Chapter 23

Plant Structure and Function

What You'll Learn

- You will describe and compare the major types of plant cells and tissues.
- You will identify and analyze the structure and functions of roots, stems, and leaves.
- You will identify plant hormones and determine the nature of plant responses.

Why It's Important

Humans and the organisms around them, including plants, share an environment. By knowing about plant structure and how plants function, you can better understand how humans and plants interact.

Understanding the Photo

These pitcher plants look different from the plants that surround them. However, they and the other plants have similar plant systems and subsystems.

Biology Online

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Section 23.1

Plant Cells and Tissues

SECTION PREVIEW

Objectives

Identify the major types of plant cells.

Distinguish among the functions of the different types of plant tissues.

Review Vocabulary

vacuole: membrane-bound, fluid-filled space in the cytoplasm of cells used for the temporary storage of materials (p. 183)

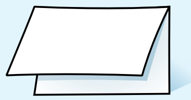
New Vocabulary

parenchyma
collenchyma
sclerenchyma
epidermis
stomata
guard cell
trichome
xylem
tracheid
vessel element
phloem
sieve tube member
companion cell
meristem
apical meristem
vascular cambium
cork cambium

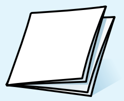
FOLDABLES Study Organizer

Plants Cells and Tissues Make the following Foldable to help you compare the types of plant cells and tissues.

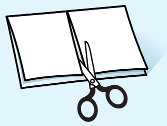
STEP 1 **Fold** a vertical sheet of paper in half from top to bottom.



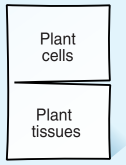
STEP 2 **Fold** in half from side to side with the fold at the top.



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.



Identify and Describe As you read Chapter 23, identify and describe the types of plant cells and plant tissues under each tab.

Types of Plant Cells

Like all organisms, plants are composed of cells. Plant cells are different from animal cells because they have a cell wall, a central vacuole, and can contain chloroplasts. *Figure 23.1* shows a typical plant cell. Plants, just like other organisms, are composed of different cell types.

Parenchyma

Parenchyma (puh RENG kuh muh) cells are the most abundant kind of plant cell. They are found throughout the tissues of a plant. These spherical cells have thin, flexible cell walls. Most parenchyma cells usually have a large central vacuole, which sometimes contains a fluid called sap.

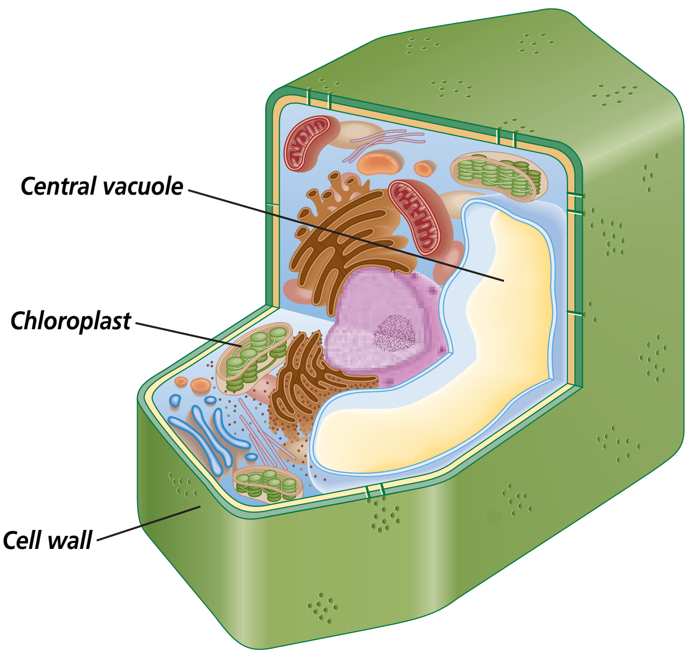


Figure 23.1
Plant cells have several distinguishing features, such as a cell wall, chloroplasts, and a large central vacuole.

Parenchyma cells, as shown in ***Figure 23.2A,*** have two main functions: storage and food production. The large vacuole found in these cells can be filled with water, starch grains, or oils. The edible portions of many fruits and vegetables are composed mostly of parenchyma cells. Parenchyma cells also can contain numerous chloroplasts that produce glucose during photosynthesis.

Word Origin

par- from the Greek word *para,* meaning "beside"

coll- from the Greek word *kolla,* meaning "glue"

scler- from the Greek word *skleros,* meaning "hard"

Parenchyma, collenchyma, and sclerenchyma are all types of plant tissues.

Collenchyma

Collenchyma (coh LENG kuh muh) cells are long cells with unevenly thickened cell walls, as illustrated in ***Figure 23.2B.*** The structure of the cell wall is important because it allows the cells to grow. The walls of collenchyma cells can stretch as the cells grow while providing strength and support. These cells are arranged in tubelike strands or cylinders that provide support for surrounding tissue. The long tough strands you may have noticed in celery are composed of collenchyma.

Sclerenchyma

The walls of **sclerenchyma** (skle RENG kuh muh) cells are very thick and rigid. At maturity, these cells often die. Although their cytoplasm disintegrates, their strong, thick cell walls remain and provide support for the plant. Sclerenchyma cells can be seen in ***Figure 23.2C.*** Two types of sclerenchyma cells commonly found in plants are fibers and sclerids (SKLER idz). Fibers are long, thin cells that form strands. They provide support and strength for the plant and are the source of fibers used for making linen and rope. A type of fiber is associated with vascular tissue, which you will learn about later in this section. Sclerids are irregularly shaped and usually found in clusters. They are the gritty texture of pears and a major component of the pits found in peaches and other fruits.

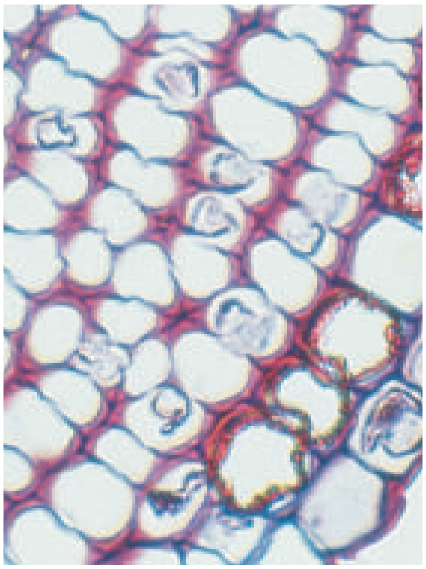
Reading Check **Compare and contrast** the structures and functions of parenchyma, collenchyma, and sclerenchyma.

Figure 23.2
Plants are composed of three basic types of cells, which are shown here stained with dyes.

A Parenchyma cells are found throughout a plant. Because their cell walls are flexible, parenchyma cells can have different shapes.

LM Magnification: 54×

B Collenchyma cells often are found in parts of the plant that are still growing. Notice the unevenly thickened cell walls.



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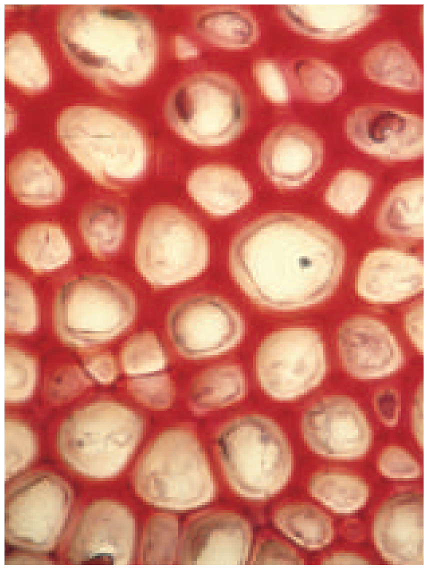
C The walls of sclerenchyma cells are very thick. These dead cells are able to provide support for the plant.



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Plant Tissues

Recall that a tissue is a group of cells that function together to perform an activity. Tissues can be referred to as plant subsystems. There are several different tissue types in plants.

Dermal tissues

The dermal tissue, or **epidermis,** is composed of flattened cells that cover all parts of the plant. It functions much like the skin of an animal, covering and protecting the body of a plant. As shown in ***Figure 23.3,*** the cells that make up the epidermis are tightly packed and often fit together like a jigsaw puzzle. The epidermal cells produce the waxy cuticle that helps prevent water loss.

Another structure that helps control water loss from the plant, a stoma, is part of the epidermal layer. **Stomata** (STOH mah tuh) (singular, stoma) are openings in leaf tissue that control the exchange of gases. Stomata are found on green stems and on the surfaces of leaves. In many plants, fewer stomata are located on the upper surface of the leaf as a means of conserving water. Cells called **guard cells** control the opening and closing of stomata. The opening and closing of stomata regulates the flow of water vapor from leaf tissues. You can learn more about stomata in the *BioLab* at the end of this chapter.

The dermal tissue of roots may have root hairs. Root hairs are extensions of individual cells that help the root absorb water and dissolved minerals. On the stems and leaves of some plants, there are structures called trichomes. **Trichomes** (TRI kohmz) are hairlike projections that give a stem or a leaf a "fuzzy" appearance. They help reduce the evaporation of water from the plant. In some cases, trichomes are glandular and secrete toxic substances that help protect the plant from predators. Stomata, root hairs, and trichomes are shown in ***Figure 23.4.***

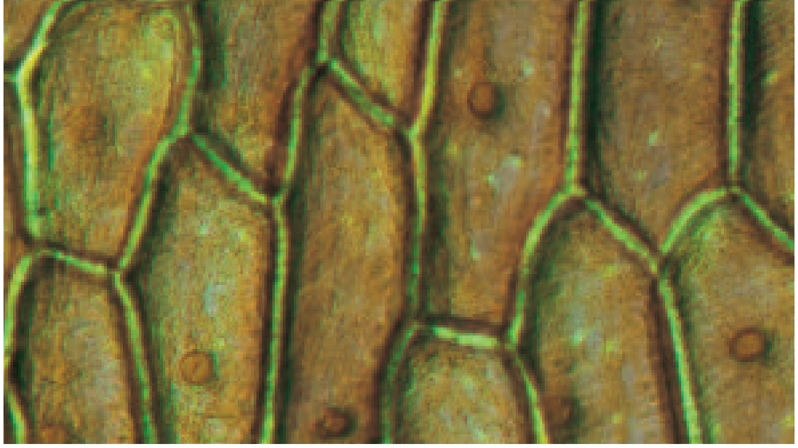
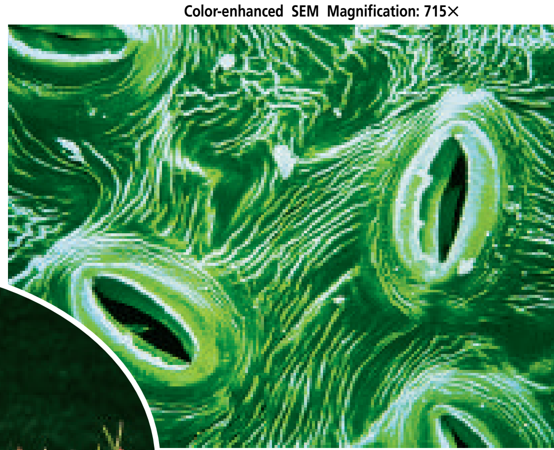


Figure 23.3
The cells of the epidermis fit together tightly, which helps protect the plant and prevents water loss.

Figure 23.4
A root hair **(A)** is an extension of a root epidermal cell. A trichome **(B)** is unicellular or multicellular growth from an epidermal cell. Stomata **(C)** are openings in the leaf epidermis. Each stoma is surrounded by two guard cells.



