Key Terms
system
root system
shoot system

2.2 Plant Organ Systems

When you first look at a plant, such as the tree shown in **Figure 2.19**, it does not look alive in the dramatic way that many animals do. Yet a plant's stationary appearance is deceiving. Its internal structure is complex, with many interactions between its various organs. These organs, working together in **systems,** maintain a constant flow of fluids, nutrients, and hormones from one part of the plant to another.

The body of a typical plant is generally considered to have two main organ systems: the **root system** and the **shoot system**. These systems are shown in **Figure 2.20**.

- A plant's root system consists of all the roots that lie below the surface of the ground. The root system is responsible for taking in water and minerals from the soil. It is constantly growing to keep pace with the plant's increased demand for materials as it grows.
- The shoot system is responsible for supporting the plant, performing photosynthesis, and transporting water, nutrients, and sugars.

Sometimes flowers and their fruit are considered part of a separate system. However, as shown here, they are also considered part of the shoot system.

system in biology, a group of tissues and organs that perform specific functions

root system an organ system in a plant, which takes in water and minerals from the soil and transports these substances to the shoot system

shoot system an organ system in a plant, which supports the plant, performs photosynthesis, and transports sap

Figure 2.19 Trees like this enormous one from British Columbia's Carmanah Valley have traditionally held spiritual value for many First Nations people. Trees are often used in First Nations teaching metaphors to help people appreciate the place of humans in a healthy ecosystem.

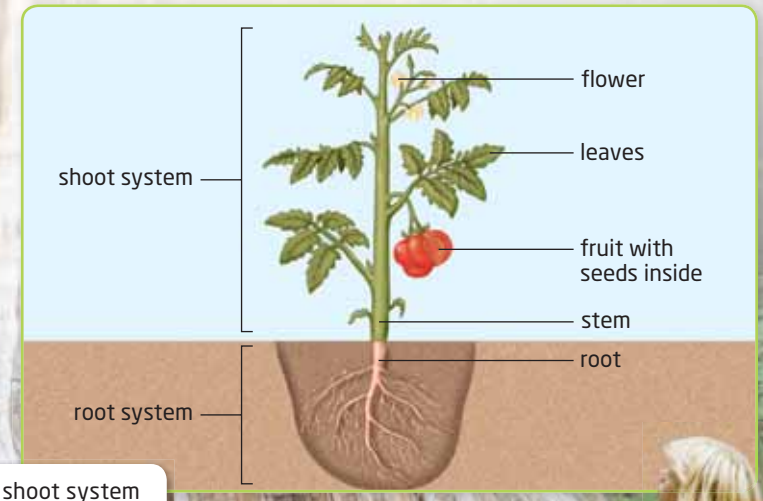


Figure 2.20 A plant's shoot system consists of organs above the ground, while its root system consists of organs below the ground.

Systems Working Together

The root and shoot systems are connected by the flow of water, nutrients, and various hormones through vascular bundles that contain xylem and phloem. Maintaining this flow is essential for the plant's ability to survive.

- Xylem tissue takes care of moving water and minerals from the roots to other plant parts, including the leaves, where these materials are needed for photosynthesis.
- Phloem tissue moves the sugars produced by photosynthesis to other plant parts.

Unlike the cells in xylem, which die at maturity, the cells in phloem are alive. Therefore, xylem tissues do not use any of the plant's energy stores, but phloem tissues do. Phloem cells actively pump substances to where they are needed in the plant. For example, phloem tissue moves glucose from the leaves, where it is made, to parts of the plant where there is high demand for energy, such as the buds, and to places for storage, such as the roots.

Study Toolkit

Comparing and Contrasting
What concepts on this page could you compare and contrast using a Venn diagram? Prepare a Venn diagram to make notes on one of these concepts.

