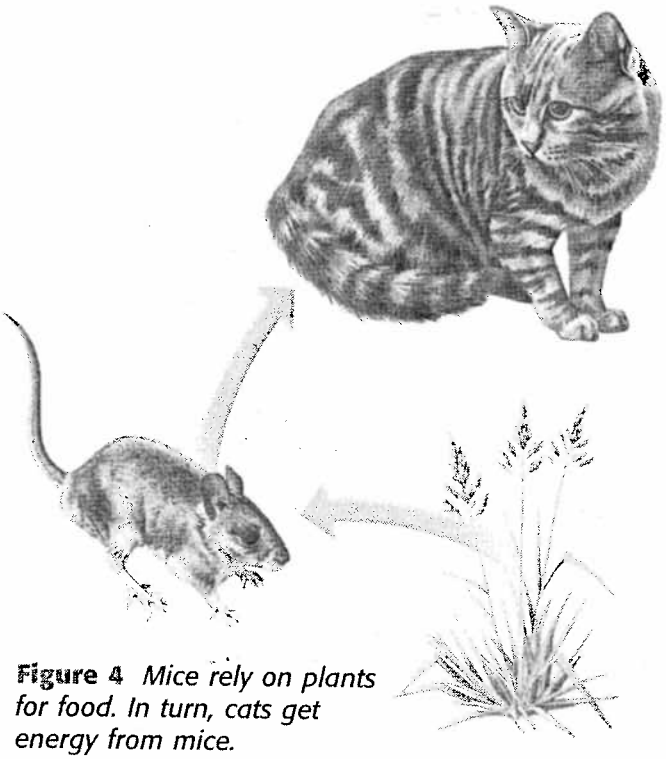


Figure 4 *Mice rely on plants for food. In turn, cats get energy from mice.*

SECTION Review

Summary

- During photosynthesis, plants use energy from sunlight, carbon dioxide, and water to make food.
- Plants get energy from food by cellular respiration, which uses oxygen and releases carbon dioxide and water.
- Transpiration, or the loss of water through the leaves, happens when stomata are open.
- Photosynthesis provides oxygen. Most animals rely on photosynthetic organisms for food.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *photosynthesis*, *chlorophyll*, and *cellular respiration*.

Understanding Key Ideas

2. During photosynthesis, plants
   - **a.** absorb energy from sunlight.
   - **b.** use carbon dioxide and water.
   - **c.** make food and oxygen.
   - **d.** All of the above
3. How is cellular respiration related to photosynthesis?
4. Describe gas exchange in plants.

Math Skills

5. Plants use 6 carbon dioxide molecules and 6 water molecules to make 1 glucose molecule. How many carbon dioxide and water molecules would be needed to make 12 glucose molecules?

Critical Thinking

6. **Predicting Consequences** Predict what might happen if plants and other photosynthetic organisms disappeared.
7. **Applying Concepts** Light filters let through certain colors of light. Predict what would happen if you grew a plant under a green light filter.