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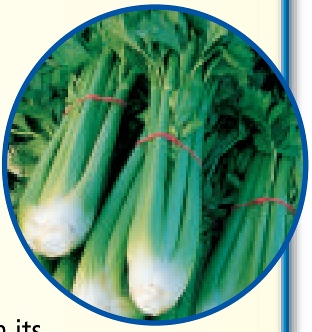
(bc)Andrew Syred/Science Photo Library/Photo Researchers (br)Andrew Syred/Science Photo Library/Photo Researchers

MiniLab 23.1

Observe

Examining Plant Tissues Pipes are hollow. Their shape or structure allows them to be used efficiently in transporting water. Plant vascular tissues have this same efficiency in structure.



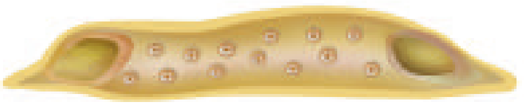
Procedure

1. Snap a celery stalk in half and remove a small section of "stringy tissue" from its inside.
2. Place the material on a glass slide. Add several drops of water. Place a second glass slide on top. **CAUTION:** ***Use caution when handling a microscope and glass slides.***
3. Press down evenly on the top glass slide with your thumb directly over the plant material.
4. Remove the top glass slide. Add more water if needed. Add a coverslip.
5. Examine the celery material under low-and high-power magnification. Diagram what you see.
6. Repeat steps 2–5 using some of the soft tissue inside the celery stalk.

Analysis

1. **Describe** Write a description of the stringy tissue under low- and high-power magnification.
2. **Describe** Write a description of the soft tissue under low- and high-power magnification.
3. **Explain** Does the structure of these tissues suggest their functions?

Figure 23.5
Tracheids and vessel elements are the conducting cells of the xylem. These cells die when they mature but their cell walls remain.



Vessel element

Tracheid

Vascular tissues

Food, dissolved minerals, and water are transported throughout the plant by vascular tissue. Xylem and phloem are the two types of vascular tissues. **Xylem** is plant tissue composed of tubular cells that transports water and dissolved minerals from the roots to the rest of the plant. In seed plants, xylem is composed of four types of cells—tracheids, vessel elements, fibers, and parenchyma.

Tracheids (TRA kee uhdz) are tubular cells tapered at each end. The cell walls between adjoining tracheids have pits through which water and dissolved minerals flow.

Vessel elements are tubular cells that transport water throughout the plant. They are wider and shorter than tracheids and have openings in their end walls, as shown in ***Figure 23.5.*** In some plants, mature vessel elements lose their end walls and water and dissolved minerals flow freely from one cell to another.

Although almost all vascular plants have tracheids, vessel elements are most commonly found in anthophytes. Conifers have tracheids but no vessel elements in their vascular tissues. This difference in vascular tissues could be one reason why anthophytes are the most successful plants on Earth. Anthophyte vessel elements are thought to transport water more efficiently than tracheids because water can flow freely from vessel element to vessel element through the openings in their end walls.

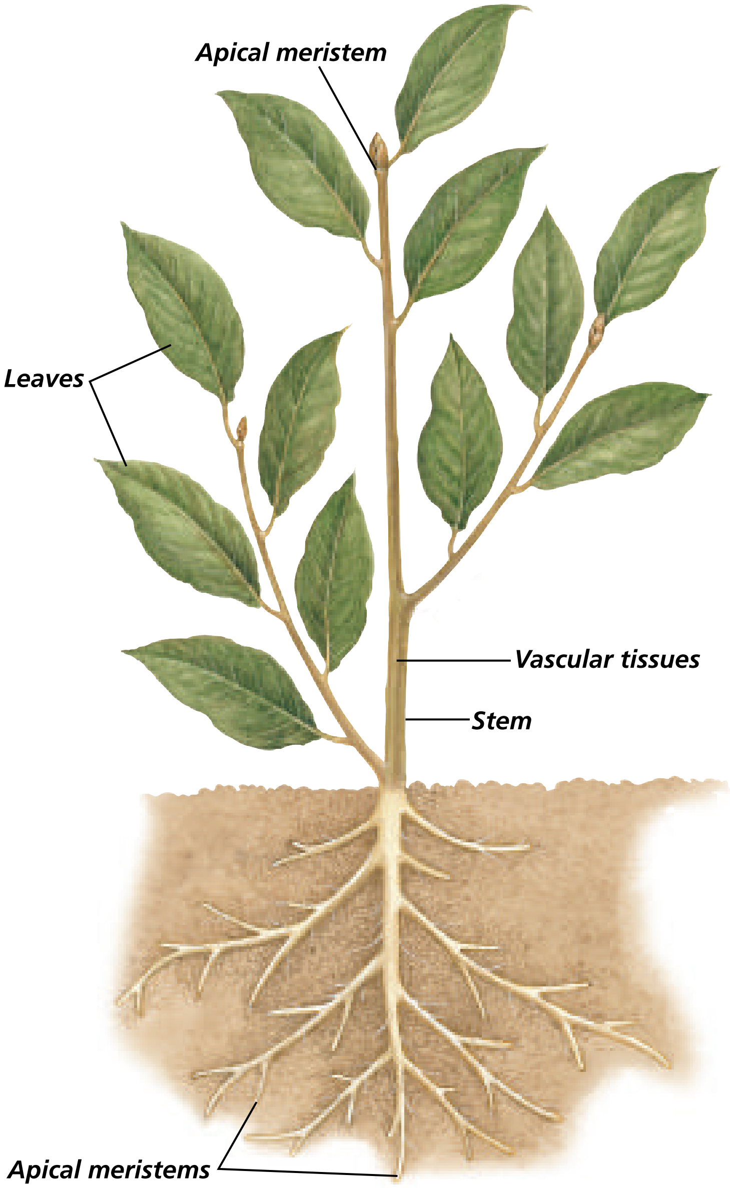
You can learn more about vascular tissues in the *MiniLab* on this page. What other types of tissues are found in vascular plants? To answer this question, look at ***Figure 23.6*** on the next page.

Sugars and other organic compounds are transported throughout a vascular plant within the phloem.

A Plant's Body Plan

Figure 23.6

There seems to be an almost endless variety of vascular plants. Regardless of their diversity and numerous adaptations, all vascular plants have the same basic body plan. They are composed of cells, tissues, and organs. **Critical Thinking** ***What are the different types of meristems, and how do they help produce new plant systems and subsystems?***



A **Cells** Most new plant cells are produced by cell divisions in regions of a plant called meristems. Meristematic cells continually divide. After each cell division, one of the two new cells remains meristematic and the other begins to differentiate. Two types of meristems—apical and lateral—produce different cell types. Apical meristems produce cells that add length to stems and roots. Lateral meristems produce cells that increase stem and root diameters.

B **Tissues** Plants have four types of tissues: dermal, vascular, ground, and meristematic. Dermal tissues cover the plant body. Vascular tissues transport water, food, and dissolved substances throughout the plant. Photosynthesis, storage, and secretion are functions of ground tissue. Meristematic tissues produce most of a plant's new cells.

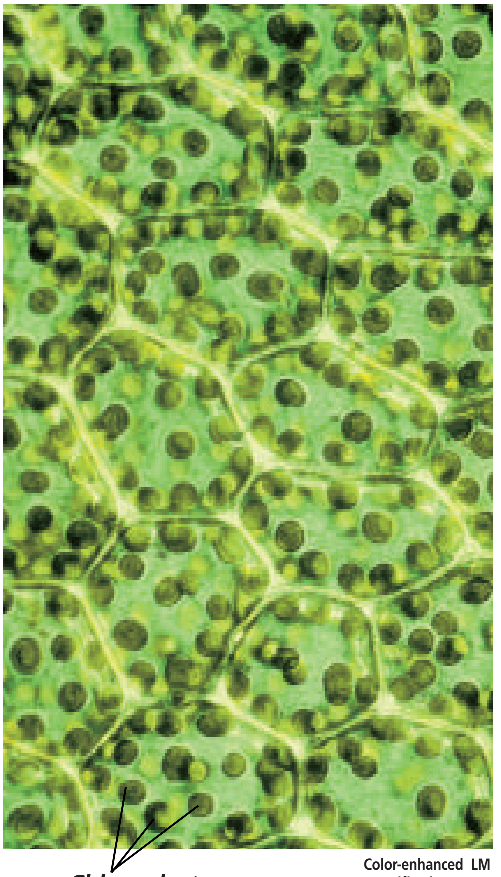
Vascular plants

C **Organs** The major plant organs are stems, leaves, and roots. They differ in structure among plant divisions but share common functions. A stem is a plant organ that provides structural support and contains vascular tissues. Leaves and reproductive structures grow from stems. Usually, leaves are the organs in which photosynthesis occurs. Leaf form differs among plants. Roots anchor a plant in soil or on another plant or structure. Most roots absorb water and dissolved substances that then are transported in vascular tissues throughout the plant.

Phloem is made up of tubular cells joined end to end, as shown in ***Figure 23.7.*** It is similar to xylem because phloem also has long cylindrical cells. However these cells, called **sieve tube members,** are alive at maturity. Sieve tube members are unusual because they contain cytoplasm but do not have a nucleus or ribosomes. Next to each sieve tube member is a companion cell. **Companion cells** are nucleated cells that help with the transport of sugars and other organic compounds through the sieve tubes of the phloem. In anthophytes, the end walls between two sieve tube members are called sieve plates. The sieve plates have large pores that allow sugar and organic compounds to move from sieve tube member to sieve tube member. Phloem can transport materials from the roots to the leaves also. You can learn more about vascular tissues in *Problem-Solving Lab 23.1.*

The vascular phloem tissue of many plants contains fibers. Although the fibers are not used for transporting materials, they are important because they provide support for the plant.

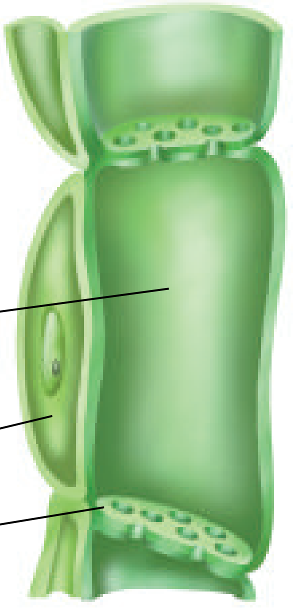
Figure 23.8
The numerous chloroplasts in this ground tissue produce food for the plant.



Ground tissue

Ground tissue is composed mostly of parenchyma cells but it may also include collenchyma and sclerenchyma cells. It is found throughout a plant and often is associated with other tissues. The functions of ground tissue include photosynthesis, storage, and support. The cells of ground tissue in leaves and some stems contain numerous chloroplasts that carry on photosynthesis. Ground tissue cells in some stems and roots contain large vacuoles that store starch grains and water. Cells, such as those shown in ***Figure 23.8,*** are often seen in ground tissue.

Figure 23.7
Phloem tissue carries sugars and other organic compounds throughout the plant.



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Meristematic tissues

A growing plant produces new cells in areas called meristems. **Meristems** are regions of actively dividing cells. Meristematic cells are differently shaped parenchyma cells with large nuclei. There are several types of meristems; two types are shown in *Figure 23.6* on page 609.

Apical meristems are found at or near the tips of roots and stems. They produce cells that allow the roots and stems to increase in length. Lateral meristems are cylinders of dividing cells located in roots and stems. The production of cells by the lateral meristems results in an increase in root and stem diameters. Most woody plants have two kinds of lateral meristems—vascular cambium and cork cambium. The **vascular cambium** produces new xylem and phloem cells in the stems and roots. The **cork cambium** produces cells with tough cell walls. These cells cover the surface of stems and roots. The outer bark of a tree is produced by the cork cambium.