Activity 2-3

The Flow of Phloem

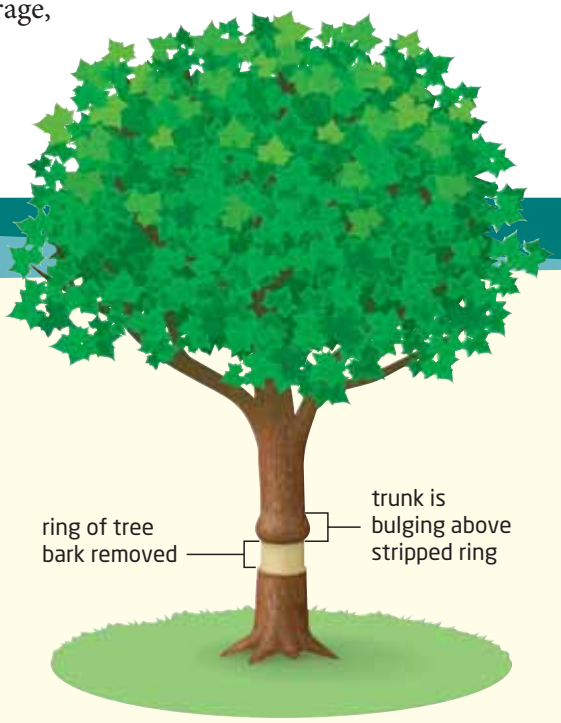
What happens to a plant if the flow of materials in vascular tissue is interrupted? In 1686, an Italian scientist named Marcello Malpighi (1628–1694) investigated this question by removing a ring of phloem tissue from a tree. What do you think happened?

Procedure

1. Read the following account of Malpighi's experiment:

In trees, phloem forms the layer of living tissue just beneath the bark. Xylem lies beneath the phloem. In his experiment, Malpighi peeled away a ring of bark and phloem from a tree. Shortly after the ring was removed, a swelling appeared in the bark of the tree immediately above the ring. Sweet-tasting fluid oozed out of this swelling. Although it appeared at first that Malpighi's experiment had not seriously damaged the tree, it died a few weeks later.

2. Using **Figure 2.10**, sketch a cross section of the tree stem in Malpighi's experiment.



Questions

1. Use your sketch and your understanding of vascular bundles to analyze Malpighi's results.
2. What would his results have been if he had blocked transport in the xylem instead of the phloem?
3. The removal of a ring of tree bark and phloem is called girdling. Farmers with orchards of fruit trees sometimes girdle trees to produce sweeter fruit.
   a. Why does this practice increase sugar transport to the fruit?
   b. How do you think girdling affects the health of the tree?

Moving Water through the Systems

Water means everything to plants. Plants can survive without soil under certain circumstances, as shown in **Figure 2.21**, but they cannot survive without water. If there is too little water in the soil, nutrients cannot be taken up by the roots. This is because the nutrient molecules need to be dissolved in water in order to be absorbed and move up the xylem in the form of sap. As well, if the supply of water to the leaf is insufficient, photosynthesis cannot take place. Eventually, the plant would die.

However, too much water in the soil can also have a negative effect on plants. If the spaces between soil molecules are filled with water, there will not be enough room for oxygen. Under these conditions, the root cells will not get enough oxygen for cellular respiration. Keeping water balanced and moving through a plant is thus vitally important. This job requires the co-ordinated action of both the root and shoot systems.

Figure 2.21 You might not notice anything odd about the plants growing in this greenhouse. However, if you could look closely, you would see that they are growing in a nutrient solution instead of soil. This type of agriculture is called hydroponics, and it is now an important part of Ontario's agricultural economy.

Sense of place

Some plants live in areas where the soil is nutrient-poor, such as bogs. Many bog plants, including Venus fly traps and pitcher plants, get extra nutrients by catching and consuming insects or other organisms.

Learning Check

1. Under what conditions can plants survive without soil?
2. Sketch a diagram that shows a plant's organ systems. Label the organs involved in each system.
3. Some plants, such as beets and carrots, store food in their root systems. How do you think growing in nutrient-rich soil, with plenty of water and sunlight, would affect this type of plant?
4. Most authorities recommend that lawns receive only about 3 cm of water per week. Why would it be unwise to double or triple this amount?

Moving Through the Roots

Have you ever wondered how water gets from the soil to the top of a 30 m tree? It begins with water absorption in the roots. The structure of the root helps the plant absorb water and minerals from the soil. As shown in **Figure 2.22**, the epidermal cells of most types of roots grow small extensions of their cell membranes called *root hairs*, which expand the root's total surface area. As shown in **Figure 2.23**, nutrients and water are transported into the root by osmosis.

Then nutrients and water move toward the xylem at the centre of the root. The endodermis helps control the passage of water and minerals from the cortex to the vascular tissue. The water and nutrients are then pushed into the xylem vessels.