Section 2

Aerobic Cellular Respiration

The Breakdown of Food

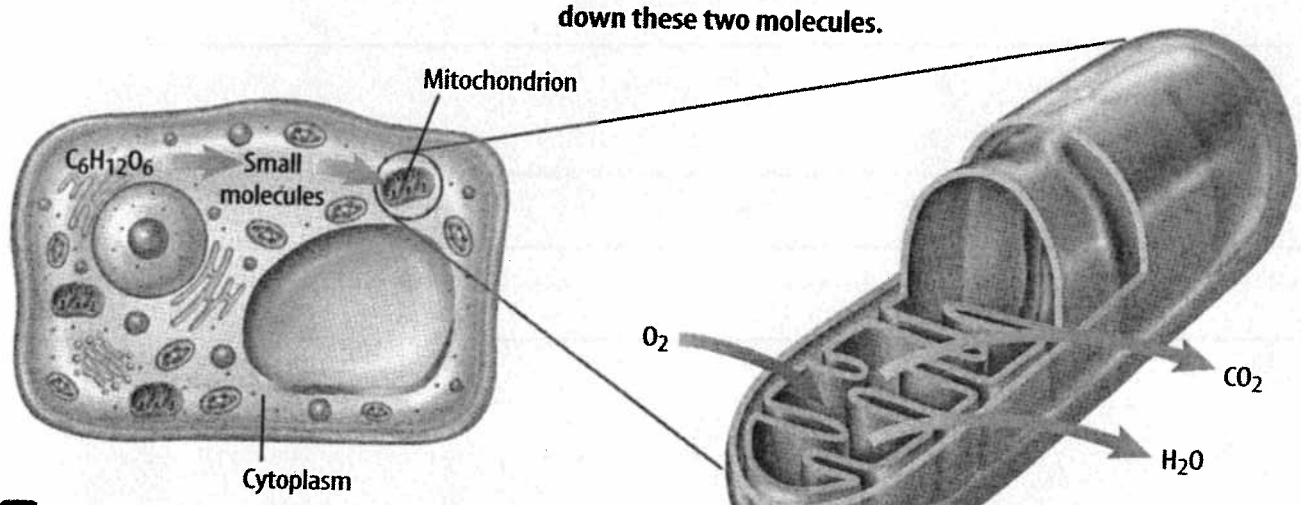
Look at the photograph in **Figure 7.** Do the fox and the plants in the photograph have anything in common? They don't look alike, but the fox and the plants are made of cells that break down food, and release energy in a process called respiration. How does this happen?

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.

$$\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \longrightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} + \text{energy}$$

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.



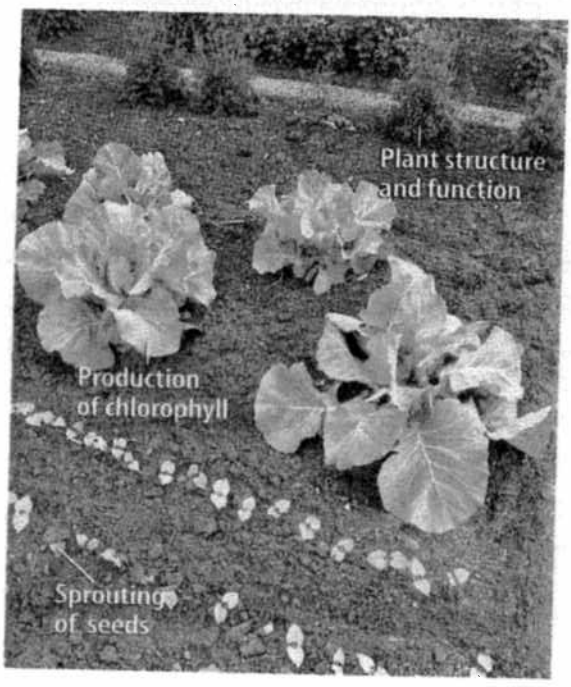
A In the cytoplasm, each glucose molecule is broken down into two smaller molecules.

B Oxygen is used in the mitochondrion to break down these two molecules.

C Water and carbon dioxide are waste products of respiration.

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 reactions that break the small molecules into the waste products 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 from the respiration of food 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 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 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 chapter to find the equations for photosynthesis and aerobic respiration. Do they resemble each other? If you look closely, you can see that overall, 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. Because all plant cells contain mitochondria, all plant cells and any cell with mitochondria can use the process of aerobic respiration. **Table 1** compares photosynthesis and aerobic respiration.

Section 1 Assessment

1. Explain how a leaf exchanges carbon dioxide and water vapor.
2. Why are photosynthesis and respiration important?
3. What must happen to glucose molecules before respiration begins?
4. Compare the number of organisms that respire to those that photosynthesize.
5. **Think Critically** Humidity is water vapor in the air. How do plants contribute to the amount of humidity in the air?