A third type of lateral meristem is found in grasses, corn, and other monocots. This meristem adds cells that lengthen the part of the stem between the leaves. These plants do not have a vascular or a cork cambium.

Problem-Solving Lab 23.1

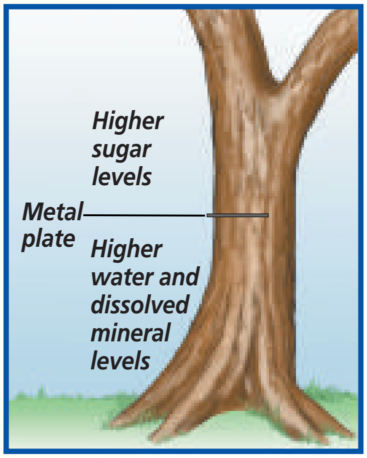
Apply Concepts

What happens if vascular tissue is interrupted? Anthophytes have tissues within their organs that transport materials from roots to leaves and from leaves to roots. What happens if this pathway is experimentally interrupted?

Solve the Problem

A thin sheet of metal was inserted halfway through the stem of a living tree as shown in the diagram. One day later, the following analysis was made:

- Concentration of water and dissolved minerals directly below the metal sheet was higher than above the metal sheet.
- Concentration of sugar directly above the metal sheet was higher than directly below the metal sheet.



Thinking Critically

1. **Explain** What is the function of phloem? Why was the concentration of sugars different on either side of the metal sheet?
2. **Explain** What is the function of xylem? Why was the concentration of dissolved minerals and water different on either side of the metal sheet?
3. **Analyze** How would the experimental findings differ if the metal sheet were inserted only into the bark of the tree?

Section Assessment

Understanding Main Ideas

1. Describe the distinguishing characteristics of the three types of plant cells.
2. Identify and analyze the function of vascular tissue. Name the two different types of vascular tissue.
3. Explain the function of stomata.
4. Draw a plant and identify and indicate where the apical meristems would be located. How do they function differently from lateral meristems in the development of a plant?

Thinking Critically

5. Explain what type of plant cell you would expect to find in the photosynthetic tissue of a leaf. What is another name for the photosynthetic tissue?

Skill Review

6. **Compare and Contrast** Compare and contrast the cells that make up the xylem and the phloem. For more help, refer to *Compare and Contrast* in the **Skill Handbook.**

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Section
23.2

Roots, Stems, and Leaves

SECTION PREVIEW

Objectives

Identify and compare the structures of roots, stems, and leaves.

Describe and compare the functions of roots, stems, and leaves.

Review Vocabulary

organ: group of two or more tissues organized to perform complex activities within an organism (p. 210)

New Vocabulary

cortex
endodermis
pericycle
root cap
sink
translocation
petiole
mesophyll
transpiration

Do you like to eat plant organs?

Using Prior Knowledge The next time you eat a salad, look closely at its contents. Did you know that most of the items you are eating are plant organs? Lettuce and spinach are leaves. Carrots and radishes are roots. Asparagus is a stem. Bean and alfalfa sprouts include immature leaves, stems, and roots. There are more than one-quarter million kinds of plants on Earth, and their organs exhibit an amazing variety.

Salad of roots, stems, and leaves

Experiment *After reading the first two sections of this chapter, design an investigation to demonstrate how vascular tissue is common to roots, stems, and leaves. Show your plan to your teacher and get permission to perform the investigation. Be sure to follow all laboratory safety rules. Share your findings with your class.*

Roots

Roots are plant organs that anchor a plant, usually absorb water and dissolved minerals, and contain vascular tissues that transport materials to and from the stem. As shown in ***Figure 23.9***, roots may be short or long, and thick and massive or thin and threadlike. The surface area of a plant's roots can be as much as 50 times greater than the surface area of its leaves. Most roots grow in soil but some do not.

The type of root system is genetically determined but can vary because of environmental factors such as soil type, moisture, and temperature. There are two main types of root systems—taproots and fibrous roots. Carrots and beets are taproots, which are single, thick structures with smaller branching roots. Taproots accumulate and store food. Fibrous roots systems have many, small branching roots that grow from a central point.

Some plants, such as the corn in ***Figure 23.10***, have a type of root

Figure 23.9
The taproot of a carrot plant can store large quantities of food and water **(A).** The fibrous roots of grasses absorb water and anchor the plant **(B).**

called prop roots, which originate above ground and help support a plant. Many climbing plants have aerial roots that cling to objects such as walls and provide support for climbing stems. When bald cypress trees grow in swampy soils, they produce modified roots called pneumatophores, which are referred to as "knees." The knees grow upward from the mud, and eventually, out of the water. Knees help supply oxygen to the roots.

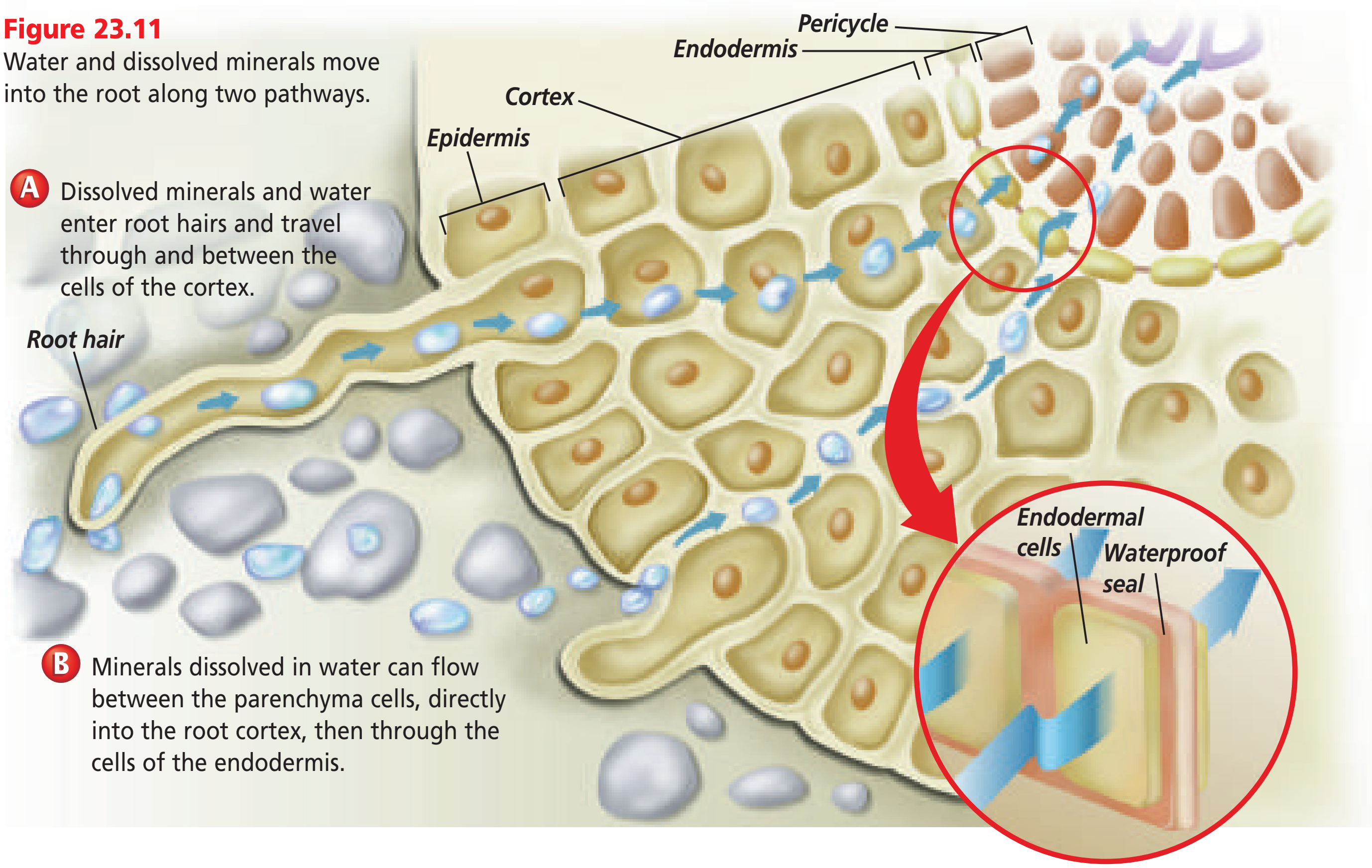
Figure 23.10
As a corn plant grows, prop roots grow from the stem and help keep the tall and top-heavy plant upright.

The structure of roots

If you look at the diagram of a root in ***Figure 23.11***, you can see that a root hair is a tiny extension of an epidermal cell. Root hairs increase the surface area of a root that contacts the soil. They absorb water, oxygen, and dissolved minerals. The next layer is a part of the ground tissue called the **cortex**, which is involved in the transport of water and dissolved minerals into the vascular tissues. The cortex is made up of parenchyma cells that sometimes store food and water.

At the inner limit of the cortex lies the **endodermis**, a layer of cells with waterproof cell walls that form a seal around the root's vascular tissues.

Figure 23.11
Water and dissolved minerals move into the root along two pathways.



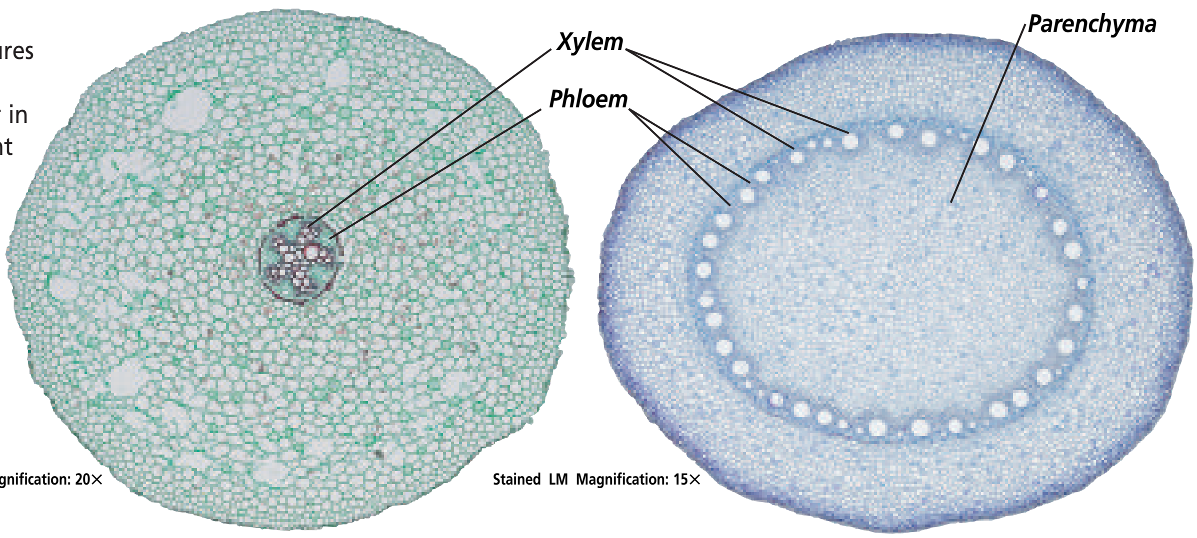


Figure 23.12 The root structures of dicots and monocots differ in the arrangement of xylem and phloem.

A The xylem in this dicot root is arranged in a central star-shaped fashion. The phloem is found between the points of the star.

B In this monocot, there are alternating strands of xylem and phloem that surround a core of parenchyma cells.

The waterproof seal of the endodermis forces water and dissolved minerals that enter the root to pass through the cells of the endodermis. Thus, the endodermis controls the flow of water and dissolved minerals into the root. Next to the endodermis is the **pericycle.** It is the tissue from which lateral roots arise as offshoots of older roots.

