2.1 Plant Cells, Tissues, and Organs

Key Terms

cell specialization
cell differentiation
tissue
organ
meristematic cell
transpiration
gall

As shown in **Figure 2.1**, tree planters help to speed the process of regrowth in a forest that has been burned or logged. However, even if seedlings are not planted, seeds will be brought in naturally, either by the wind or by animals. How do these seeds change, turning into seedlings and finally adult trees? The answer lies in the processes of mitosis and **cell specialization**.

Cell Specialization

For many years, scientists wondered how the cells of a tiny seed specialize to become all the different parts of a plant. They knew that all body cells in an organism are produced through mitosis, which results in daughter cells with identical genetic information. Yet all cells are not identical, as you can see in **Figure 2.2**. At some point in their development, cells that start out being the same undergo **cell differentiation**, which results in cells specialized for different functions.

Cells are specialized according to the set of proteins they contain. Genes are responsible for producing proteins. Although all the cells in an organism contain all the same genes, not all genes are turned on in any given cell. One set of genes is turned on in one cell type and another set of genes is turned on in another cell type. The proteins produced in a cell determine the eventual function of that cell. The cell is then said to be specialized for a given task.

cell specialization the process by which cells develop from similar cells into cells that have specific functions within a multicellular organism

cell differentiation a stage of development of a living organism during which specialized cells form

Figure 2.1 Many students work as tree planters during the summer months, often planting hundreds of seedlings each day.

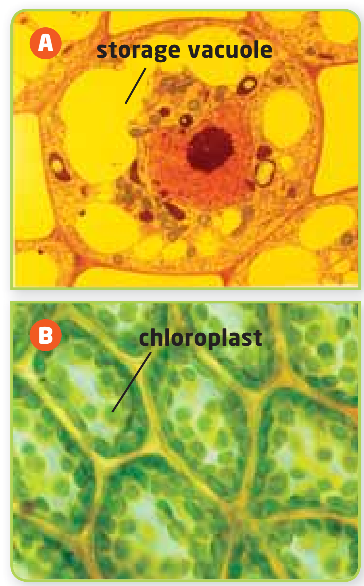


Figure 2.2 Differences between various specialized plant cells can be seen easily using a compound light microscope. **A** Cells that are specialized for storing energy usually have big storage vacuoles that take up most of the cell's inner space. **B** Cells that are specialized for photosynthesis are packed full of *chloroplasts*–the organelle where photosynthesis occurs.

Specialized Cells and Tissues in Plants

tissue a cluster of similar cells that share the same specialized structure and function

organ a combination of several types of tissue working together to perform a specific function

meristematic cell an unspecialized plant cell that gives rise to a specific specialized cell

A healthy plant is always growing and making new specialized cells—except when dormant during cold or very hot weather. Groups of specialized cells form **tissues**, and groups of tissues work together in **organs**, such as roots, stems, and leaves. Each plant organ performs critical tasks for a plant's survival.

What is responsible for this constant growth? Special cells, called **meristematic cells** or meristem, are responsible. Meristematic cells are undifferentiated cells that can form specialized cells in plants. These cells have also been called "permanent embryos" because of their lifelong ability to produce the cells that can become new tissues and organs in their part of a plant.

Meristematic cells are constantly producing more cells, which then become specialized. These cells combine to form the three types of tissues found in the body of a plant: dermal tissue, ground tissue, and vascular tissue, as shown in **Figure 2.3**. The cells in each of these tissues are specialized to perform specific tasks, such as photosynthesis or controlling gas exchange.

A *Dermal tissue* forms the outermost covering of the plant's organs. It is a barrier between the plant and its external environment. Dermal tissue protects the delicate inner tissues from damage and controls the exchange of water and gases between the plant and its environment. An epidermal cell is one type of cell that makes up dermal tissue.

B *Ground tissue* has several functions. For example, some ground tissue is made of cells that perform photosynthesis, while other ground tissue is made of cells that provide support for the plant's body.

C *Vascular tissue* performs the critical job of transporting water, nutrients, and sugars throughout the plant. It also helps to provide physical support for the plant's body.