Figure 2.22 Tiny root hairs, such as those on this radish seedling, extend off main roots and expand the surface area available for absorbing nutrients and water.

The Effect of Root Pressure on Water Movement

Once water from the roots reaches the xylem, how does it move upward, against the force of gravity, to reach the leaves at the top of a tall tree? Is it pushed from below, by root pressure, or pulled from above, as a result of transpiration?

Root pressure is created under certain conditions, such as at night when transpiration is low and when soil is very moist. As root cells bring minerals into the xylem, the mineral concentration in the xylem increases. This high concentration of minerals increases the tendency of water to diffuse into the root xylem by osmosis. As water flows in, root pressure builds in the xylem vessels. This pressure forces fluid up the xylem. Although root pressure can push water up the xylem, experiments have shown that root pressure is not enough to move water to the top of a tall tree, such as a giant redwood, and may only account for several meters of water movement up the xylem. A much more important factor acting on the movement of water through a plant is transpiration, which pulls water up from the roots.

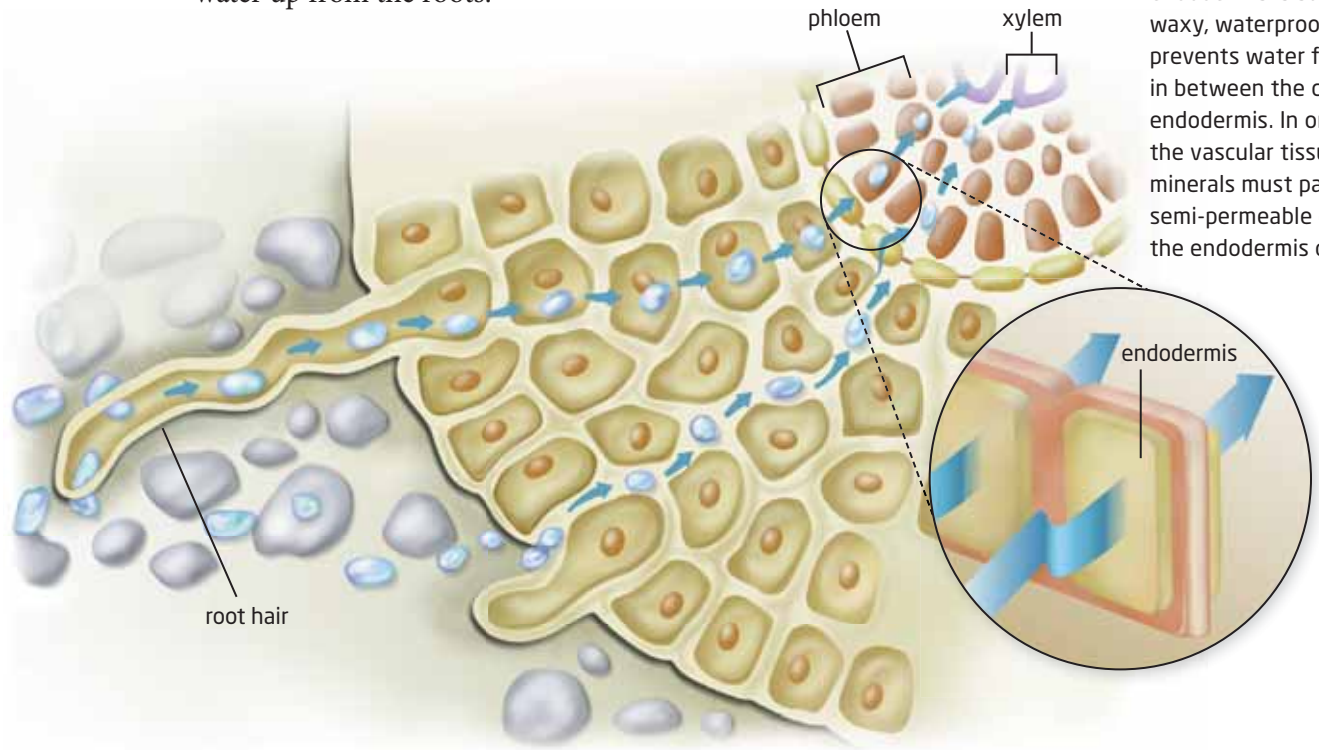


Figure 2.23 Water and nutrients enter the roots by osmosis and continue to move in, toward the centre of the root. The water and minerals can travel either through cells or through the spaces surrounding cells until they reach the endodermis. The endodermis is surrounded by a waxy, waterproof substance that prevents water from passing in between the cells of the endodermis. In order to pass into the vascular tissue, the water and minerals must pass through the semi-permeable cell membrane of the endodermis cells.