Xylem and phloem are located in the center of the root. The arrangement of xylem and phloem tissues, as shown in ***Figure 23.12,*** accounts for one of the major differences between monocots and dicots. In dicot roots, the xylem forms a central star-shaped mass with phloem cells between the rays of the star. Monocot roots usually have strands of xylem that alternate with strands of phloem. There is sometimes a central core of parenchyma cells in the monocot root called a pith.

Word Origin

pericycle from the Greek words *peri,* meaning "around," and *kykos,* meaning "circle"; In vascular plants, the pericycle can produce lateral roots.

endodermis from the Greek words *endon,* meaning "within," and *dermis,* meaning "skin"; In vascular plants, the endodermis is the innermost layer of cells of the root cortex.

Root growth

There are two areas of rapidly dividing cells in roots where the production of new cells initiates growth. The root apical meristem produces cells that

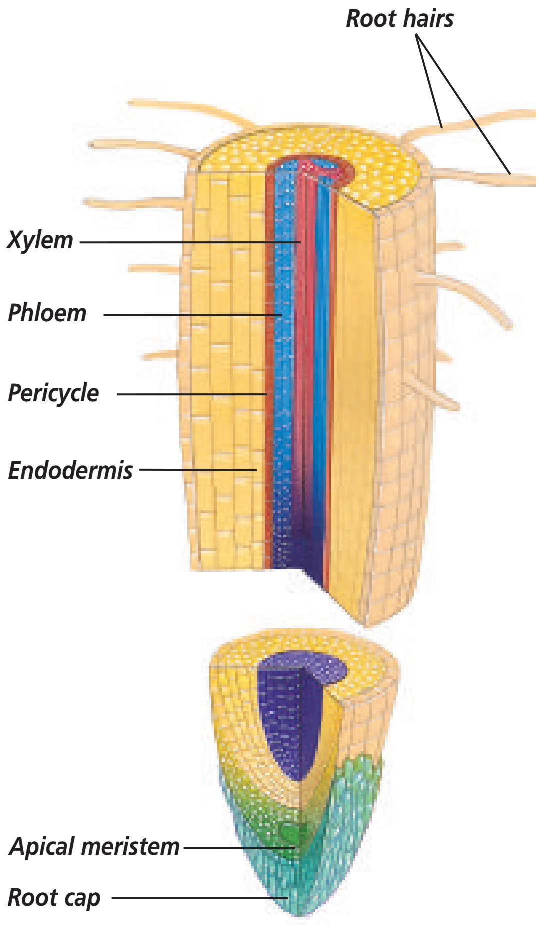


Figure 23.13 Roots develop by both cell division and elongation. As the number and size of cells increases, the root grows in length and width.

cause a root to increase in length. As these cells begin to mature, they differentiate into different types of cells. In dicots, the vascular cambium develops between the xylem and phloem and contributes to a root's growth by adding cells that increase its diameter.

Each layer of new cells produced by the root apical meristem is left farther behind as new cells are added and the root grows forward through the soil. The tip of each root is covered by a protective layer of parenchyma cells called the **root cap.** As the root grows through the soil, the cells of the root cap wear away. Replacement cells are produced by the root apical meristem so the root tip is never without its protective covering. Examine ***Figure 23.13*** on the previous page to see if you can locate all the structures of a root.

Figure 23.14
Plants can use food stored in stems to survive when conditions are less than ideal.

A A white potato is a tuber.

B This gladiolus corm is a thickened, underground stem from which roots, leaves, and flower buds arise.

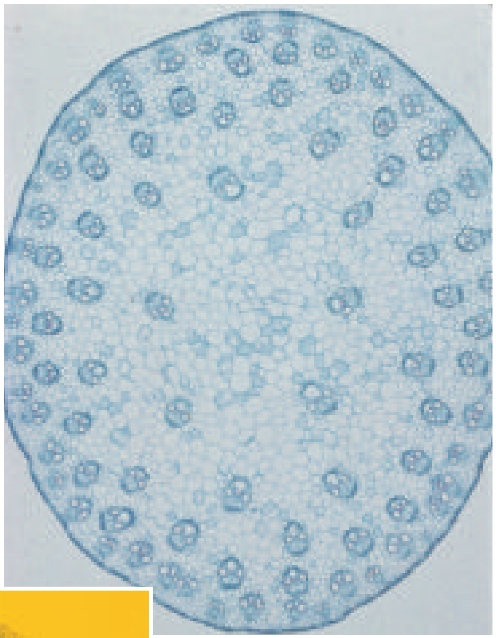
C The rhizome of an iris grows horizontally underground.

Stems

Stems usually are the aboveground parts of plants that support leaves and flowers. They have vascular tissues that transport water, dissolved minerals, and sugars to and from roots and leaves. Their form ranges from the thin, herbaceous stems of basil plants to the massive, woody trunks of trees. Green, herbaceous stems are soft and flexible and usually carry out some photosynthesis. Petunias, impatiens, and carnations are other examples of plants with herbaceous stems. Trees, shrubs, and some other perennials have woody stems. Woody stems are hard and rigid and have cork and vascular cambriums.

Some stems are adapted to storing food. This can enable the plant to survive drought or cold, or grow from year to year. Stems that act as food-storage organs include corms, tubers, and rhizomes. A corm is a short, thickened, underground stem surrounded by leaf scales. A tuber is a swollen, underground stem that has buds from which new plants can grow. Rhizomes also are underground stems that store food. Some examples of these food-storing stems are shown in ***Figure 23.14.***

Figure 23.15
Stems have vascular bundles.



A The vascular bundles in a monocot are scattered throughout the stem as seen in this cross section.

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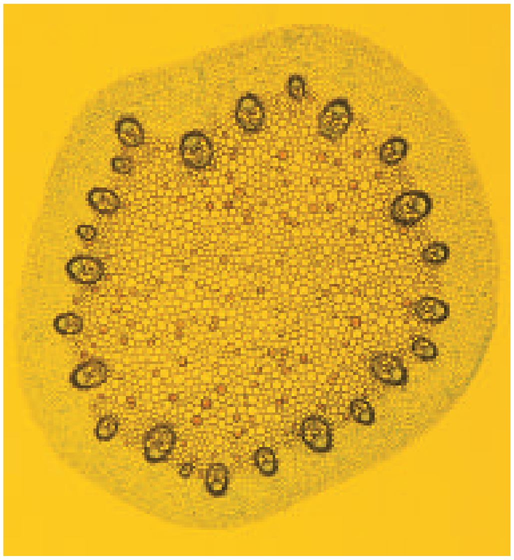

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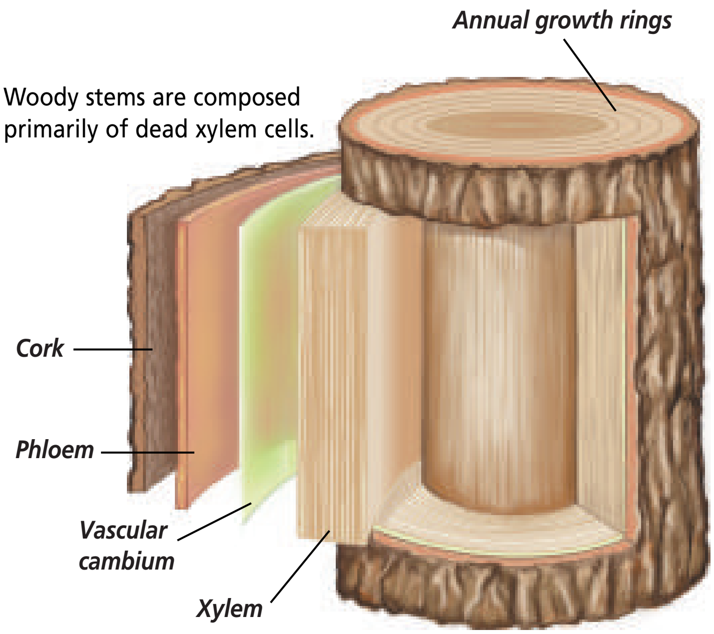
B As seen in this cross section, young herbaceous dicot stems have separate bundles of xylem and phloem that form a ring. In older stems, the vascular tissues form a continuous cylinder.



C Woody stems are composed primarily of dead xylem cells.

Internal structure

Both stems and roots have vascular tissues. However, the vascular tissues in stems are arranged differently from that of roots. Stems have a bundled arrangement or circular arrangement of vascular tissues within a surrounding mass of parenchyma tissue. As you can see in ***Figure 23.15A*** and ***B***, monocots and dicots differ in the arrangement of vascular tissues in their stems. In most dicots, xylem and phloem are in a circle of vascular bundles that form a ring in the cortex. The vascular bundles of most monocots are scattered throughout the stem.

Woody stems

Many conifers and perennial dicots produce thick, sturdy stems, as shown in ***Figure 23.15C***, that may last several years, or even decades. As the stems of woody plants grow in height, they also grow in thickness. This added thickness, called secondary growth, results from cell divisions in the vascular cambium of the stem. The xylem tissue produced by secondary growth is also called wood. In temperate regions, a tree's annual growth rings are the layers of vascular tissue produced each year by secondary growth. These annual growth rings can be used to estimate the age of the plant. The vascular tissues often contain sclerenchyma fibers that provide support for the growing plant.

As secondary growth continues, the outer portion of a woody stem develops bark. Bark is composed of phloem cells and the cork cambium. Bark is a tough, corky tissue that protects the stem from damage by burrowing insects and browsing herbivores.

Stems transport materials

Water, sugars, and other compounds are transported within the stem. Xylem transports water and dissolved minerals from the roots to the leaves. Water that is lost through the leaves is continually replaced by water moving in the xylem. Water forms an unbroken column within the xylem. As water moves up through the xylem, it also carries dissolved minerals to all living plant cells.

The contents of phloem are primarily dissolved sugars but phloem also can transport hormones, viruses, and other substances. The sugars originate in photosynthetic tissues that are usually in leaves. Any portion of the plant that stores these sugars is called a **sink,** such as the parenchyma cells that make up the cortex in the root. The movement of sugars in the phloem is called **translocation** (trans loh KAY shun). ***Figure 23.16*** shows the movement of materials in the vascular tissues of a plant.

Growth of the stem

Primary growth in a stem is similar to primary growth in a root. This increase in length is due to the production of cells by the apical meristem, which lies at the tip of a stem. As mentioned earlier, secondary growth or an increase in diameter is the result of cell divisions in the vascular cambium or lateral meristem. Meristems located at intervals along the stem, called nodes, give rise to leaves and branches.