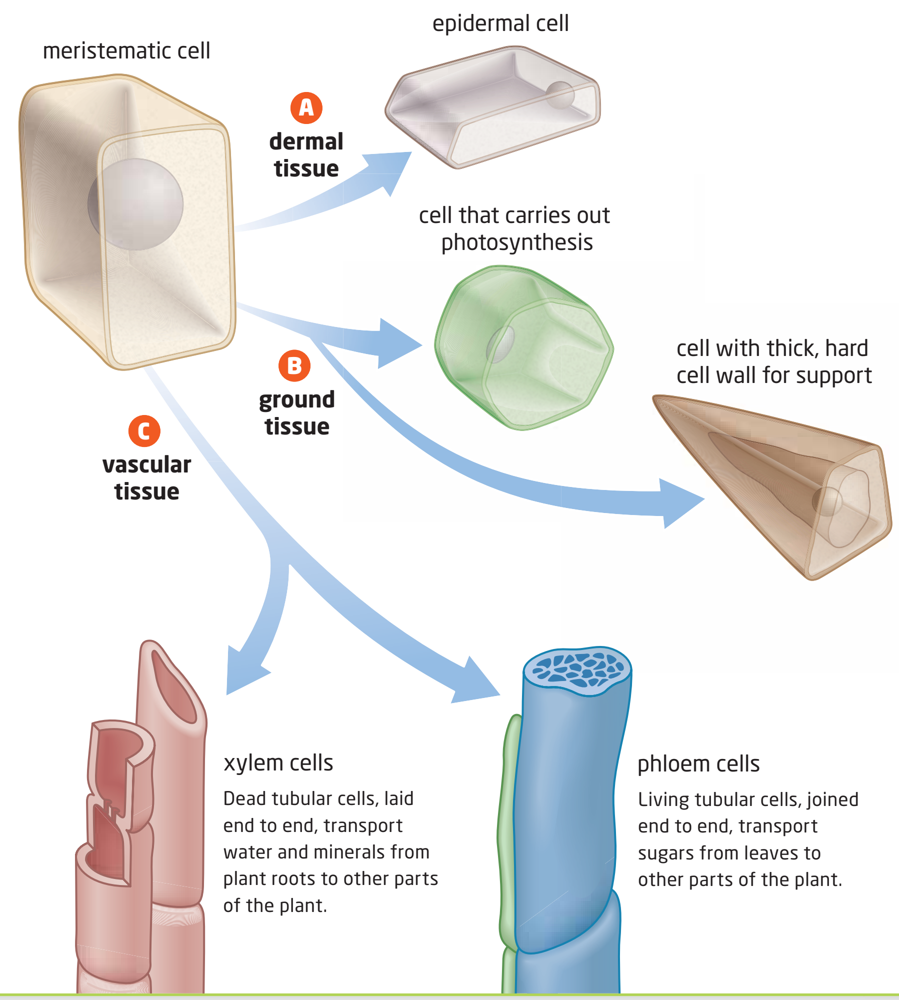


Figure 2.3 Meristematic cells produce new cells that differentiate into the specialized cells that make up different plant tissues.

Repairing and Replacing Specialized Cells

The cells, tissues, and organs of multicellular animals, such as worms, fish, frogs, snakes, birds, and mammals are formed as the embryo develops. While some cells and tissues can be repaired and replaced, organs must last for an animal's lifetime.

Plants are different. In addition to forming new cells and tissues, plants form new organs periodically throughout their lives. For example, as leaves become less efficient with age, these light-collecting organs die and are replaced by new, more efficient leaves. Roots grow continuously, too, so there are always fresh roots to absorb water and minerals from the soil.

As shown in **Figure 2.4**, growing plants push upward, downward, and outward because of rapidly dividing meristematic cells (meristem) at the tips of roots and branches. Some produce cells specialized for leaves and flowers. A *bud* is a swelling of the stem that contains meristem for new, not yet developed, tissues in organs such as leaves and flowers. A plant's most active growth occurs near the *terminal bud*. The *lateral buds* are dormant (inactive), but they have the potential to produce new branches, leaves, and flowers.

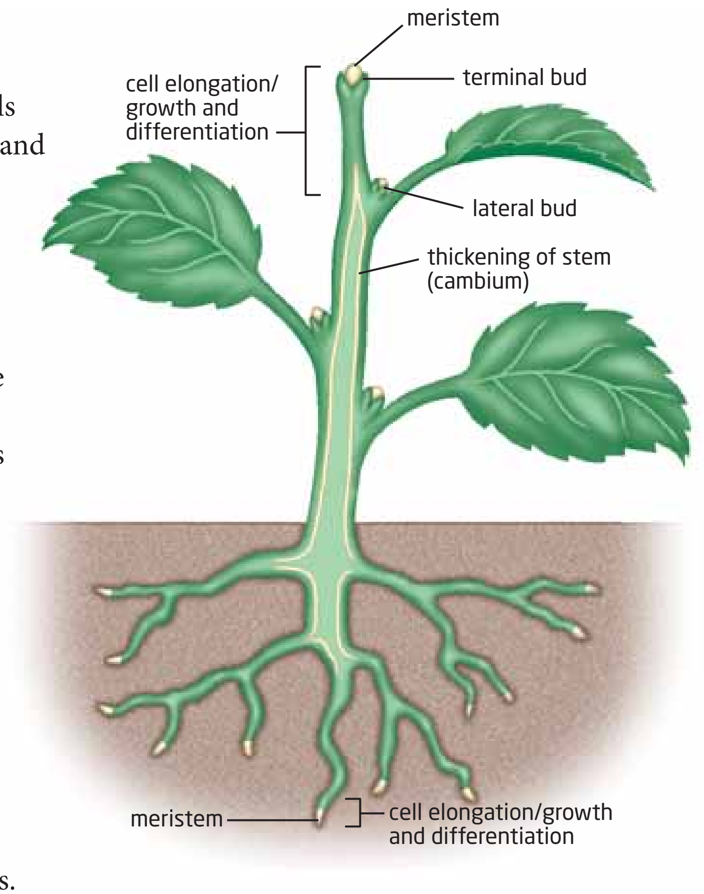


Figure 2.4 Branches and roots grow because of dividing meristematic cells. A plant's stem becomes wider because of meristematic cells in a layer called the cambium.

Growing Up or Branching Out

The cells in actively growing areas give off a chemical called *auxin* (a plant hormone), which controls the cells below and behind them. For example, **Figure 2.5** shows how cells at a plant's terminal bud produce auxin that inhibits, or holds back, the development of cells in lateral buds. The result is that plants tend to grow upward rather than outward. However, if you remove the tip of a plant (or if this is done naturally when a moose or deer nibbles its top branches) this "hold back" signal is removed. The plant will bush out at the lateral buds. If you replace the auxin lost from the tip, the control is restored, and the bushing out will stop.