Suggested Investigation

Inquiry Investigation 2-B, Moving Nutrients Through the Stem, on page 78

The Pull from Above

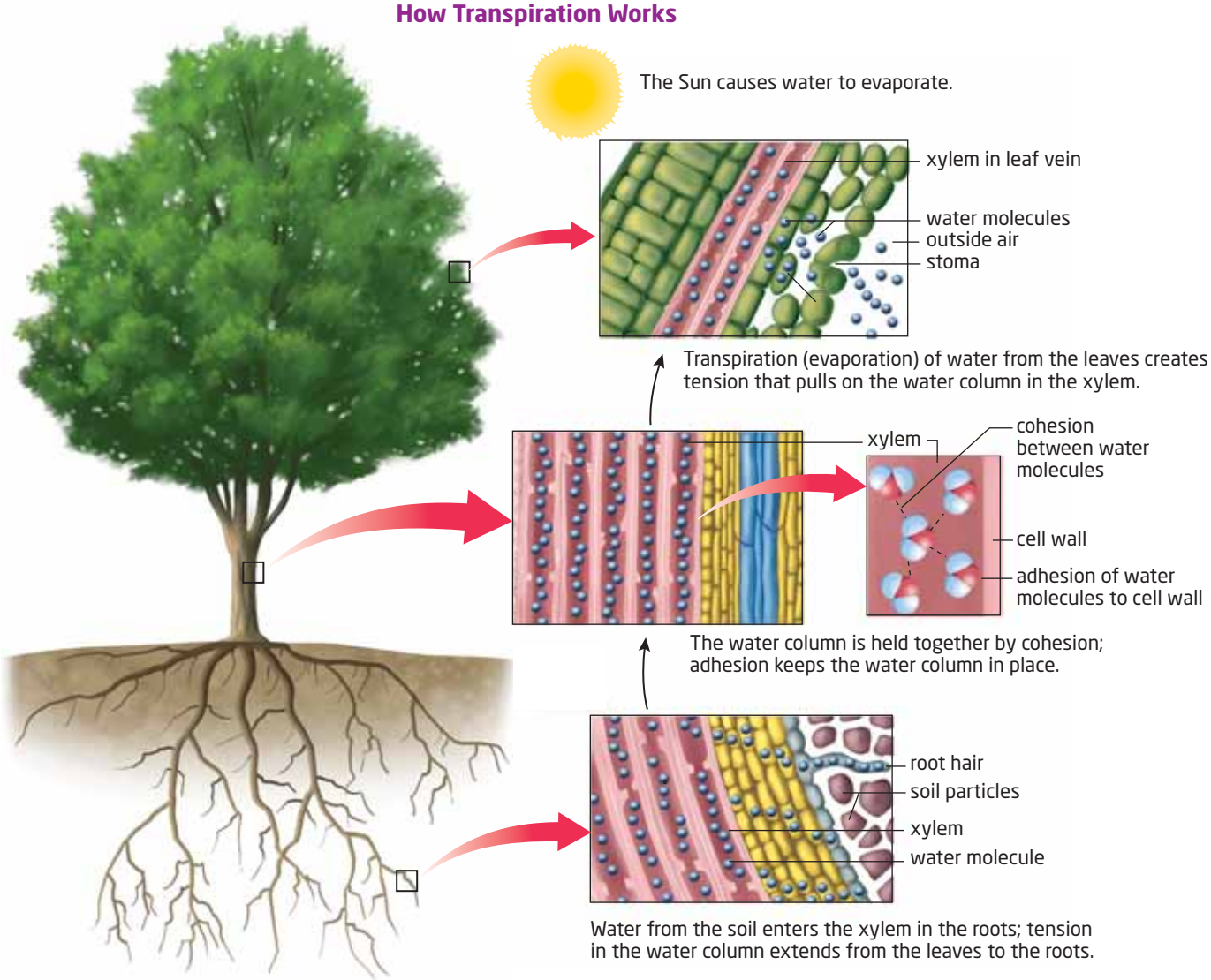
Xylem tissue ends when it reaches the leaves. Here, liquid water turns into water vapour in the spaces between the spongy parenchyma cells in the middle of a leaf. Some of this water will be used during photosynthesis. However, much more of the water vapour will simply evaporate when stomata open to take in carbon dioxide and release oxygen. Transpiration makes room for more water from the xylem to move into the leaves, pulling the water column up.