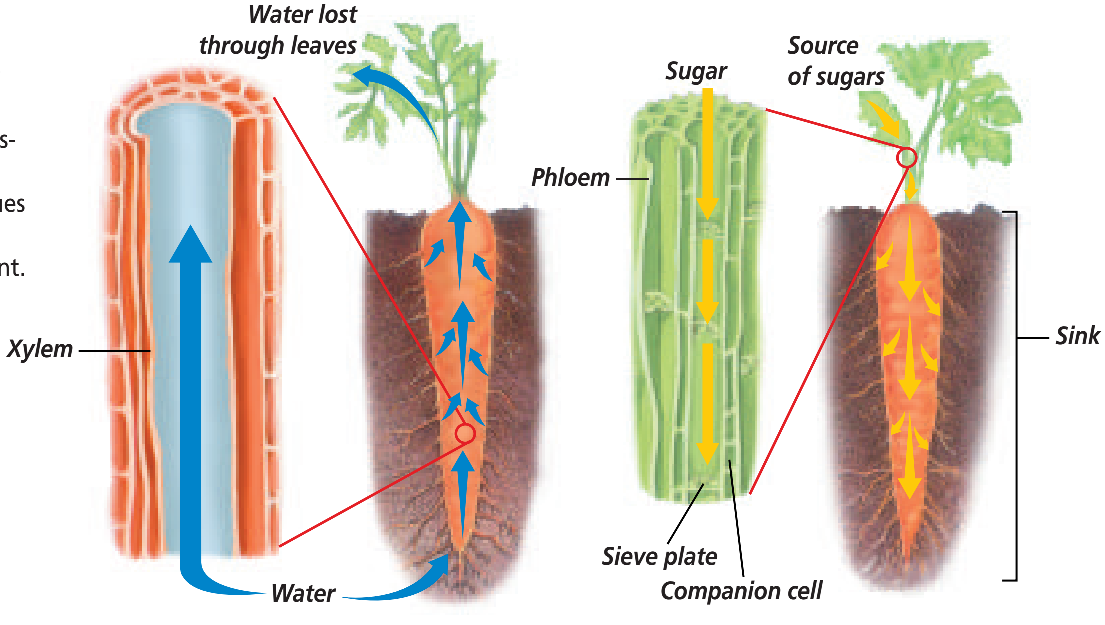
Leaves

The primary function of the leaves is photosynthesis. Most leaves have a relatively large surface area that receives sunlight. Sunlight passes through the transparent cuticle and epidermis into the photosynthetic tissues just beneath the leaf surface.

Leaf variation

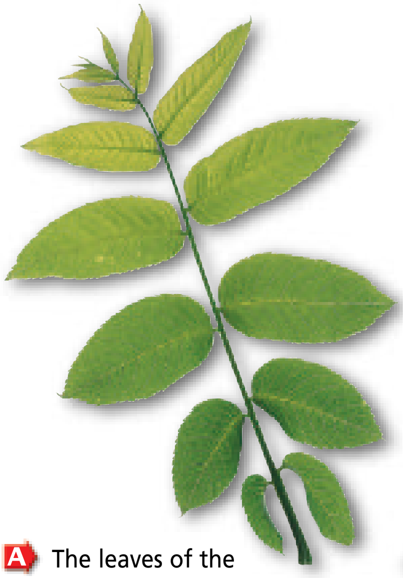
When you think of a leaf, you probably think only of a flat, broad, green structure. This part of the leaf is called the leaf blade. Sizes, shapes, and types of leaves vary enormously. The giant Victoria water lily that grows in some of the rivers of Guyana has floating, circular leaves that can be more than two meters in diameter.

Figure 23.16
Xylem carries water up from roots to leaves. Phloem transports sugars from photosynthetic tissues to sinks located throughout the plant.



A The open ends of xylem vessel cells form complete pipelike tubes.

B Sugars in the phloem of this carrot plant are moving to sinks.



A The leaves of the walnut are compound with many leaflets.

B The needlelike leaves of the evergreen yew can receive sunlight year round.

C The tulip poplar is a deciduous tree with broad, distinctive, simple leaves.

Figure 23.17
Leaf shapes vary, but most are adapted to receive sunlight.

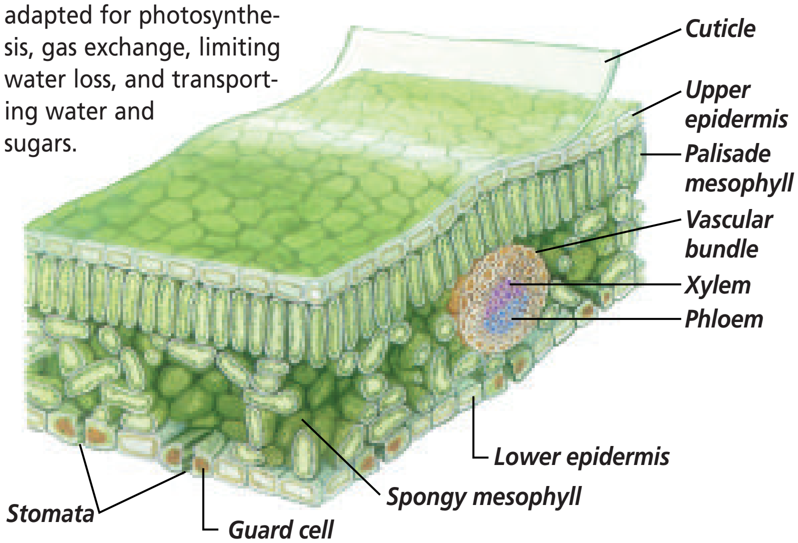
The leaves of duckweed, a common floating plant of ponds and lakes, are measured in millimeters. Some plant species commonly produce different forms of leaves on one plant.

Some leaves, such as grass blades, are joined directly to the stem. In other leaves, a stalk joins the leaf blade to the stem. This stalk, which is part of the leaf, is called the **petiole** (PE tee ohl). The petiole contains vascular tissues that extend from the stem into the leaf and form veins. If you look closely, you will notice these veins as lines or ridges running along the leaf blade.

Leaves vary in their shape and arrangement on the stem. A simple leaf is one with a blade that is not divided. When the blade is divided into leaflets, it is called a compound leaf. ***Figure 23.17*** gives some examples of the variety of leaf shapes.

The arrangement of leaves on a stem can vary. Leaves can grow from opposite sides of the stem in an alternating arrangement. If two leaves grow opposite each other on a stem, the arrangement is called opposite. Three or more leaves growing around a stem at the same position is called a whorled arrangement.

Figure 23.18
The tissues of a leaf are adapted for photosynthesis, gas exchange, limiting water loss, and transporting water and sugars.



Leaf structure

The internal structure of a typical leaf is shown in ***Figure 23.18.*** The vascular tissues are located in the midrib and veins of the leaf. Just beneath the epidermal layer are two layers of mesophyll. **Mesophyll** (MEH zuh fihl) is the photosynthetic tissue of a leaf. It is usually made up of two types of parenchyma cells—palisade mesophyll and spongy mesophyll. The palisade mesophyll is made up of column-shaped cells containing many chloroplasts. These cells are found just under the upper epidermis

(l)Runk-Schoenberger/Grant Heilman Photography (c)Aaron Haupt (r)Runk-Schoenberger/Grant Heilman Photography

and receive maximum exposure to sunlight. Most photosynthesis takes place in the palisade mesophyll. Below the palisade mesophyll is the spongy mesophyll, which is composed of loosely packed, irregularly shaped cells. These cells usually are surrounded by many air spaces that allow carbon dioxide, oxygen, and water vapor to freely flow around the cells. Gases can also move in and out of a leaf through the stomata, which are located in the upper and/or lower epidermis.

Transpiration

You read previously that leaves have an epidermis with a waxy cuticle and stomata that help reduce water loss. Guard cells are cells that surround and control the size of a stoma, as shown in ***Figure 23.19.*** The loss of water through the stomata is called **transpiration.** Learn more about how a plant's surroundings may influence rate of transpiration in *Problem-Solving Lab 23.2* on this page.

Problem-Solving Lab 23.2

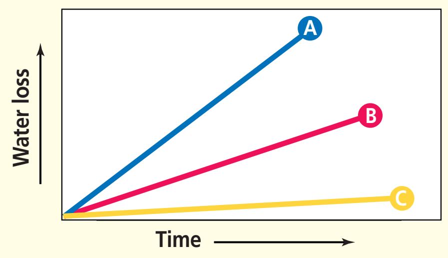
Draw Conclusions

What factors influence the rate of transpiration? Plants lose large amounts of water during transpiration. This process aids in pulling water up from roots to stem to leaves where it can be used in photosynthesis.

Solve the Problem

A student was interested in seeing if a plant's surroundings might affect its rate of water loss. A geranium plant was set up as a control. A second geranium was sealed within a plastic bag and a third geranium was placed in front of a fan. All three plants were placed under lights. The student's experimental data are shown in the graph.

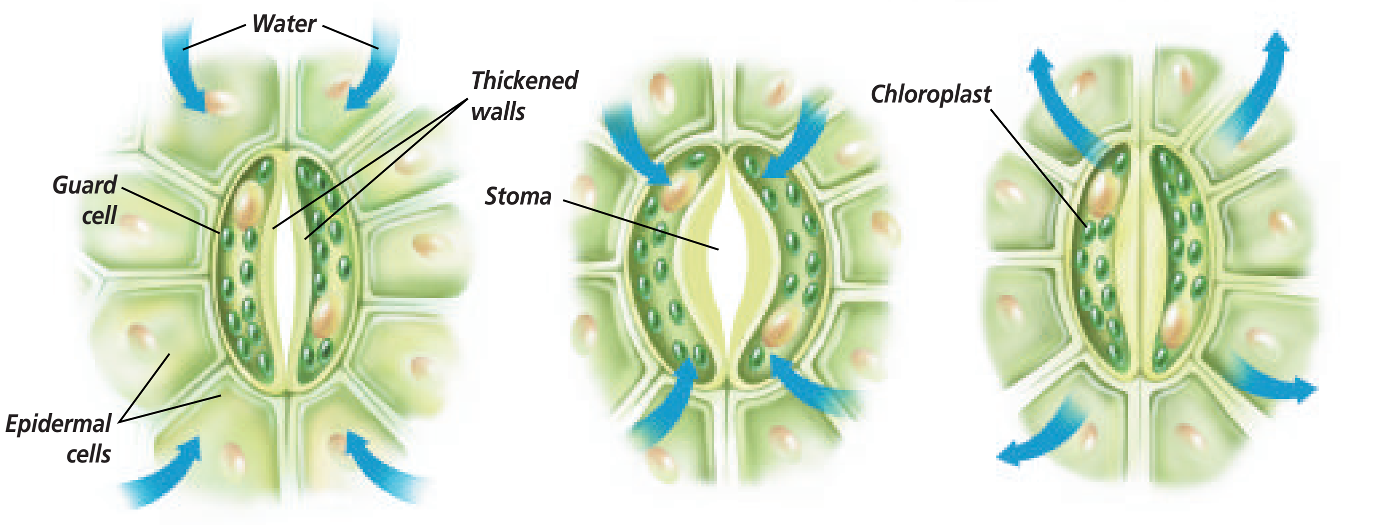
Rate of Water Loss



Thinking Critically

1. **Infer** Which line, A, B, or C, might best represent the student's control data? Explain.
2. a. **Infer** Which line might best represent the data with the plant sealed within a bag? Explain.
   b. **Identify** What abiotic environmental factor was being tested?
3. **Infer** Which line might best represent the data with the plant in front of a fan? Explain.
4. **Conclude** Write a conclusion for the student's experiment.

Figure 23.19
Guard cells regulate the size of the opening of the stomata according to the amount of water in the plant.



A The guard cells have flexible cell walls.

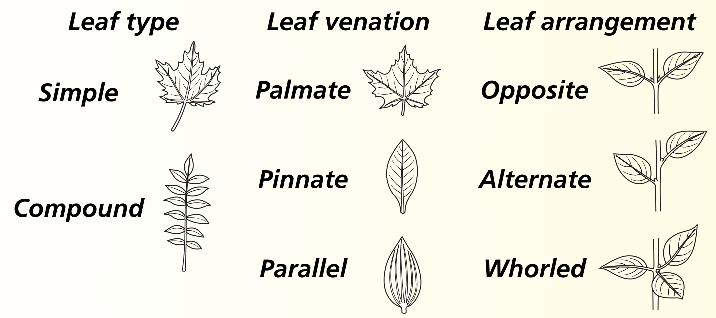
B When water enters the guard cells, the pressure causes them to bow out, opening the stoma.

C As water leaves the guard cells, the pressure is released and the cells come together, closing the stoma.