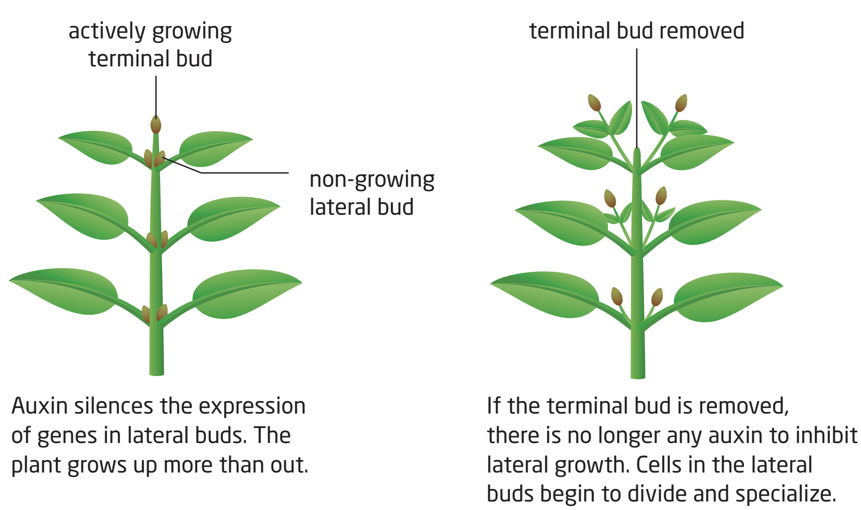


Figure 2.5 Cells in the terminal bud produce the plant hormone auxin, which holds back growth in buds elsewhere in the plant.

Figure 2.6 This Gerber Daisy shows the four types of organs of a flowering plant: the root, the stem, the leaf, and the flower. Each organ performs specific functions.

Tissues Working Together: Plant Organs

Different kinds of tissues combine to make up organs. You have many organs in your body, but flowering plants have only three or four. As you can see in **Figure 2.6**, three types of organs make up the body of a plant: the leaves, stem, and root. These organs make it possible for the plant to live and grow. A fourth organ is the reproductive organ, which, in many plants, is the flower.

The Leaf

A leaf's most important job is to provide a large surface area where photosynthesis can take place. Even leaves that look more like thin needles, like those on many coniferous trees, produce a large area because the plant has so many of them. If photosynthesis produces more glucose (a simple sugar) than the leaf needs, the excess is converted into starch and stored in the leaf. **Figure 2.7** shows the specialized cells of a leaf, which help this organ perform its most important functions.

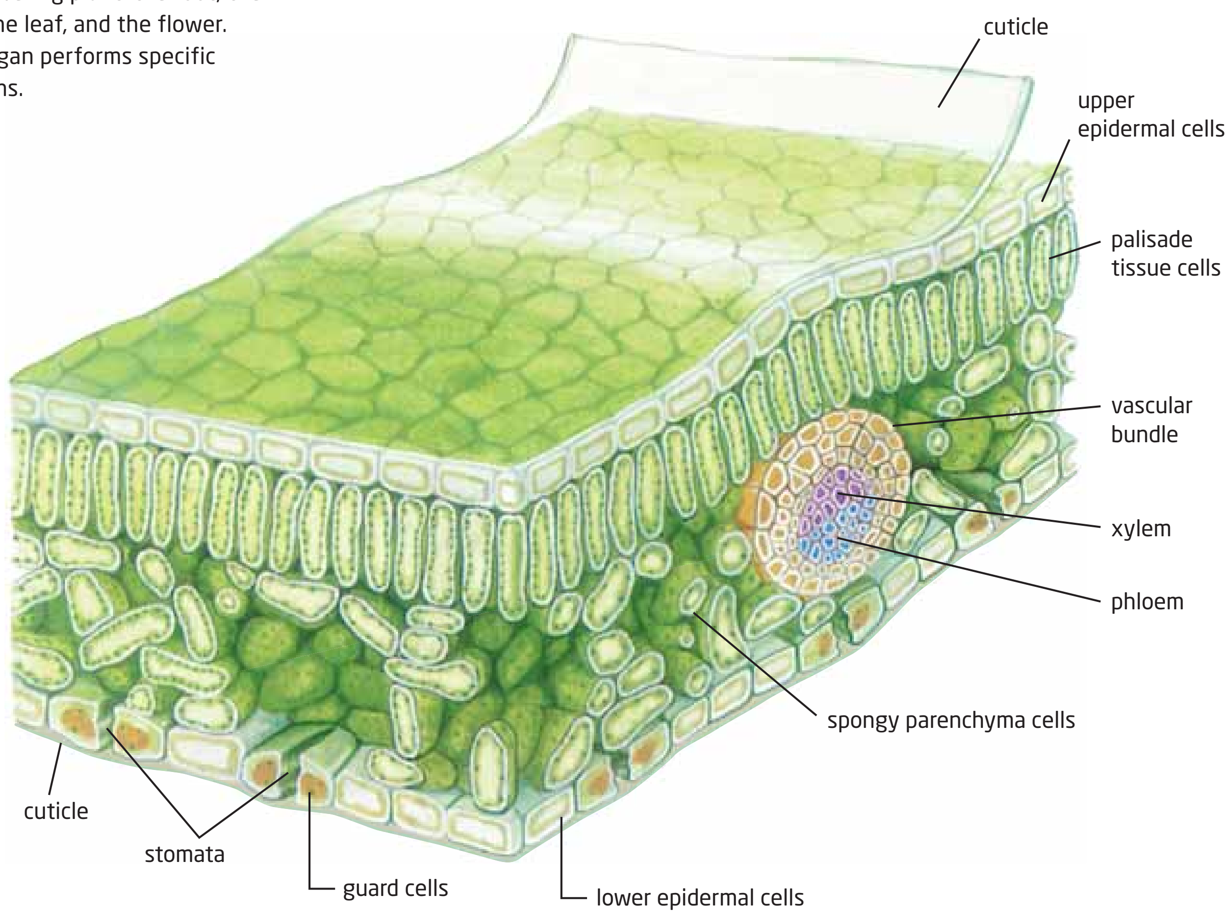


Figure 2.7 Many specialized cells work together to help a leaf perform photosynthesis.