Skill Builder Activities

6. **Forming Hypotheses** White potatoes sometimes have green areas on their skins. Hypothesize what process can take place in the green part but not in the white part of the potato. **For more help, refer to the Science Skill Handbook.**
7. **Solving One-Step Equations** How many CO_2 molecules result from the aerobic respiration of a glucose molecule ($C_6H_{12}O_6$)? Refer to the equation in this section. **For more help, refer to the Math Skill Handbook.**

SECTION 3

Plant Responses to the Environment

What happens when you get really cold? Do your teeth chatter? Or do you shiver? Anything that causes a reaction in your body is a **stimulus** (plural, **stimuli**). But would a plant respond to a stimulus?

Plants do respond to stimuli! For example, they respond to light, gravity, and changing seasons.

What You Will Learn

- Describe how plants may respond to light and gravity.
- Explain how some plants respond to night length.
- Describe how some plants respond to the changes of season.

Vocabulary

tropism

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Plant Tropisms

Some plants respond to an environmental stimulus by growing in a particular direction. Growth in response to a stimulus is called a **tropism** (TROH PIZ uhm). Tropisms are either positive or negative. Plant growth toward a stimulus is a positive tropism. Plant growth away from a stimulus is a negative tropism.

tropism the growth of all or part of an organism in response to an external stimulus, such as light

Light

What happens if you place a houseplant so that it gets light from only one direction, such as from a window? The shoot tips probably bend toward the light. Bending toward the light is a positive tropism. A change in the direction a plant grows that is caused by light is called *phototropism* (FOH toh TROH PIZ uhm). The result of phototropism is shown in **Figure 1.** Shoots bend because cells on one side of the shoot grow longer than cells on the other side of the shoot.

Reading Check **What happens when a plant gets light from only one direction?** *(See the Appendix for answers to Reading Checks.)*

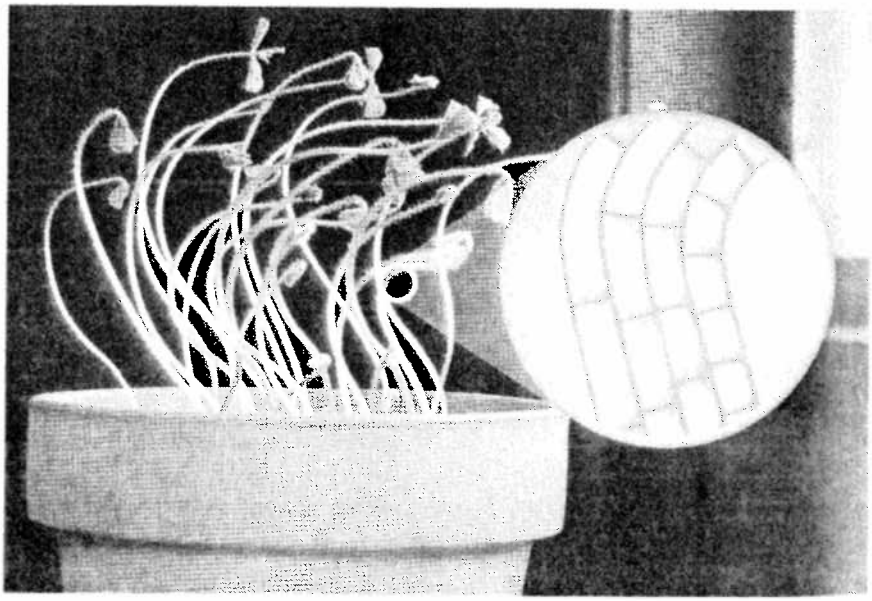
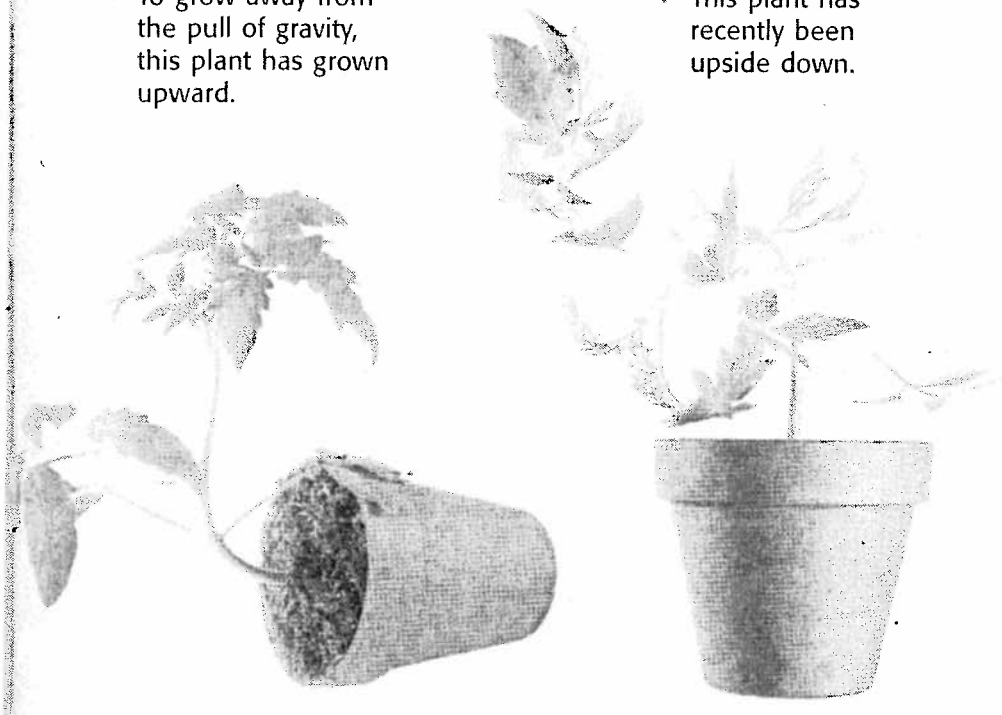