MiniLab 23.2

Compare and Contrast

Observing Leaves Identifying leaf characteristics can help you identify plants. Use these leaf images to complete this field investigation.



Procedure

CAUTION: ***Keep your hands away from your mouth while doing this investigation. Wash your hands thoroughly after you complete your work.***

1. With your teacher's permission, examine leaves on five different plants on your school campus, or observe preserved leaves. Do not use conifers.
2. Sketch a leaf from each plant. Beside each sketch, label the leaf as simple or compound, list its venation, and write the word that describes its arrangement on the stem.

Analysis

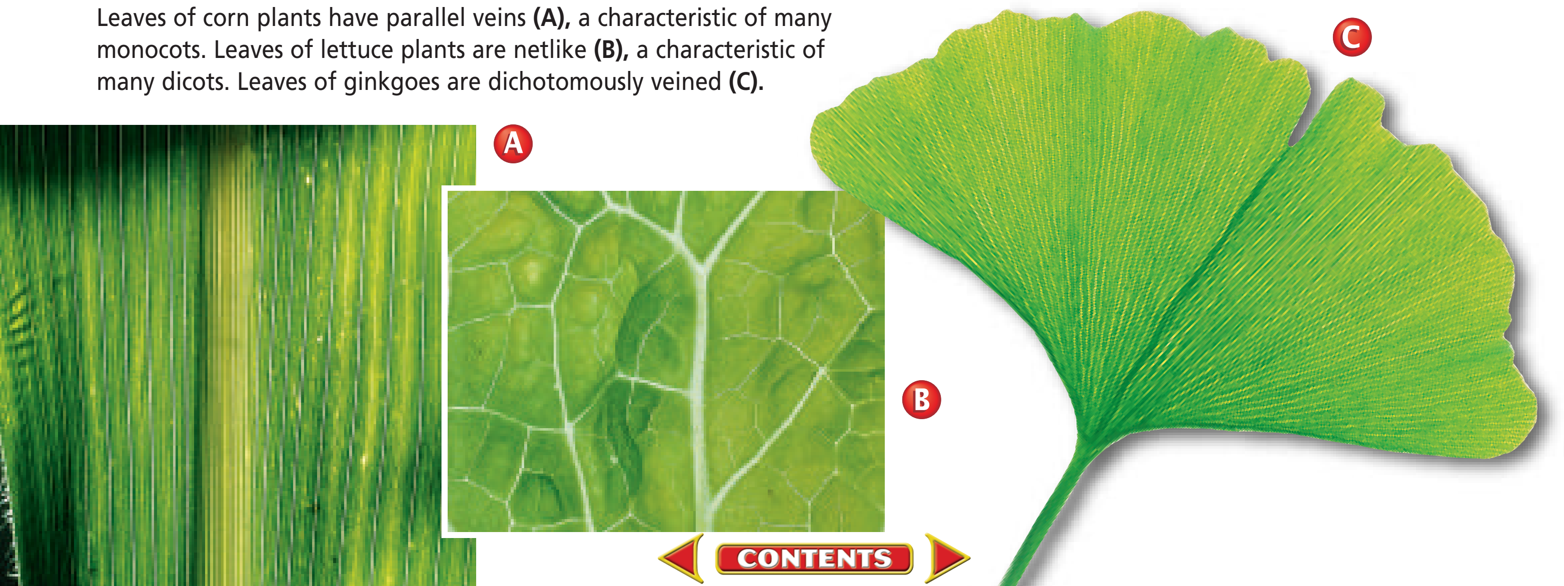
1. **Collect and Organize Data** As a class, place leaves having the same three characteristics into groups. List the characteristics and count the number of leaves in each group. Display class results in a bar graph.
2. **Infer** Why would a botanist compare and contrast leaf structure?

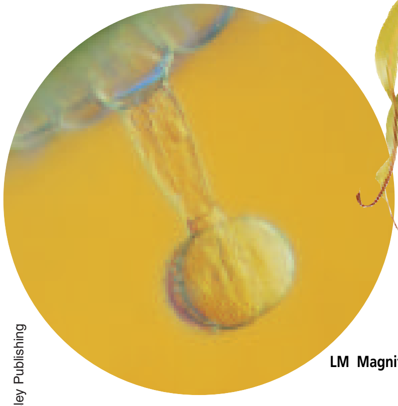
The opening and closing of guard cells regulate transpiration. As you read about how guard cells work, look again at the diagrams in ***Figure 23.19.*** Guard cells are cells scattered among the cells of the epidermis. The walls of these cells contain fiberlike structures. When there is more water available in surrounding cells than in guard cells, water enters guard cells by osmosis. These fiberlike structures in the cell walls of guard cells prevent expansion in width, not in length. Because the two guard cells are attached at either end, this expansion in length forces them to bow out and the stoma opens. When there is less water in surrounding tissues, water leaves the guard cells. The cells return to their previous shape, which reduces the size of the stoma. The proper functioning of guard cells is important because plants lose up to 90 percent of all the water they transport from the roots by transpiration.

Venation patterns

One way to distinguish among different groups of plants is to examine the pattern of veins in their leaves. The veins of vascular tissue run through the mesophyll of the leaf. As shown in ***Figure 23.20,*** leaf venation patterns may be parallel, netlike, or dichotomous. You can learn more about leaf venation in the *MiniLab* shown here.

Figure 23.20
Leaf venation patterns help distinguish between monocots and dicots. Leaves of corn plants have parallel veins **(A),** a characteristic of many monocots. Leaves of lettuce plants are netlike **(B),** a characteristic of many dicots. Leaves of ginkgoes are dichotomously veined **(C).**





A The surface of a tomato leaf has glandular hairs that help repel insects and other predators.

B The leaves of the pitcher plant are modified for trapping insects.

C The leaves of *Aloe vera* are adapted to store water in a dry desert environment.

Figure 23.21
Modified leaves serve many functions in addition to photosynthesis.

Leaf modifications

Many plants have leaves with structural adaptations for functions besides photosynthesis. Some plant leaves have epidermal growths, as shown in ***Figure 23.21A,*** that release irritants when broken or crushed. Animals, including humans, learn to avoid plants with such leaves. Cactus spines are modified leaves that help reduce water loss from the plant and provide protection from predators.

Carnivorous plants, like the pitcher plant in ***Figure 23.21B,*** have leaves with adaptations that can trap insects or other small animals. Other leaf modifications include tendrils, the curly structures on sweet peas, the overlapping scales that enclose and protect buds, and the colorful bracts of poinsettias.

Leaves often function as water or food storage sites. The leaves of *Aloe vera*, shown in ***Figure 23.21C,*** store water. This adaptation ensures the long-term survival of the plant when water resources are scarce. A bulb consists of a shortened stem, a flower bud, and thickened, immature leaves. Food is stored in the bases of the leaves. Onions, tulips, narcissus, and lilies all grow from bulbs.

✓Reading Check **Evaluate** the significance of leaf structural adaptations to their environments.

Section Assessment

Understanding Main Ideas

1. Compare and contrast the arrangement of xylem and phloem in dicot roots and stems.
2. Infer where you would expect to find stomata in a plant with leaves that float on water, such as a water lily. Explain.
3. Describe the primary function of most leaves. List some other functions of leaves.
4. Explain how guard cells function and regulate the size of a stoma.

Thinking Critically

5. Compare and contrast the function and structure of the epidermis and the endodermis in a vascular plant.

Skill Review

6. **Get the Big Picture** Construct a table that summarizes the structure and functions of roots, stems, and leaves. For more help, refer to *Get the Big Picture* in the **Skill Handbook.**

ca.bdol.glencoe.com/self_check_quiz

Section 23.3

Plant Responses

SECTION PREVIEW

Objectives

Identify the major types of plant hormones.

Identify and analyze the different types of plant responses.

Review Vocabulary

stimulus: anything in an organism's internal or external environment that causes the organism to react (p. 9)

New Vocabulary

hormone
auxin
gibberellin
cytokinin
ethylene
tropism
nastic movement

Humans and Plants Respond to Sunlight

Using an Analogy You step outside into the bright sunlight and immediately raise your hand to shade your eyes. You react quickly to the bright sunlight. Plants react to sunlight, too. Often, however, plant responses to things in their environment are so slow that they can only be captured by time-lapse photography. When filmed in this way, the flower heads of sunflowers can be seen moving with the sun's apparent movement across the sky. In this section, you will read about other plant stimuli and responses.

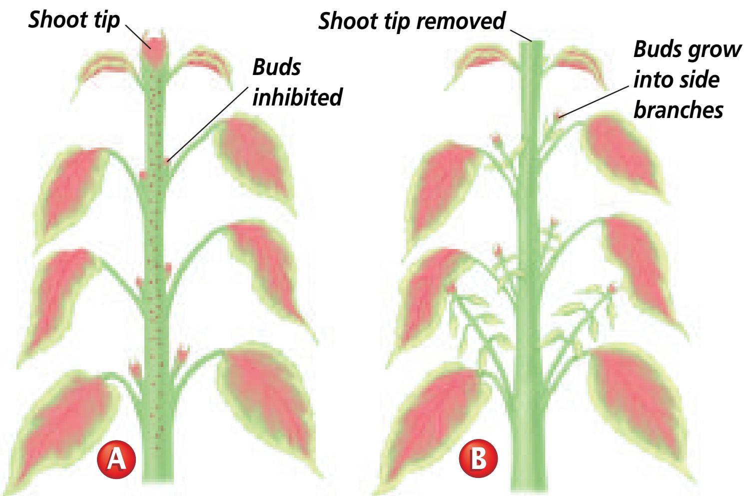
Sunflowers

Make and Use Tables *As you read this section, make a table of plant stimuli and responses. Include the source of the stimulus and describe how the plant responds. When studying this chapter, use the table to review this section.*

Plant Hormones

Plants, like animals, have hormones that regulate growth and development. A **hormone** is a chemical that is produced in one part of an organism and transported to another part, where it causes a physiological change. Only a small amount of the hormone is needed to make this change.

Figure 23.22
Auxin produced in the tip of the main shoot inhibits the growth of side branches **(A)**. Once the tip is removed, the side branches start to grow **(B)**.



Auxins cause stem elongation

The group of plant hormones called **auxins** (AWK sunz) promotes cell elongation. Indoleacetic (in doh luh SEE tihk) acid (IAA)—a naturally occurring auxin—is produced in apical meristems of plant stems. IAA weakens the connections between the cellulose fibers in the cell wall, which allows a cell to stretch and grow longer. The combination of new cells from the apical meristem and increasing cell lengths leads to stem growth. Auxin is not transported in the vascular system. It moves from one parenchyma cell to the next by active transport.

Envision/Priscilla Connell

Auxins have other effects on plant growth and development. Auxin produced in the apical meristem inhibits the growth of side branches. Removing the stem tip reduces the amount of auxin present and allows the development of branches, as shown in ***Figure 23.22.***

Auxin also delays fruit formation and inhibits the dropping of fruit from the plant. When auxin concentrations decrease, the ripened fruits of some trees fall to the ground and deciduous trees begin to shed their leaves.

Reading Check **Infer** how a fruit grower might use auxins.

Gibberellins promote growth

The group of plant growth hormones called **gibberellins** (jih buh REH lunz) causes plants to grow taller because, like auxins, they stimulate cell elongation. Unlike auxins, gibberellins are transported in vascular tissue. Many dwarf plants, such as those in ***Figure 23.23,*** are short because the plant does not produce gibberellins or its cells are not receptive to the hormone. If gibberellins are applied to the tip of a dwarf plant, it will grow taller. Gibberellins also increase the rate of seed germination and bud development. Farmers have learned to use gibberellins to enhance fruit formation. Florists often use gibberellins to induce flower buds to open.