The Upper and Middle Leaf

The upper surfaces of a leaf is made of a sheet of dermal tissue called the epidermis. The cells of the epidermis secrete a waxy *cuticle* that helps reduce the amount of water that evaporates from the leaf's surface. The main function of the epidermis is protection, so these epidermal cells do not perform photosynthesis. The sunlight passes through them to the photosynthesizing cells.

Between the upper and lower surface of a leaf is *mesophyll* tissue. *Meso-* means middle. Mesophyll tissue consists of *palisade* tissue cells and *spongy parenchyma* cells. The palisade cells are specialized to perform most of the photosynthesis in the leaf. They are arranged in lines that resemble the long poles used in the walls, or palisades, of old fortresses—hence their name. The tops of these cells are arranged to meet the Sun's rays head on, so that the rays pass through the length of the cell. As the rays of light journey through the cell, they encounter the many chloroplasts, where photosynthesis takes place. These cells are very active, so they are packed with mitochondria, which perform cellular respiration.

Below the palisade cells is a layer of spongy parenchyma cells. Parenchyma cells are loosely packed to form a network with open spaces, like a sponge. The spaces contain the gases needed or produced by photosynthesis: water vapour, oxygen, and carbon dioxide.

The centre of the leaf contains xylem and phloem tissue arranged into *vascular bundles*. These vascular bundles form *veins* that dissect the interior of the leaf at regular intervals. At their tips, the vessels meet the open spaces in the parenchyma tissue. There, the xylem delivers water, in the form of water vapour, to the photosynthesizing cells, and the phloem picks up sugars that have been produced and delivers them to cells throughout the rest of the plant. The small branches of veins ensure that every cell in the leaf is close to a supply of water and *nutrients*, which are elements essential for the life of the plant.

Study Toolkit

Multiple Meanings Which terms on this page have an everyday meaning? How can these everyday meanings help you remember the scientific meanings?

Suggested Investigation

Plan Your Own Investigation 2-A, Transpiration in Different Plant Types, on page 77

transpiration the evaporation of water from leaves

The Lower Leaf Surface

The lower surface of the leaf is made of an epidermis that is critical for the exchange of gases between the leaf and the outside environment. To allow the gases to move in and out, *guard cells*, which you can see in **Figure 2.8**, are scattered across the lower surface of the leaf. These cells change their shape to control the opening and closing of pores in the leaf, which are called stomates or *stomata* (singular *stoma*). The stomata are connected to the open spaces in the spongy parenchyma cells. Guard cells and stomata play a significant role in **transpiration**. Carbon dioxide enters through these pores, and oxygen and water vapour exit through them.

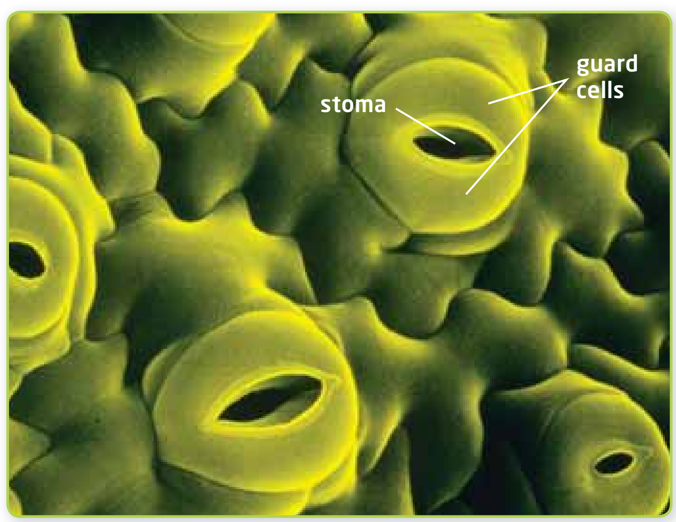


Figure 2.8 When guard cells fill with water, they take on a curved sausage shape and push the stomata open, as shown here. As the guard cells lose their water, they collapse and the stomata close, reducing water loss from the leaf.

Activity 2-2

Inside a Leaf

Use a microscope or microviewer to observe the specialized cells of leaves. What structures can you see?

Materials

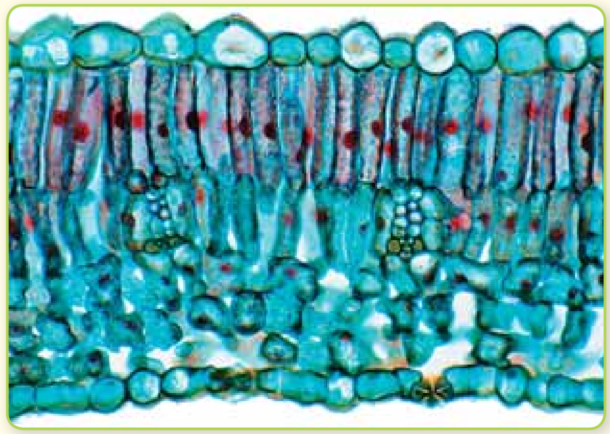
- prepared slides of leaf cross sections
- compound light microscope or microviewer

Safety Precaution

- Handle microscope slides and cover slips carefully so they do not break and cut you.

Procedure

1. Place a prepared slide of a cross section of a leaf under the microscope. Examine the specimen under low power, and gradually increase the magnification as necessary.
2. Use the micrograph of stained cells above, on the right, to help you identify the following cell types and structures in each specimen:
    - epidermal cells
    - palisade cells
    - spongy parenchyma cells
    - stoma and guard cells
    - vascular cells
3. Describe the shape and arrangement of the cells in various tissues in the leaf. Explain how these shapes and arrangements relate to each tissue's functions.