As shown in **Figure 2.24**, transpiration, along with some of water's unique properties, moves water up the xylem. *Cohesion*, the ability of water molecules to cling to each other, holds the water column in the xylem together. Another property of water, *adhesion,* helps water fight the force of gravity. Adhesion is the tendency of water molecules to stick, or adhere, to certain surfaces, such as the wall of a xylem vessel. The clinging of water to the xylem walls helps to prevent the water from flowing back down to the roots.

The rate of transpiration is controlled by the amount of water vapour in the leaves. When the amount of water vapour is large, the guard cells open the stomata and water vapour moves out of the leaves. If the amount of water vapour is small, the guard cells relax and the stomata close.

Figure 2.24 The process of transpiration pulls water in the xylem up toward the leaves.

How Transpiration Works



Moving Nutrients through the Systems

Photosynthesis produces a form of sugar called glucose. Once formed, the glucose is either used or it combines with other molecules to produce sucrose and other carbohydrates. Sucrose is soluble in water and is the main molecule distributed to other parts of the plant through the phloem. Sucrose that makes its way to the roots is usually chemically changed to starch and stored. When the stored starch is needed by other plant organs it must be removed from storage and transported back to them. However, starch cannot be transported through the stem. It is not soluble in water, so it must first be converted to sucrose, which then dissolves in water and is transported again as sap.

Sense of Value

About one million litres of maple syrup are produced annually in Ontario. The province's maple industry is worth an estimated $15 000 000 a year.

The Movement of Maple Sap

The process that provides us with maple syrup occurs during the spring. At this time, trees need to nourish the many buds that must divide and grow to produce leaves that can photosynthesize. **Figure 2.25** shows sap movement in a maple tree. The sap that flows upward from the roots through the phloem of maple trees in the spring contains large amounts of sucrose, which has been converted from starch. The sap moves through the phloem to where it is needed. Once the leaves have grown, they can make their own glucose through photosynthesis. In the summer and fall, as the leaves begin to produce more glucose than their cells require, the extra glucose is transported to other plant tissues or stored in the roots as starch.