Cytokinins stimulate cell division

The hormones called **cytokinins** (si tuh KI nihnz) stimulate mitosis and cell division. Cytokinins stimulate the production of proteins needed for mitosis and cell division. Most cytokinins are produced in root meristems. This hormone travels up the xylem to other parts of the plant. The effects of cytokinins are often enhanced by the presence of other hormones.

Figure 23.23
The bean plants in this picture are genetic dwarfs. The two plants on the right were treated with gibberellin and have grown to a normal height.

(t)Runk-Schoenberger/Grant Heilman Photography

Ethylene gas promotes ripening

The plant hormone **ethylene** (EH thuh leen) is a simple, gaseous compound composed of carbon and hydrogen. It is produced primarily by fruits, but also by leaves and stems. Ethylene is released during a specific stage of fruit ripening. It causes cell walls to weaken and become soft. Ethylene speeds the ripening of fruits and promotes the breakdown of complex carbohydrates to simple sugars. If you have ever enjoyed a ripe red apple you know that it tastes sweeter than an immature fruit.

Many farmers use ethylene to ripen green fruits or vegetables after they have been picked, as shown in ***Figure 23.24.***

Word Origin

auxin from the Greek word *auxein,* meaning "to increase"; Auxin causes stem elongation by increasing cell length.

Figure 23.24
Tomatoes are usually picked when they are green then they are treated with ethylene. Most of the tomatoes you see in grocery stores have been ripened in this manner.

(bl)Envision/Osentoski & Zoda (br)A. Louis Goldman/Photo Researchers

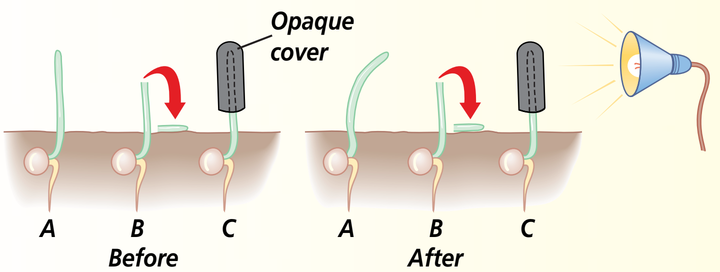
Problem-Solving Lab 23.3

Draw a Conclusion

How do plant stems respond to light? While working with young oat plants, Charles Darwin made discoveries about the response of young plant stems to light that helped explain why plants undergo phototropism. Scientists now know that this response is the result of an auxin that causes rapid cell elongation to occur along one side of a young plant stem. However, auxins were unknown during Darwin's time.

Solve the Problem

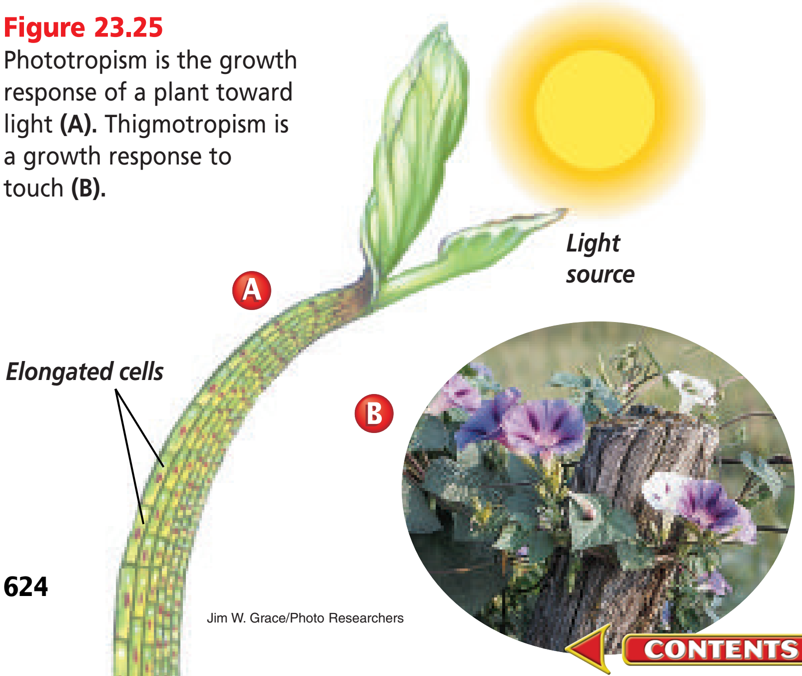
Study the before and after diagrams. The three plants are young oat stems. Note that the light source is directed at the plants from one side.



Thinking Critically

1. **Interpret Scientific Illustrations** Which diagram (or diagrams) supports the conclusion that light is the stimulus for phototropism? Explain.
2. **Interpret Scientific Illustrations** Which diagram (or diagrams) supports the conclusion that the stem tip is the stimulus for phototropism? Explain.
3. **Conclude** Where might the auxin responsible for phototropism be produced? Explain.

Figure 23.25
Phototropism is the growth response of a plant toward light **(A).** Thigmotropism is a growth response to touch **(B).**



Jim W. Grace/Photo Researchers

Plant Responses

Why do roots grow down and most stems grow up? Although a plant lacks a nervous system and usually cannot make quick responses to stimuli, it does have mechanisms that enable it to respond to its environment. Plants grow, reproduce, and reposition their roots, stems, and leaves in response to environmental conditions, such as gravity, light, temperature, and amount of darkness.

Tropic responses in plants

At the beginning of this section, you read that the flower heads of sunflowers slowly respond to the sun's apparent movement across the sky. **Tropism** is a plant's response to an external stimulus. The tropism is called positive if the plant grows toward the stimulus. The tropism is called negative if the plant grows away from the stimulus.

The growth of a plant toward light is called phototropism. It is caused by an unequal distribution of auxin in the plant's stem. There is more auxin on the side of the stem away from the light. This results in cell elongation, but only on that side. As these cells lengthen, the stem bends toward the light, as shown in ***Figure 23.25A.*** You can learn more about phototropism in the *Problem-Solving Lab* on this page.

There is another tropism associated with the upward growth of stems and the downward growth of roots. Gravitropism is plant growth in response to gravity. Gravitropic responses are beneficial to plants. Roots that grow down into the soil are able to anchor the plant and can take in water and dissolved minerals. Stems usually exhibit a negative gravitropism.

Some plants exhibit another tropism called thigmotropism, which is a growth response to touch. The tendrils

Figure 23.26 When leaflets of *Mimosa pudica* are touched, they move inward **(A).** Trigger hairs must be touched to close the hinged leaf of a Venus's-flytrap **(B).** Infer ***How do these adaptations help ensure the long-term survival of each species?***

of the vine in ***Figure 23.25B*** have coiled around a fence after making contact during early growth.

Because tropisms involve growth, they are not reversible. The position of a stem that has grown several inches in a particular direction cannot be changed. But, if the direction of the stimulus is changed, the stem will begin growing in another direction.

Nastic responses in plants

A responsive movement of a plant that is not dependent on the direction of the stimulus is called a **nastic movement.** An example of a nastic movement is the movement of *Mimosa pudica* leaflets when they are touched, as shown in ***Figure 23.26A.*** This is caused by a change in water pressure in the cells at the base of each leaflet. A dramatic drop in pressure causes the cells to become limp and the leaflets to change orientation.

Another example of a nastic response is the sudden closing of the hinged leaf of a Venus's-flytrap, ***Figure 23.26B.*** If an insect triggers sensitive hairs on the inside of the leaf, the leaf snaps shut. Nastic responses that are due to changes in cellular water pressure are reversible because they do not involve growth. The *Mimosa pudica* and Venus's-flytrap leaves return to their original positions once the stimulus ends.

Section Assessment

Understanding Main Ideas

1. Define a hormone.
2. Compare and contrast tropic responses and nastic movements.
3. Explain how a plant can bend toward sunlight. What term describes this response?
4. Name one plant hormone and describe how it functions.
5. Explain why gardeners often remove stem tips of chrysanthemum plants during early summer.

Thinking Critically

6. One technique that has been used for years to ripen fruit is to put a ripened banana in a paper bag with the unripe fruit. Infer what happens inside the bag.

Skill Review

7. **Experiment** Explain how you would design an experiment to investigate the effects of different colors of light on the phototropism of a plant. For more help, refer to *Experiment* in the **Skill Handbook.**

INTERNET

BioLab

Before You Begin

If asked to count the total number of stomata on a leaf, you might answer by saying "that's an impossible task." It may not be necessary for you to count each and every stoma. Sampling is a technique that is used to arrive at an answer that is close to the actual number. You will use a sampling technique in this *BioLab.*

Determining the Number of Stomata on a Leaf

PREPARATION

Problem

How can you count the total number of stomata on a leaf?

Objectives

In this BioLab, you will:

- **Measure** the area of a leaf.
- **Observe** the number of stomata seen under a high-power field of view.
- **Calculate** the total number of stomata on a leaf.
- **Use the Internet** to collect and compare data from other students.

Materials

microscope
glass slide
water and dropper
single-edged razor blade
ruler
coverslip
green leaf from an onion plant

Safety Precautions

CAUTION: ***Wear latex gloves when handling an onion.***

Skill Handbook

If you need help with this lab, refer to the **Skill Handbook.**

PROCEDURE

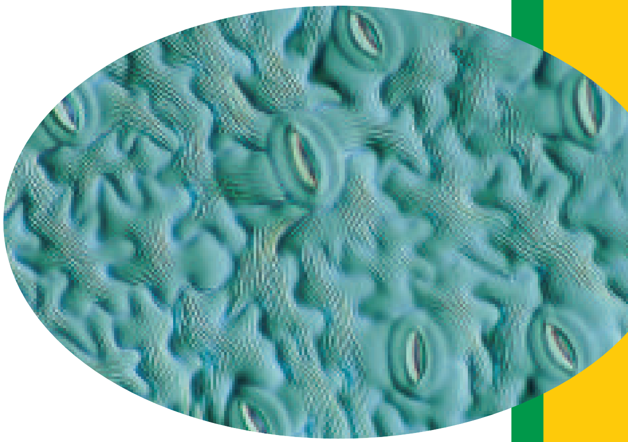
1. Copy Data Table 1 and Data Table 2.
2. To calculate the area of the high-power field of view for your microscope, go to *Math Skills* in the **Skill Handbook.** Enter the area in Data Table 2.
3. Obtain an onion leaf and carefully cut it open lengthwise using a single-edged razor blade. **CAUTION:** ***Be careful when cutting with a razor blade.***
4. Measure the length and width of your onion leaf in millimeters. Record these values in Data Table 2.
5. Remove a small section of leaf and place it on a glass slide with the dark green side facing DOWN.
6. Add several drops of water and gently scrape away all green leaf tissue using the razor blade. An almost transparent layer of leaf epidermis will be left on the slide.

Data Table 1

Trial	Number of Stomata
1	
2	
3	
4	
5	
Total	
Average	

CONTENTS

7. Add water and a coverslip to the epidermis. Observe under low-power magnification and locate an area where guard cells and stomata can be seen clearly. **CAUTION:** ***Use caution when handling a microscope, microscope slides, and coverslips.***
8. Switch to high-power magnification.
9. Count the number of stomata in your field of view. This is Trial 1. Record your count in Data Table 1.
10. Move the slide to a different area. Count the number of stomata in this field of view. This is Trial 2. Record your count in Data Table 1.
11. Repeat step 10 for Trials 3, 4, and 5. Calculate the average number of stomata observed.
12. Calculate the total number of stomata on the entire onion leaf by following the directions in Data Table 2.
13. **CLEANUP AND DISPOSAL** Clean all equipment as instructed by your teacher, and return everything to its proper place. Dispose of leaf tissue and coverslips properly. Wash your hands thoroughly.