Lilac leaf cross section, 400×

Questions

1. On which part of the leaf did you observe the most stomata?
2. If you observed both open and closed stomata, describe the difference in the appearance of the guard cells in each case.
3. Explain how the shape and arrangement of each group of cells relate to the tissue's functions.
4. Explain how the arrangement of cells in the leaf contributes to the efficiency of photosynthesis.

Study Toolkit

Interpreting Cross Sections Visualize how a leaf would need to be cut to create the leaf cross section you see on this page. How does visualization help you understand how the cross section shows cellular organization in the leaf?

Learning Check

1. Describe what happens to a cell during cell differentiation.
2. Draw a diagram of a plant to show where you might find an example of each of the three types of plant tissues.
3. Draw and label a plant with four organs.
4. Based on the information in **Figure 2.5**, what advice would you give to a gardener who wants to grow bushier basil or oregano plants?

Inside the Chloroplast: One of the Leaf's Organelles

As you are reading this page, specialized cells in the leaves of plants all over the world are doing what they do all day, every day there is light. In every cell with chloroplasts, photosynthesis is occurring. As shown in **Figure 2.9**, light energy from the Sun combines with carbon dioxide from the air and water from the soil to produce glucose. Glucose is a carbohydrate used by both plant and animal cells as a source of energy. Animals eat to acquire glucose and other food molecules, but most plants must make their own. Oxygen gas is a product of photosynthesis and, as you know, is essential for cellular respiration in both plants and animals.

Chloroplasts can change their shape and location in a cell to increase the amount of light they capture. They contain little sacs called *thylakoids*, which contain light-trapping chlorophyll molecules. This is the part of a chloroplast where photosynthesis occurs. Thylakoids are arranged in a stack called a *granum* (plural *grana*).

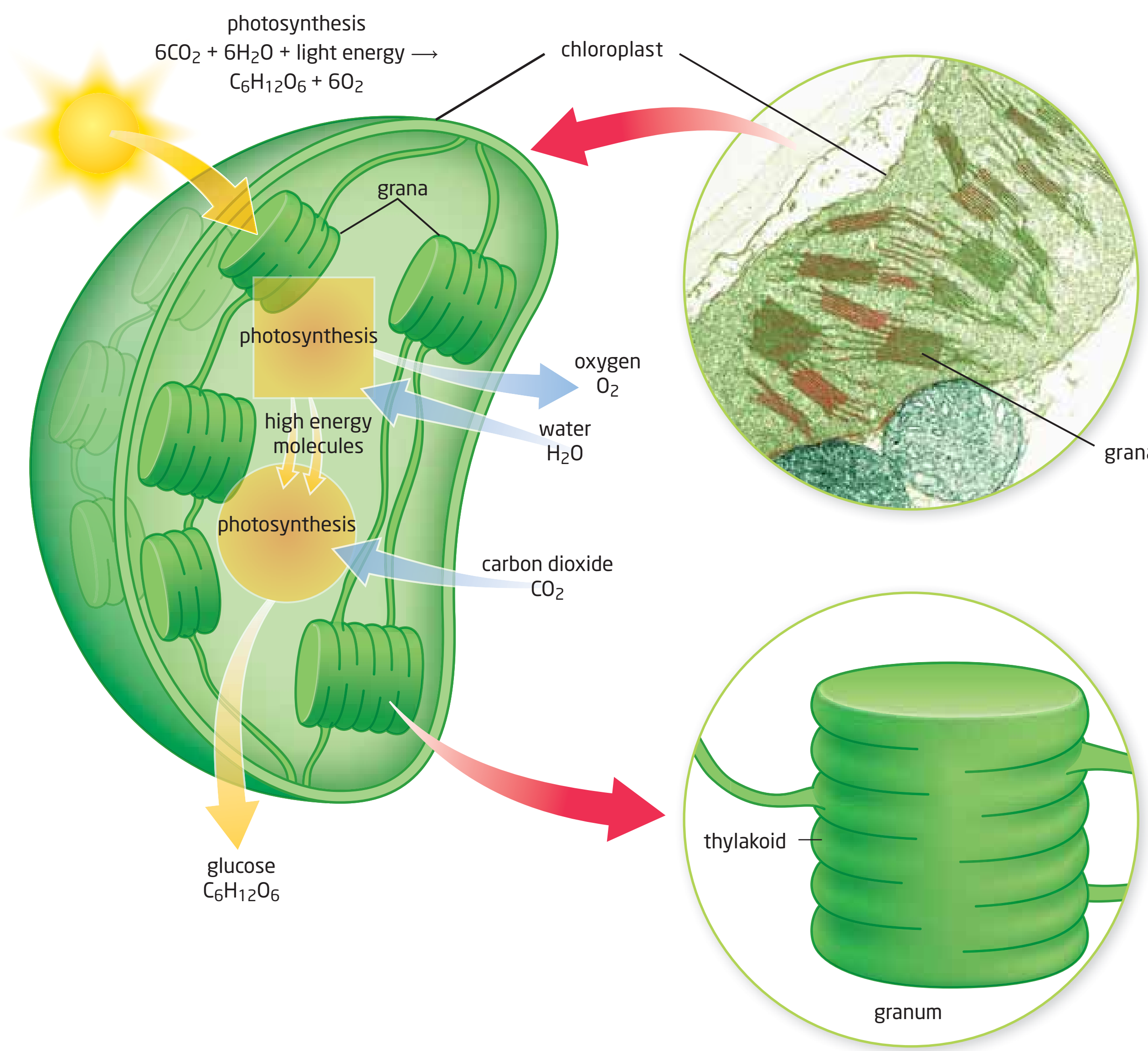


Figure 2.9 Chloroplasts are filled with grana, which are stacks of chlorophyll-containing thylakoids. Chlorophyll gives plants their green colour and allows the thylakoids to trap light energy from the Sun. This energy is used to fuel photosynthesis, the chemical reaction that produces glucose and oxygen.