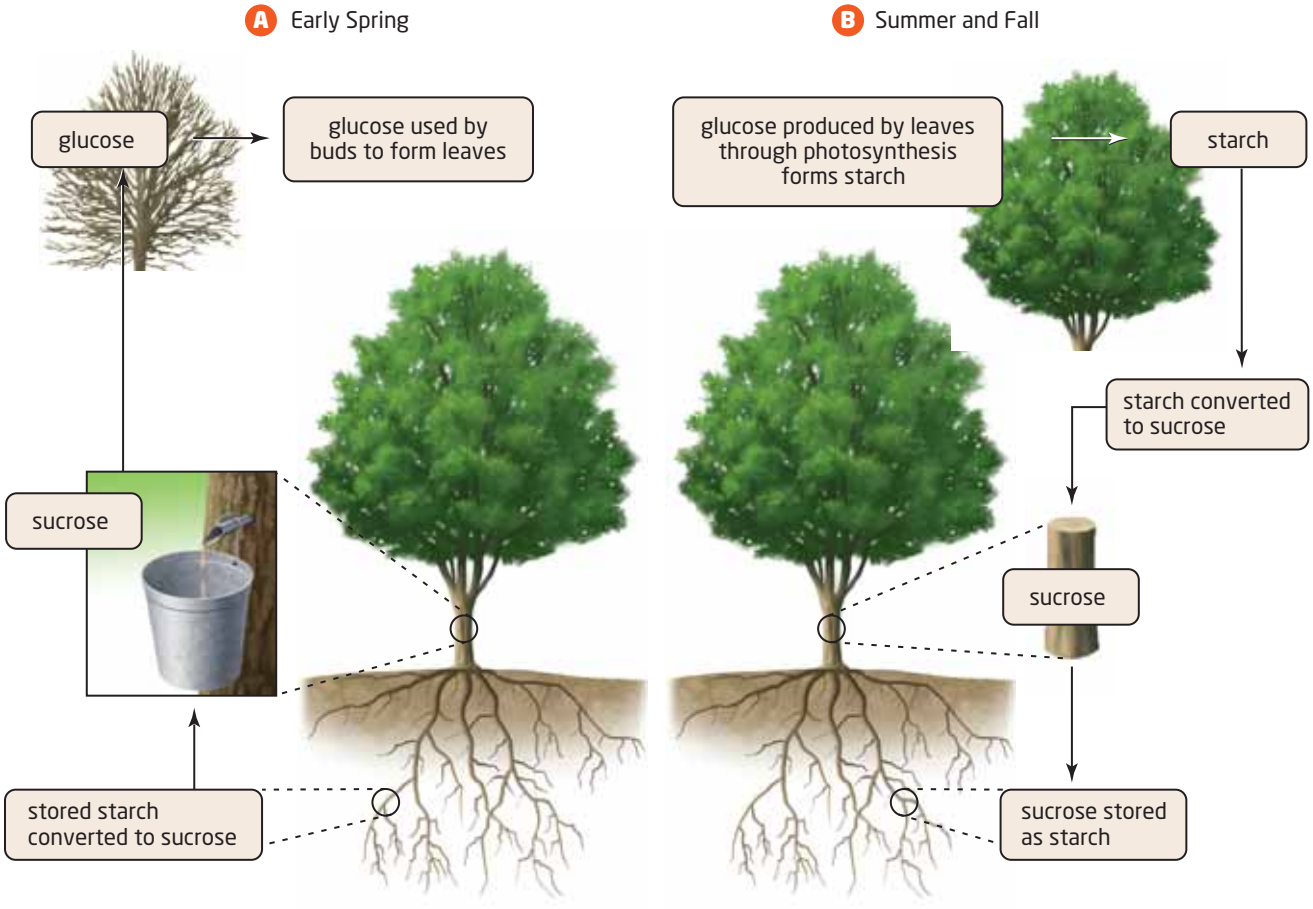


Figure 2.25 This diagram shows the formation and use of maple sap in a maple tree. **A** In the spring, the flow of sucrose is mainly upward. **B** In the summer and fall, the flow is mostly downward, as the plant prepares for the winter.

Section 2.2 Review

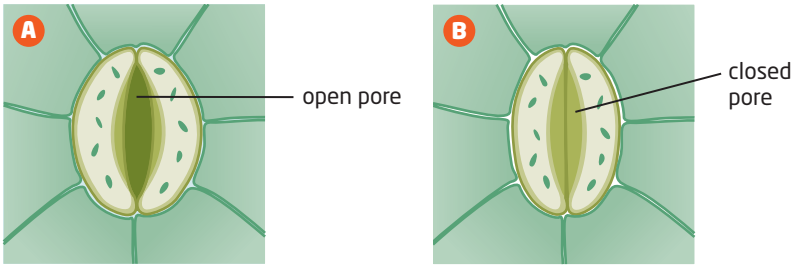
Section Summary

- Plants have two organ systems for sustaining life: the root system and the shoot system.
- The root system takes in water and nutrients from the soil and moves these substances to the stem.
- The shoot system supports the plant, performs photosynthesis, and transports water, nutrients, and sugars.
- Transpiration pulls water from the roots to the leaves through the xylem tissue. This pull is aided by two properties of water—cohesion and adhesion.
- Nutrients in the form of dissolved sucrose move through the plant in the phloem tissue. The sucrose is stored as starch if it is not needed immediately.

Review Questions

K/U **1.** Compare and contrast the functions of the xylem and the phloem.

T/I **2.** In which of the diagrams below will the leaves exert a stronger pull on water from the roots? Explain your answer.



T/I **3.** How could you demonstrate that it is a structure on the bottom side of leaves that regulates the amount of transpiration that occurs in a plant?

A **4.** Will a tulip transpire more in a humid environment or in a dry environment? Explain your reasoning.

A **5.** If the stem of a plant is bent or snapped, the part of the plant above the bend will usually die, even if propped up with a support. Explain why.

K/U **6.** Why is maple sap collected in the spring instead of in the fall?

C **7.** Use the information in **Figure 2.25** to create a flowchart showing how food is transported through a tree.

A **8.** Would the rate of maple sap retrieved from a tree be greater during the day or during the night? Why?