Figure 1 *The plant cells on the dark side of the shoot grow longer than the cells on the other side. So, the shoot bends toward the light.*

Figure 2 Gravitropism

To grow away from the pull of gravity, this plant has grown upward.

This plant has recently been upside down.



Gravity

Plant growth also changes in response to the direction of gravity. This change is called *gravitropism* (GRAV i TROH PIZ uhm). The effect of gravitropism is demonstrated by the plants in **Figure 2.** A few days after a plant is placed on its side or turned upside down, the roots and shoots change direction of growth. Most shoot tips have negative gravitropism. They grow upward, away from the center of the Earth. In contrast, most root tips have positive gravitropism. Roots grow downward, toward the center of the Earth.

Seasonal Responses

What would happen if a plant living in an area that has very cold winters flowered in December? Would the plant be able to successfully produce seeds and fruits? Probably not. The plant's flowers would likely freeze and die. So, the flowers would never produce mature seeds.

Plants living in regions with cold winters can detect the change in seasons. How do plants do this? As fall and winter approach, the days get shorter, and the nights get longer. The opposite happens when spring and summer approach. Plants respond to the change in the length of day.

Reading Check How do plants detect seasonal changes?

MATH PRACTICE

Bending by Degrees

Suppose a plant has a positive phototropism and bends toward light at a rate of 0.3° per minute. In how many hours will the plant bend 90°?

