12.4 Roots

Roots are usually hidden from view and are rarely thought attractive. However, roots can have surprising beauty. **Figure 1** shows the Ta Prohm temple in Cambodia. The temple is almost completely overgrown by the roots of banyan and kapok trees. It is a popular tourist attraction and has been used as a location in a number of movies.

Figure 1 The beauty of the Ta Prohm temple is in part due to the large roots that cover it.

Function of Roots

A main role of plant roots is to anchor the plant and keep it upright. Another main role of roots is to absorb water and nutrients other than carbohydrates (which are produced by photosynthesis). Some roots store water and carbohydrates for the plant.

Types of Root Systems

If you have ever done work in a garden, you have likely noticed that there are two basic types of root systems. A **taproot system** has a large, thick, main root called a taproot, which grows straight downward (**Figure 2(a)**). The taproot may also have **lateral roots** branching from it. Both taproots and lateral roots are covered with root hairs. A **root hair** is a microscopic hair-like outgrowth from an epidermal cell. Taproots are able to push deep into the soil. Gymnosperms and angiosperm eudicots have taproot systems.

In contrast, a **fibrous root system** has many small roots (**Figure 2(b)**). Each of these roots may have lateral roots. Like taproots, fibrous roots have root hairs. Fibrous roots tend to be shallower than taproots. Fibrous roots occur in angiosperm monocots.

taproot system a root system composed of a large, thick root; can have smaller lateral roots

lateral root a smaller root that branches from a larger root

root hair a microscopic extension of the epidermal cells of the root

fibrous root system a root system made up of many small, branching roots

Figure 2 Both types of roots, (a) taproots and (b) fibrous roots, can have lateral roots.

General Structure of Roots

All roots have the same general structure (**Figure 3**). The tip of the root contains the root cap and a meristem. The **root cap** is a thick layer of cells that produce a slippery substance that helps the root to penetrate the soil, minimizing damage to the root cells. The meristem produces new cells to increase the length of the root.

The root hairs are found above the root tip, projecting outward from the epidermis of the plant root (**Figure 4(a)**). Root hairs dramatically increase the surface area of the epidermis. As a result, the root can absorb water and dissolved nutrients much more efficiently. The **root cortex** is a region of parenchyma cells beneath the epidermis. The cells of the root cortex store carbohydrates and also help transport water from the epidermis to the xylem. The root cortex ends at the **endodermis**. The walls of the cells in the endodermis are wrapped with a wax-like substance, forming a continuous barrier called the **Casparian strip** (**Figure 4(b)**). (You will learn about the function of the Casparian strip in the next section.)

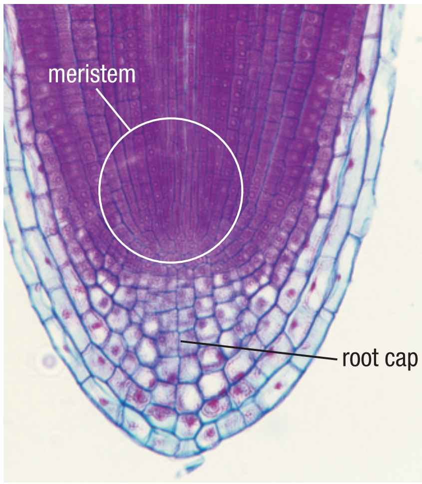

Figure 3 The root tip contains the root cap and a meristem.

root cap the mass of cells that form a protective covering for the meristem at the root tip

root cortex a region of parenchyma cells under the epidermis of a root

endodermis the innermost layer of cells in the cortex of a root

Casparian strip the wax-like strip that runs through the cell wall of an endodermal cell

vascular cylinder the central portion of a root that contains the xylem and the phloem