LM Magnification: 200×

Data Table 2

Area of high-power field of view	= ____ mm^2
Length of leaf portion in mm	= ____ mm
Width of leaf portion in mm	= ____ mm
Calculate area of leaf (length × width)	= ____ mm^2
Calculate number of high-power fields of view on leaf (area of leaf ÷ the area of one high-power field of view)	= ____
Calculate total number of stomata (number of high-power fields of view × average number of stomata from Data Table 1)	= ____

ANALYZE AND CONCLUDE

1. **Communicate** Compare your data with those of your classmates. Offer several reasons why your total number of stomata for the leaf may not be identical to your classmates.
2. **Predict** Would you expect all plants to have the same number of stomata per high-power field of view? Explain your answer.
3. **Compare and Contrast** What are the advantages to using sampling techniques? What are some limitations?
4. **ERROR ANALYSIS** Analyze the following procedures from this experiment and explain how you can change them to improve the accuracy of your data.
   a. five trials in Data Table 1
   b. calculating the area of your high-power field of view

Share Your Data

Interpret Data Find this BioLab using the link below, and post your data in the data tables provided for this activity. Using the additional data from other students on the Internet, analyze the combined data and complete your graph.

ca.bdol.glencoe.com/internet_lab

Connection to Art

Red Poppy

by Georgia O'Keeffe (1887–1986)

"When you take a flower in your hand and really look at it," O'Keeffe said, cupping her hand and holding it close to her face, "it's your world for the moment. I want to give that world to someone else. Most people in the city rush around so, they have no time to look at a flower. I want them to see it whether they want to or not."

American artist Georgia O'Keeffe attracted much attention when the first of her many floral scenes was exhibited in New York in 1924. Everything about these paintings—their color, size, point of view, and style—overwhelmed the viewer's senses, just as their creator had intended.

In describing her huge paintings of solitary flowers, Georgia O'Keeffe said: "I decided that I wasn't going to spend my life doing what had already been done." Indeed, she did do what had not been done by painting enormous poppies, lilies, and irises on giant canvases. Her use of colors and emphasis on shapes suggests nature rather than copying it with photographic realism. Her work can be described as abstract. "I found that I could say things with color and shapes that I couldn't say in any other way—things that I had no words for," she said.

The viewer's eye is drawn into the flower's heart In this early representation of one of her familiar poppies, O'Keeffe directed the viewer's eye down into the poppy's center by contrasting the light tints of the outer ring of petals with the darkness of the poppy's center. The viewer's eye is drawn to the center of the flower, much as the flower naturally attracts an insect for reproduction purposes. The overwhelming size and detailed interiors of O'Keeffe's flowers give an effect similar to a photographer's close-up camera angle.

During her long life, O'Keeffe created hundreds of paintings. Her subjects included the flowers for which she is perhaps most famous, as well as other botanical themes. Her paintings of New Mexico deserts are characterized by sweeping forms that portray sunsets, rocks, and cliffs.

Georgia O'Keeffe died in New Mexico in 1986. She is remembered for her bold, vivid paintings that are, indeed, larger than life.

Writing About Biology

Critique It's easy to identify the flowers in O'Keeffe's paintings, but can they be considered scientific models? Look at the poppy flower photograph on page 957 of this book. Write a critique that evaluates each of these models—O'Keeffe's poppy and the photograph—according to its adequacy in representing a poppy flower.

To find out more about Georgia O'Keeffe, visit ca.bdol.glencoe.com/art

Chapter 23 Assessment

Study Guide

Section 23.1

Plant Cells and Tissues

Color-enhanced SEM Magnification: 200×

Key Concepts

- Most plant tissues are composed of parenchyma cells, collenchyma cells, and sclerenchyma cells.
- Dermal tissue is a plant's protective covering.
- Xylem moves water and dissolved minerals up from roots and throughout the plant. Phloem transports sugars and organic compounds throughout the plant.
- Ground tissue often functions in food production and storage.
- Meristematic tissues undergo cell divisions. Most plant growth results from new cells produced in the meristems.

Vocabulary

apical meristem (p. 611)
collenchyma (p. 606)
companion cell (p. 610)
cork cambium (p. 611)
epidermis (p. 607)
guard cell (p. 607)
meristem (p. 611)
parenchyma (p. 605)
phloem (p. 610)
sclerenchyma (p. 606)
sieve tube member (p. 610)
stomata (p. 607)
tracheid (p. 608)
trichome (p. 607)
vascular cambium (p. 611)
vessel element (p. 608)
xylem (p. 608)

Section 23.2

Roots, Stems, and Leaves

Key Concepts

- Roots anchor plants and contain vascular tissues. Root hairs absorb water, oxygen, and dissolved minerals. A root cap covers and protects each root tip.
- Stems provide support, contain vascular tissues, and produce leaves. Some stems are underground.
- Leaves undergo photosynthesis. A stoma is an opening in the leaf epidermis, is surrounded by two guard cells, and takes in and releases gases. Veins in leaves are bundles of vascular tissues.

Vocabulary

cortex (p. 613)
endodermis (p. 613)
mesophyll (p. 618)
pericycle (p. 614)
petiole (p. 618)
root cap (p. 615)
sink (p. 617)
translocation (p. 617)
transpiration (p. 619)

Section 23.3

Plant Responses

Key Concepts

- Plant hormones affect plant growth and functions.
- Tropisms are growth responses to external stimuli.
- Some nastic responses are caused by changes in cell pressure.

Vocabulary

auxin (p. 622)
cytokinin (p. 623)
ethylene (p. 623)
gibberellin (p. 623)
hormone (p. 622)
nastic movement (p. 625)
tropism (p. 624)

FOLDABLES Study Organizer To help you review plant structure and function, use the Organizational Study Fold on page 605.

ca.bdol.glencoe.com/vocabulary_puzzlemaker

Chapter 23 Assessment

Vocabulary Review

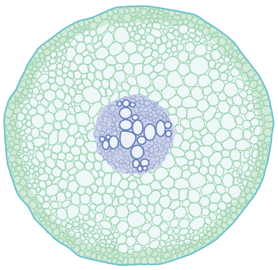
Review the Chapter 23 vocabulary words listed in the Study Guide on page 629. For each set of vocabulary words, choose the one that does not belong. Explain why it does not belong.

1. parenchyma—sclerenchyma—apical meristem
2. vessel element—sieve tube member—companion cell
3. stomata—vascular cambium—epidermis
4. root cap—translocation—sink
5. cytokinin—hormone—tropism

Understanding Key Concepts

6. The tissue that makes up the protective covering of a plant is ________ tissue.
   A. vascular **C.** ground
   B. meristematic **D.** dermal

7. This root cross section with a core of vascular tissue is typical of ________ plants.



   A. horsetail
   B. monocot
   C. dicot
   D. moss

8. A cambium and a meristem are examples of ________ tissues.
   A. support **C.** growth
   B. protective **D.** transport

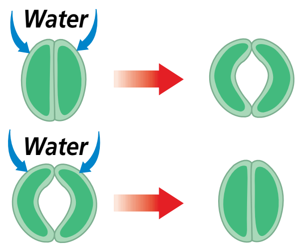
9. One of the primary structural differences between dicot roots and stems is the ________.
   A. arrangement of vascular tissues in roots and stems
   B. presence of stomata in roots
   C. lack of an epidermis in stems
   D. presence of an apical meristem in stems only

10. The ripening of fruit is stimulated by the presence of ________.
   A. gibberellin
   B. ethylene
   C. auxin
   D. cytokinin

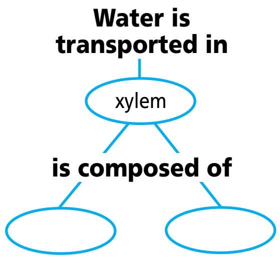
11. Which diagram correctly shows the functioning of guard cells?

A.

B.



12. Which terms complete this concept map?
   A. tracheids and vessel elements
   B. companion cells and fibers
   C. tracheids and sieve tubes
   D. companion cells and sieve tubes



Constructed Response

13. **Open Ended** In late winter, some sugar maple trees have holes drilled in their trunks in order to collect their sap, a sugary fluid. This sap is processed to make maple syrup. Explain the source of the sap, and identify the plant system and subsystem that contains it.

14. **Open Ended** How does the endodermis control the flow of water and ions into root vascular tissues?

Thinking Critically

15. **Compare and Contrast** Identify and analyze characteristics of plant systems and subsystems.

16. **REAL WORLD BIOCHALLENGE** More than 5000 products are made from the vascular tissues of about 1000 tree species in the United States. Investigate the production of lumber, paper, fuel, charcoal and its products, fabrics, maple syrup, spices, dyes, and drugs that come from vascular tissues. Visit ca.bdol.glencoe.com to research these topics. Prepare and present a poster or multimedia presentation of your findings.

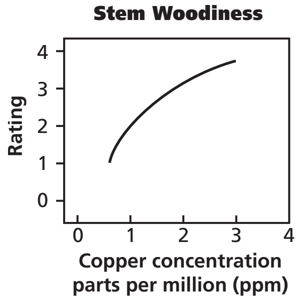
ca.bdol.glencoe.com/chapter_test

California Standards Practice

All questions aligned and verified by The Princeton Review

Part 1 Multiple Choice

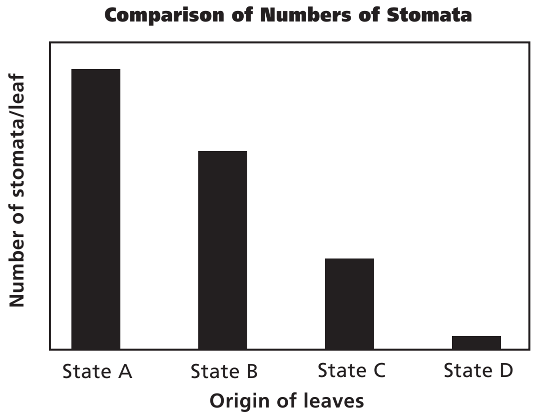
Use data in the graph below to answer questions 17 and 18.



17. Copper is an important soil micronutrient for plants. According to the graph, the copper concentration that resulted in the woodiest stem is ________.
- **A.** 3 ppm
- **B.** 0.5 ppm
- **C.** 1.5 ppm
- **D.** 4 ppm

18. Without enough copper, branches of some conifers twist as they grow. If you were a tree grower and some of your conifer trees' branches were twisted and bent, what is the correct course of action to take first?
- **A.** Water the trees more.
- **B.** Apply fertilizer.
- **C.** Test the soil to determine nutrient levels.
- **D.** Apply a pesticide.

Leaf samples from the same plant species were collected from four different locations. Stomata were counted and averaged, and the data were graphed as shown below. Use the graph to answer questions 19 and 20.



19. In which location might there be the most rainfall?
- **A.** State A
- **B.** State B
- **C.** State C
- **D.** State D

20. How might the number of stomata correlate with the amount of rainfall?
- **A.** more stomata, less rainfall
- **B.** no stomata, no rainfall
- **C.** more stomata, more rainfall
- **D.** fewer stomata, more rainfall

Part 2 Constructed Response/Grid In

Record your answers on your answer document.

21. **Open Ended** Sometimes foresters kill selected trees to reduce competition for limited environmental resources. They often use a process called girdling that involves removing a band of bark and some wood from around the trunk of a tree. Once this circle of material is removed, the tree eventually dies. Explain why this can happen.

22. **Open Ended** In the last decade, over three million acres of privately owned, forested land has been converted to agricultural uses, real estate development, and other uses. Describe what might be the biological and ecological results of these changes.