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HL5PL2W.**

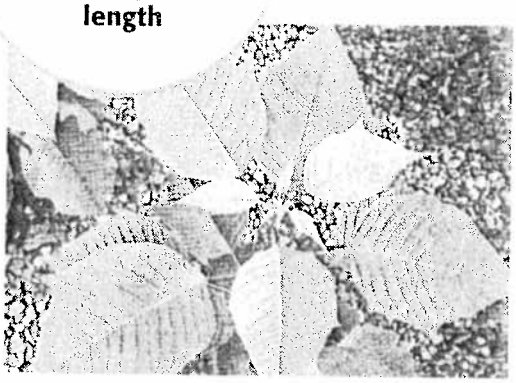
NOT Required

Figure 3 Night Length and Flower Color

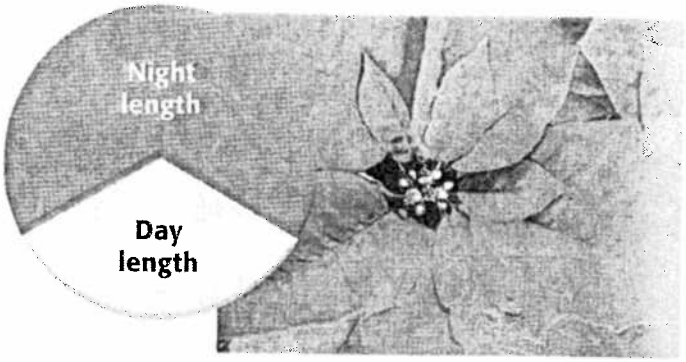
Early summer

In the early summer, night length is short. At this time, poinsettia leaves are all green, and there are no flowers.

Day length



Late fall



Poinsettias flower in the fall, when nights are longer. The leaves surrounding the flower clusters turn red. Professional growers use artificial lighting to control the timing of this color change.

SECTION NOT Required

Length of Day

The difference between day length and night length is an important environmental stimulus for many plants. This stimulus can cause plants to begin reproducing. For example, some plants flower in fall or winter. At this time, night length is long. These plants are called *short-day plants*. Poinsettias, such as those shown in **Figure 3,** are short-day plants. Chrysanthemums are also short-day plants. Other plants flower in spring or early summer, when night length is short. These plants are called *long-day plants*. Clover, spinach, and lettuce are examples of long-day plants.

SCHOOL to HOME

Earth's Orbit and the Seasons

The seasons are caused by Earth's tilt and its orbit around the sun. Research how Earth's orbit determines the seasons. With a parent, make a model of the Earth's orbit around the sun to illustrate your findings.

ACTIVITY

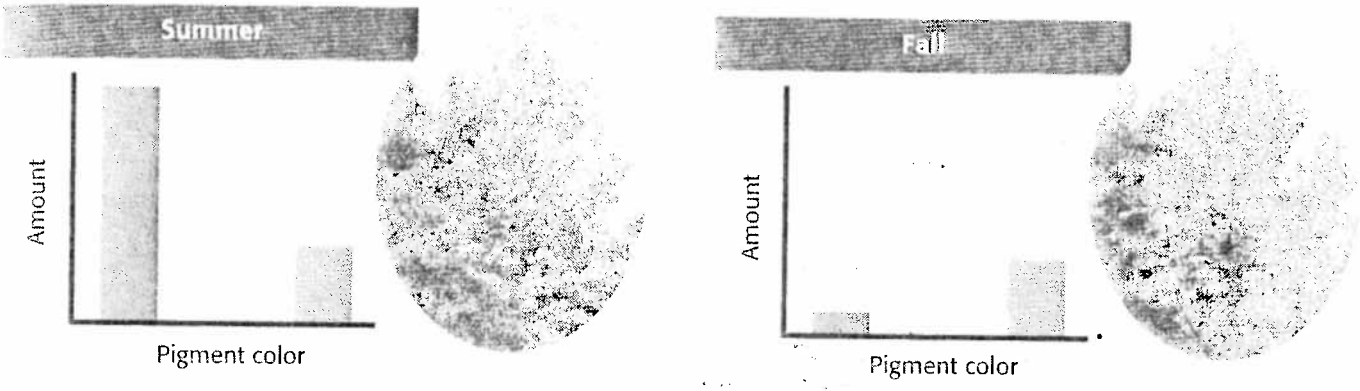
Seasons and Leaf Loss

All trees lose their leaves. Some trees, such as pine and holly, shed some of their leaves year-round so that some leaves are always on the tree. These trees are called *evergreen trees*. Evergreen trees have leaves adapted to survive throughout the year. The leaves are often covered with a thick cuticle. This cuticle protects the leaves from cold and dry weather.

Other trees, such as maple, oak, and elm trees, are called *deciduous* (dee SIJ oo uhs) *trees*. These trees lose all of their leaves around the same time each year. In colder areas, deciduous trees usually lose their leaves before winter begins. In warmer climates that have wet and dry seasons, deciduous trees lose their leaves before the dry season. The loss of leaves helps plants survive low temperatures or long periods without rain.