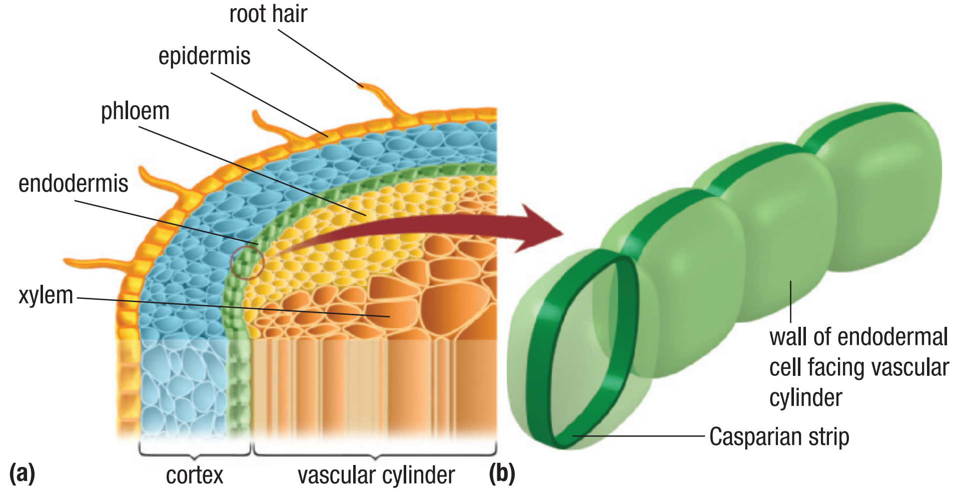

Figure 4 (a) The general features of a root (b) Each endodermal cell has a Casparian strip in its cell wall.

The vascular tissue of roots is contained in the **vascular cylinder**. The arrangement of xylem and phloem within the vascular cylinder varies among the groups of angiosperms (**Figure 5**). In gymnosperms and eudicots, the centre of the root contains xylem cells forming an "X" or star-shape in the centre of the vascular cylinder. The phloem cells are also in the centre of the root, around the xylem. In monocots, however, the centre of the root contains parenchyma cells. These cells are surrounded by a ring of xylem cells and a ring of phloem cells.

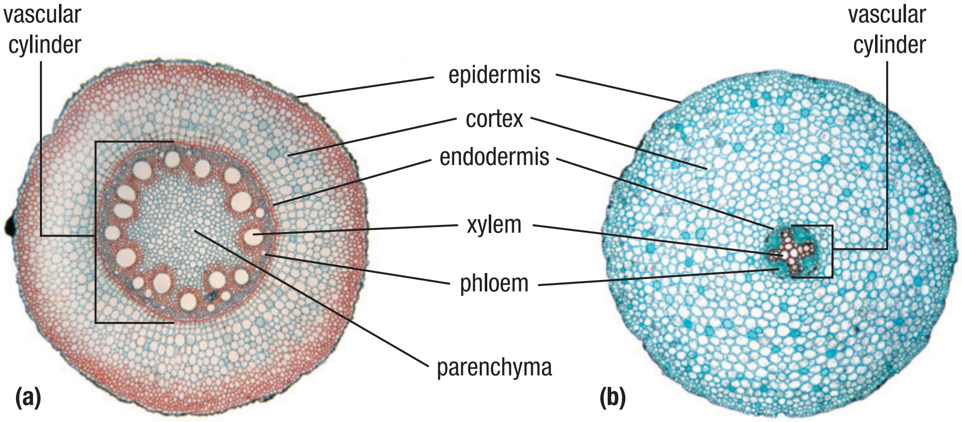

Figure 5 Cross-sections of (a) a monocot root and (b) a eudicot root. In monocots, the centre of the vascular cylinder has parenchymal cells. In eudicots xylem cells are at the centre of the root.

Investigation 12.4.1

Comparing Monocot and Eudicot Root Cross-Sections (page 577)
Now that you have read about the structure and function of roots, you can complete Investigation 12.4.1.

In this observational study you will compare and contrast prepared slides of root cross-sections from a number of plant species and create labelled biological drawings.

As in stems, the roots of gymnosperms and some eudicot species form wood as the plant ages. The anatomy of a woody root is very much like that of a woody stem. Woody roots are made up primarily of xylem, which forms growth rings.

Root Specializations

UNIT TASK BOOKMARK

Will root specializations be a factor you will consider as you evaluate the importance of a species for the Unit Task on page 630?

Root specializations may help roots to more efficiently absorb water and nutrients, anchor the plant, or store carbohydrates. Other specializations help protect the plant root from being eaten.

A primary role of a root is to absorb water and nutrients for the plant. Almost all plants have some kind of relationship with other organisms to help them in this task. In fact, the roots of over 80 % of plants have a mutualistic relationship with mycorrhizal fungi (**Figure 6**). These fungi can get into smaller spaces in the soil than root hairs can, and are able to release digestive enzymes that break down organic matter. The fungi exchange water and nutrients with the plant in return for carbohydrates. Another important mutualistic relationship occurs between roots of some plant species and nitrogen-fixing bacteria. The bacteria take nitrogen from the air and convert it to a form that the plant can use. In return, the bacteria receive carbohydrates. The bacteria live within nodules in plant roots.

Figure 6 Plants grown in soil that lacks mycorrhizae tend to be smaller than plants that have mycorrhizae.