The Stem

A plant's stem has two main functions: physical support and transportation of water, nutrients, and sugars. Stems contain most of a plant's xylem tissue. As xylem cells grow, they form long, straw-like tubes, or vessels. The cells then die, but their thick cell walls remain behind, forming long fibrous "pipes" through which water can flow. The xylem vessels are hollow, so they provide a relatively easy passage through the plant. It has been calculated that water moves 10 billion times more easily through xylem than it would if it had to travel through cells filled with cytoplasm!

The dead xylem cells are fortified with a hard substance called lignin, which makes them strong, helping them keep the plant upright. Xylem vessels are grouped with phloem vessels in *vascular bundles*. This further strengthens the stem's ability to support the plant. Phloem tissue is also made of vertically stacked tubes. Their cell walls are porous, which allows materials to be exchanged between the phloem and the neighbouring cells. **Figure 2.10** shows the arrangement of xylem and phloem in a plant stem.

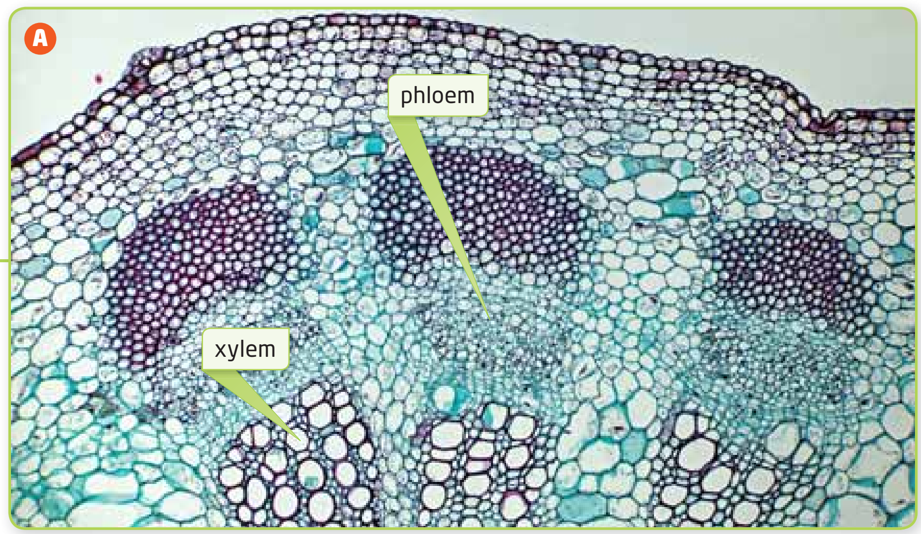
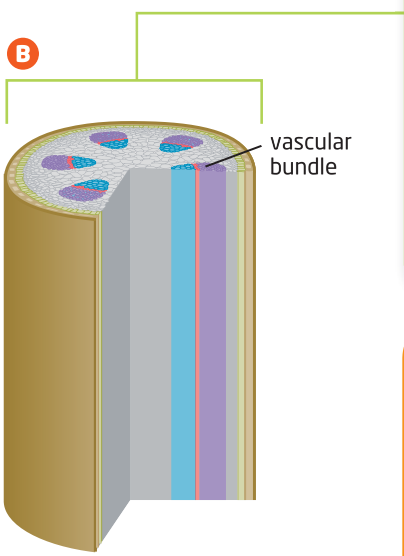


Figure 2.10 In **A**, you can see a cross section of a sunflower stem, magnified 25 times. In **B**, you can see how strands of xylem and phloem are grouped together in bundles that run the length of the stem.



Learning Check

5. Write a sentence that describes the relationship between grana, thylakoids, and chloroplasts.
6. Name two functions of a stem, and describe how the arrangement of its tissues facilitates these functions.
7. Look back to **Figure 2.9**, which shows where photosynthesis takes place. Make a flowchart showing the inputs and outputs of the process of photosynthesis, beginning with sunlight being captured in grana. Go to Study Toolkit 4 to learn more about making a flowchart.
8. Draw and label a sketch of what the stomata of a leaf would look like on a hot, dry day.

The Roots

Roots anchor a plant to the ground and allow it to take up water and minerals from the soil. As shown in **Figure 2.11**, some roots also act as a plant's storage area. **Figure 2.12** shows a cross section of a root. The root hairs are the main site of water and mineral absorption. *Cortex* cells usually do not contain chlorophyll and can be used by the plant to store starch. There are lots of spaces between these cells, through which water and minerals can flow to the endodermis. The endodermis helps control the transport of minerals between the cortex and the vascular tissues. The *pericycle* is the layer of tissue that surrounds the phloem and xylem. It gives rise to branch roots. You will learn more about water movement in plant roots in Section 2.2.

Figure 2.11 Vegetables such as this beet use their roots to store extra energy supplies and mineral reserves for later use.