READING SKILLS **Compare evergreen trees and deciduous trees.**

Figure 4 Amount of Pigment Based on Season



Seasons and Leaf Color

As shown in **Figure 4,** the leaves of deciduous trees may change color before they are lost. As fall approaches, green chlorophyll breaks down. Orange or yellow pigments in the leaves are then revealed. These pigments were always present in the leaves. But they were hidden by green chlorophyll.

SECTION Review

Summary

- Plant growth in response to a stimulus is called a tropism. Tropisms are positive or negative.
- Plants react to light, gravity, and changing seasons.
- Short-day plants flower when night length is long. Long-day plants flower when night length is short.
- Evergreen trees do not lose all their leaves at one time. Deciduous trees lose their leaves at the same time each year.

Using Key Terms

1. In your own words, write a definition for the term *tropism*.

Understanding Key Ideas

2. Deciduous trees lose their leaves
   a. to conserve water during the dry season.
   b. around the same time each year.
   c. to survive low winter temperatures.
   d. All of the above
3. How do light and gravity affect plants?
4. Describe how day length can affect the flowering of plants.

Math Skills

5. A certain plant won't bloom until it is dark for 70% of a 24 h period. How long is the day when the plant will bloom?

Critical Thinking

6. **Making Inferences** Many evergreen trees live in areas with long, cold winters. Why might these evergreen trees keep their leaves all year?
7. **Analyzing Ideas** Some short-day plants bloom during the winter. If cold weather reduces the chances that a plant will produce seeds, what might you conclude about where these short-day plants are found?

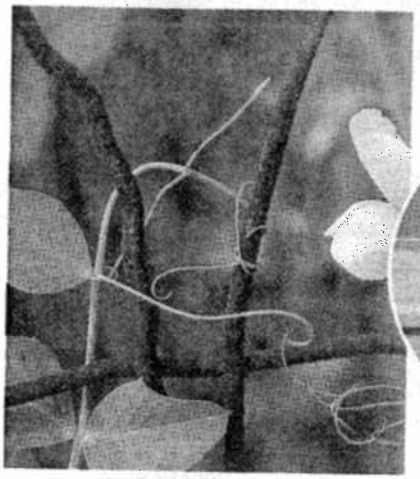
SCILINKS NSTA

For a variety of links related to this chapter, go to

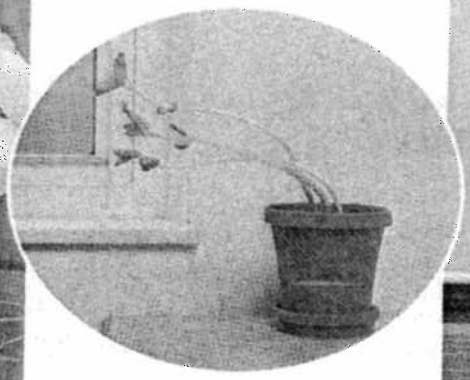
Topic:

SciLinks code:

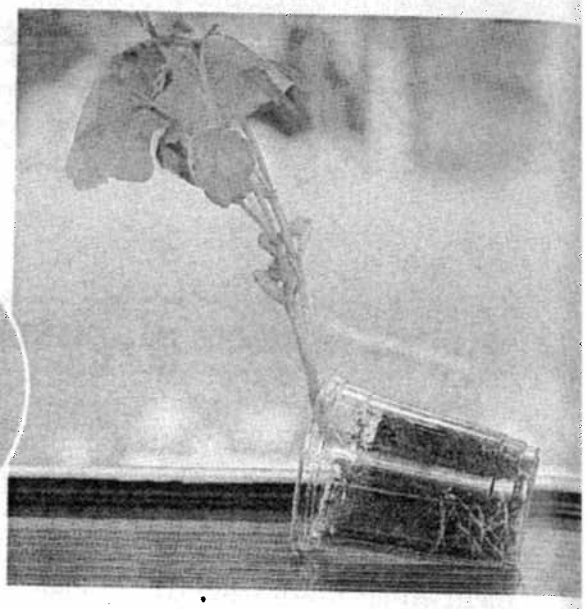
Figure 11
Tropisms are responses to external stimuli.