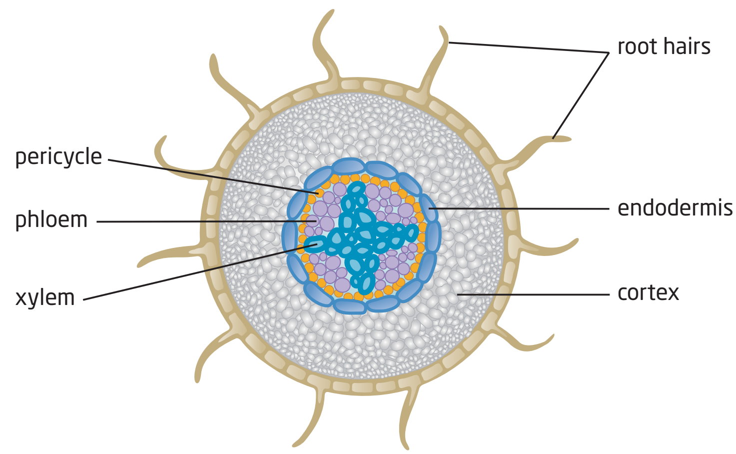


Figure 2.12 This cross section shows the structure of a typical root. Water and nutrients from the soil flow through the root's layers to the central vascular tissue. Then the water and nutrients are transported to the rest of the plant.

Types of Roots

Plants like dandelions have a *taproot*, one main root that grows larger and thicker than the rest, as shown in **Figure 2.13A**. The taproot allows the plant to reach far underground for water. The taproot anchors the plant firmly in the ground. In contrast, plants such as grasses have *fibrous roots* with branches that are all about the same size. Fibrous roots (shown in **Figure 2.13B**) spread out horizontally near the surface of the soil. They provide the plant with a large surface area over which water can be taken up from just under the surface of the soil. Fibrous roots also stabilize the soil and help to prevent erosion and landslides.

Figure 2.13 **A** Many common weeds, such as dandelions, have a large, main taproot. A taproot makes it hard to pull the entire plant from the ground, as many gardeners know! **B** Other plants, such as this yarrow, have fibrous roots, which are specialized to absorb water from near the surface of the soil.

Plants Under Attack

Figure 2.14 The virus that affects these flowers makes them attractive to humans.

Plant tissues and organs can be attacked by *viruses*, just as animal tissues and organs can. More than 400 different viruses are known to infect plant cells, causing as many as 1000 plant diseases. Not all plant diseases are fatal or even harmful. For example, the beautiful Rembrandt tulips shown in **Figure 2.14** get their stripes from a virus that is transmitted from plant to plant. Other viruses, such as the tobacco mosaic virus (TMV) shown in **Figure 2.15**, are highly destructive, attacking the leaves of tomato, potato, pepper, and cucumber plants. TMV often lowers crop yields dramatically. Today, many anti-viral drugs are available to fight these viruses.

Go to **scienceontario** to find out more

Figure 2.15 This research technician holds up a healthy tomato plant (on the left) and one infected with tobacco mosaic virus (on the right).

STSE Case Study

Eliminating Wheat Rust with Transgenic Therapy

Almost one third of the world's population relies on wheat as a primary source of food. Wheat is vulnerable, however, to several diseases and pathogens. The most common types belong to a group called rusts. Rust diseases are particularly damaging because they are easily carried by the wind from one area to another. As well, they mutate quickly and attack new, previously resistant varieties of wheat.

The rate of infestation by various kinds of rusts is growing. If long-term solutions are not found, the world may soon face global wheat shortages.

Brown rust, shown here, is a type of fungi that affects Canadian crops. It can reduce wheat harvests by up to 20 percent.

Traditional Treatments

Traditionally, wheat crops that were affected by fungal diseases were treated with fungicides. Although fungicides kill the fungi, they can also damage the wheat. Many types of wheat depend on a beneficial type of fungus called mycorrhizal [pronounced mi-cor-RI-zal] fungus. The tiny mycorrhizal fungus gets nutrients from the roots of the plant. In return, it converts nutrients, such as nitrogen, into usable forms, making the nutrients easier for the plant to absorb. When fungicides are used, they kill the mycorrhizal fungus along with the fungi that cause diseases. As a result, the plant may die.

Another strategy to fight rust diseases involves breeding wheat plants that carry rust-resistant genes with each other (selective breeding). Until recently, this strategy offered only a short-term solution, because rusts can mutate quickly and re-infect resistant wheat.

Plant Galls

Plant **galls**, as shown in **Figure 2.16**, are similar to tumours in animals. Like tumours, galls are produced by the abnormal growth of groups of cells. Plants produce galls in response to attacks by organisms such as insects, fungi, bacteria, and viruses. The attackers have a purpose—they use the plant's resources to support themselves or their offspring. For example, some types of insects lay their eggs in a specific kind of plant, such as an oak tree. Their larvae develop in a gall that grows in the tissue of the tree.

Insects promote the development of galls by injecting a chemical into a plant's tissues. This chemical interacts with the plant's fluids and alters which genes are turned on and off in the cells. The change stimulates the growth of a structure where young insects develop.

The most significant difference between plant galls and animal tumours is that galls do *not* normally spread to other tissues (as human tumours can, producing cancer). Gall growth is usually contained, and the effect on the plant is seldom fatal. Learning why these tumour-like growths do not spread may someday provide important information about how cancer in humans can be treated.

gall an abnormal growth of plant tissue caused by insects or micro-organisms

Figure 2.16 Galls often look as though they cause serious damage, but most do not harm the plant's normal functions.

A Genetic Solution?

Researchers in Australia recently discovered two genes that protect wheat against rust diseases. One gene, called Lr34, produces a protein that transports disease-fighting molecules throughout the plant cells. The other gene, called Yr36, triggers a resistance response, although scientists are not completely sure how this response occurs. As long as the rusts are not able to mutate, transferring these genes into non-resistant wheat plants may be the answer for protecting wheat crops around the world.

The spores of a rust are shown below, magnified 250 times. Rusts can interfere with the growth and health of plant tissues.

Your Turn

1. Identify different stakeholders (such as farmers, scientists, and people opposed or undecided about the benefits of GMO crops) who might be affected by the Australian research and the possible development of transgenic wheat. Describe the Australian research to a partner, from the point of view of one of the stakeholders.
2. Imagine that you are a scientist who is about to appear on a radio talk show to discuss GMO crops. What questions do you think you will be asked? What kinds of information would you want to find in order to prepare for the interview?
3. Research the benefits and risks of transgenic crops in terms of one of the following common crop diseases: stem rust, striped rust, black rust, or tobacco mosaic virus. Write a newspaper article to communicate your research. Imagine that your readers will be primarily from one of the stakeholder groups you identified in question 1.

The Reproductive Organ: The Flower

Figure 2.17 Flowering plants require pollination in order to reproduce.

The flower is an organ that does not take part in the maintenance of the plant itself. Its task is reproduction. Although many plants do not produce flowers and can reproduce by other methods, flowering plants are abundant.

The different parts of the flower are really just specialized leaves. One set of these leaves is specialized to produce *pollen*, which manufactures sperm, while another set produces eggs. Most plants accomplish pollination with the assistance of the wind, or animals such as birds, bats, or insects, as shown in **Figure 2.17**. Through colour or scent, the flower attracts insects or other animals to the plant. Once there, these animals pick up pollen from the male parts of the flower. When they later visit another plant of the same type, they may transfer this pollen to the female parts of the second plant, setting the stage for *fertilization*. In some cases, they transfer pollen from a flower to the female parts of another flower on the same plant.

Go to **scienceontario** to find out more

After the flower is pollinated, seeds are produced. The seeds are embedded in fruits. Here again, plant hormones are involved. A hormone called ethylene stimulates the ripening of fruits. As shown in **Figure 2.18**, companies use this knowledge to ship fruits, such as bananas and tomatoes, to markets all over the world.

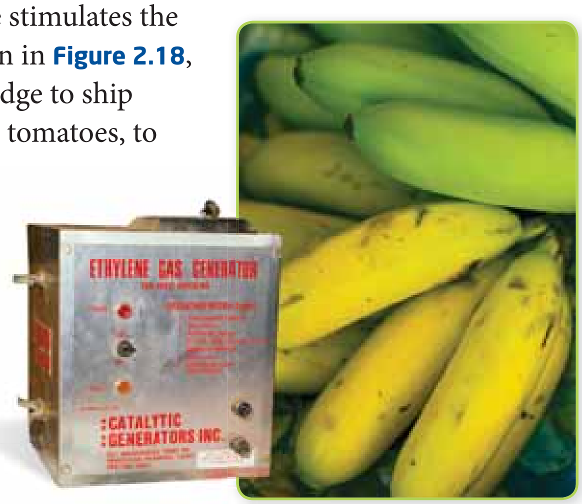


Figure 2.18 Fruits such as bananas are often picked while still green. They can be shipped to customers, and ripened with ethylene gas (C_2H_4) once they reach their markets.

Making a Difference

In high school, Isdin Oke decided to test the effects of a compound that slows aging in plants. With help from a University of Guelph professor, Isdin and his classmate Colin Perkins exposed snapdragon flowers to 1-methylcyclopropene (1-MCP) and ethylene gas. 1-MCP is used to increase the shelf life of flowers, fruits, and vegetables. Isdin and Colin found that flowers exposed to 1-MCP aged at a much slower rate than flowers that were not exposed. They observed this effect even when the flowers were also exposed to the plant hormone ethylene, which stimulates aging. Their results could help scientists develop ways to prevent flowers from wilting and fresh produce from spoiling. Isdin and Colin took their project to the National Sanofi-Aventis Biotalent Challenge and earned gold at the 2008 Waterloo-Wellington Science and Engineering Fair. Isdin received a scholarship to the University of Guelph and is now studying nanoscience.

What are some possible social and economic benefits of slowing the aging of plants?

Section 2.1 Review

Section Summary

- Meristems produce cells that differentiate into specialized cells.
- New tissues and organs are produced from meristem in growing areas called buds.
- Plant tissues join together into four types of organs: the root, stem, leaf, and reproductive organ.
- Leaves provide a large surface area where photosynthesis takes place. Photosynthesis occurs inside chloroplasts, which are found in specialized cells in the leaf.
- Stems support the plant and transport water, nutrients, and sugars.
- Roots anchor the plant and take up minerals and water from the soil.
- Not all plants have flowers. In those that do, flowers are responsible for reproduction.

Review Questions

T/I **1.** Could a plant live without meristem? Explain your answer.

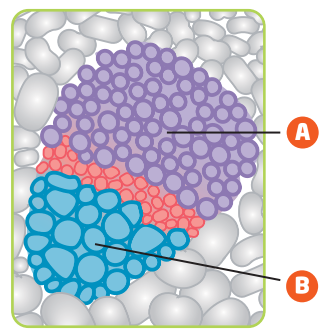
K/U **2.** Look back to **Figure 2.3**. Make a graphic organizer that shows the same information. Go to Study Toolkit 4 to learn more about graphic organizers.

K/U **3.** Examine the diagram on the right.

a. What two structures are labelled?

b. When grouped together as shown, what are these structures called?

c. What type of tissue are they?



C **4.** Draw and label a plant to show the three organs that a plant needs to sustain its life, as well as a brief description of what each of these organs does.

T/I **5.** On a leaf's surface, the epidermis is covered with cuticle. Explain why root epidermis is not covered with cuticle.

K/U **6.** The epidermal cells of most leaves are transparent. Why is this adaptation beneficial to the plant?

A **7.** Erosion, as shown in the photograph on the right, can be a major problem in many natural areas. What would you suggest planting to stabilize and renew an area that has washed away after a flood?

A **8.** Scientists often have difficulty getting funding for their research. Why do you think tobacco mosaic virus was the first major plant virus whose structure was investigated?