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



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



C 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, shown in **Figure 11A,** 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, as shown in **Figure 11B.**

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

Physics INTEGRATION

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. This means that ethylene produced by one plant can cause a response in a nearby plant. One plant response to ethylene causes a layer of cells to form between a leaf and the stem. That's why most leaves fall from plants.

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 still green. During shipping the green fruits are exposed to ethylene and they ripen.

Math Skills Activity

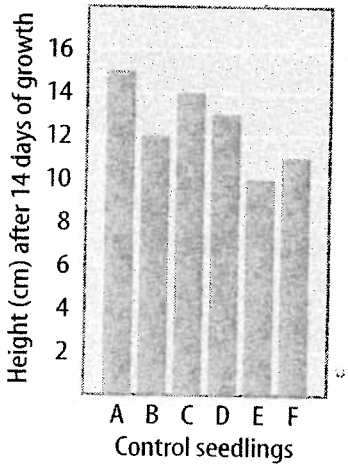
Calculating Averages

Example Problem

What is the average height of control bean seedlings after 14 days?

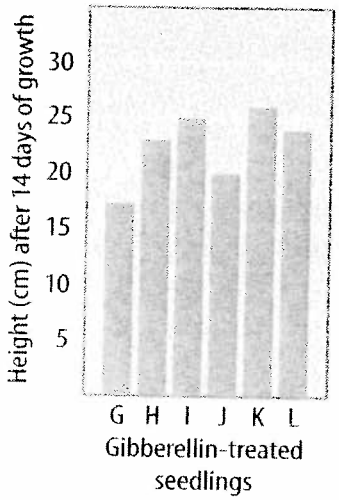
Solution

1. *This is what you know:*
   height of control seedlings after 14 days
   number of control seedlings
2. *This is what you need to find:*
   average height of control seedlings after14 days
3. *This is what you must do:*
   total the heights of all control seedlings
   15 + 12 + 14 + 13 + 10 + 11 = 75 cm
4. *Divide the total height by the total number of control seedlings:*
   75 cm/6
   average height of control seedlings = 12.5 cm



Practice Problem

Calculate the average height of seedlings treated with gibberellin.



For more help, refer to the Math Skill Handbook.

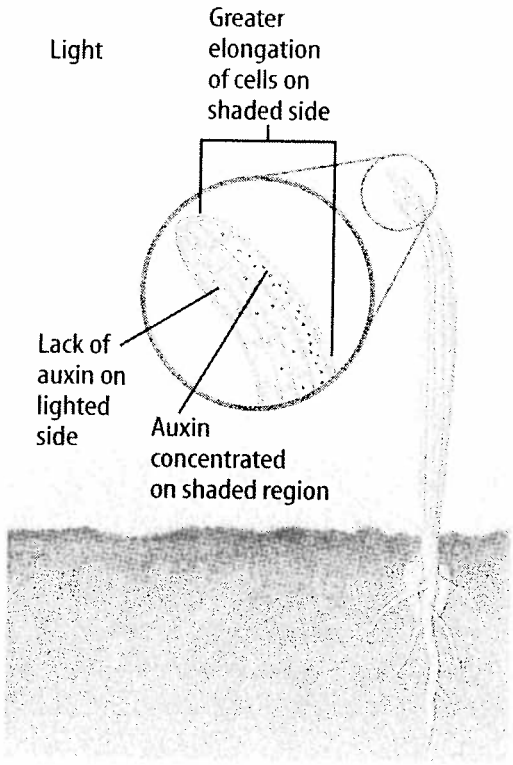


Figure 12
The concentration of auxin on the shaded side of a plant causes cells to lengthen on that side.

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.

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.

TRY AT HOME 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?