Figure 7 The strangler fig roots (left) encircle the host tree (right) and eventually kill it by cutting off the flow of materials between the roots and leaves.

Some species, such as the strangler fig, have unusual relationships with other organisms. This plant is found in tropical rain forests. Monkeys, birds, and other animals deposit seeds of the strangler fig in the branches of other trees. These trees become the host in the relationship. As the seed begins to grow, its roots hold on to and obtain water and nutrients from the crevices in the host tree trunk. The roots also grow downward, wrapping around the trunk of the host tree until they reach the soil (**Figure 7**). The fig's shoot system at first grows slowly, shaded by the leaves of the host tree. Eventually, the fig's roots prevent the host's trunk from growing outward. This kills or "strangles" the host tree. As the host tree dies, it loses all its leaves. The fig shoot system is now in the open sun and grows rapidly, and its root system completely engulfs the trunk of the host. The host tree trunk rots away, leaving behind a large hollow space within the strangler fig.

Most of the roots eaten by humans and other organisms are specialized for carbohydrate storage. For example, carrots and beets are taproots that have a thicker cortex for greater carbohydrate storage (**Figure 8(a)**). In other species, the lateral roots are specialized for storage. Lateral roots modified for storage are called **tuberous roots**. Yams, cassava, and sweet potatoes are tuberous roots that are important for our food supply (**Figure 8(b)**).

tuberous root a lateral root specialized to store carbohydrates

Figure 8 (a) Taproots, such as carrots, and (b) tuberous roots, such as cassava, store carbohydrates in a thick layer of parenchyma cells.

Roots that store carbohydrates are at higher risk of being eaten by other organisms. Some roots therefore produce chemicals to reduce this risk. For example, the roots of the plants called bitter root and bear root taste so bad that few animals will eat them. Cassava roots protect themselves by producing a deadly toxin. To make cassava root safe to eat, humans soak and cook it, which removes the toxin. Some insects, such as the mealy bug, are resistant to the cassava root toxin.

The roots of some plants produce chemicals that harm other plants. Two examples are the black walnut and the common reed. The black walnut root secretes a toxin that inhibits the growth of other plants. The common reed releases a corrosive acid that breaks down the roots of neighbouring plants. Preventing other plants from growing nearby reduces competition for resources.

Figure 9 shows an example of a root adaptation that gives additional support to the plant. In this example the prop roots are growing from the stem of a young corn plant. A prop root is a type of adventitious root. An **adventitious root** is any root that does not grow from the root apical meristem that emerges from the seed after it begins to grow.

Figure 9 The adventitious roots provide the corn plant with additional support. These are also known as prop roots.

adventitious root a root that develops from somewhere other than the root apical meristem that emerges from the seed

Human Uses of Roots

As with leaves and stems, humans have found many ways to benefit from the diversity among roots of vascular plants. We use roots as food, for ourselves and our livestock, and as a source of useful chemicals.

Many of the vegetables we eat are roots, including parsnips, turnips, beets, taro, and sweet potatoes. Licorice root has a distinctive flavour that is sometimes used in candy. Roots may also be used to make beverages. For example, root beer was originally prepared from the root of the sassafras plant. Cassava, turnips, yams, rutabaga, and other roots are used widely to feed livestock.

There are many uses for the wide variety of chemicals produced by roots. Some roots can be used to dye textiles. For example, red dyes can be prepared from roots of beet or madder, and dandelion root can be used to dye textiles brown. Some pesticides, such as rotenone, come from roots. Rotenone is produced by the roots of plants in the pea family to protect them from being eaten. Rotenone may be used to control insects in gardens or on pets.

As with some leaves and stems, the roots of some plants produce chemicals that have medicinal uses. Ipecac is a substance that may be given to someone who has swallowed something poisonous. Ipecac will rapidly induce vomiting and prevent any further absorption of the poison. (In all cases of suspected poisoning, do not attempt any treatment. Go directly to a hospital.) Ipecac is produced by the root of the ipecacuanha plant, native to Brazil (**Figure 10(a)**). Kava kava root produces a substance that has been shown in scientific studies to reduce anxiety. Scientists are working to identify the active ingredient (**Figure 10(b)**).The root of valerian, a common garden plant (**Figure 10(c)**), produces a mild sedative that can be used to relieve insomnia.

CAREER **LINK**

Pharmacist
Pharmacists have knowledge of potential interactions between over-the-counter herbal remedies and prescription drugs. To find out more about a career as a pharmacist,

GO TO NELSON SCIENCE

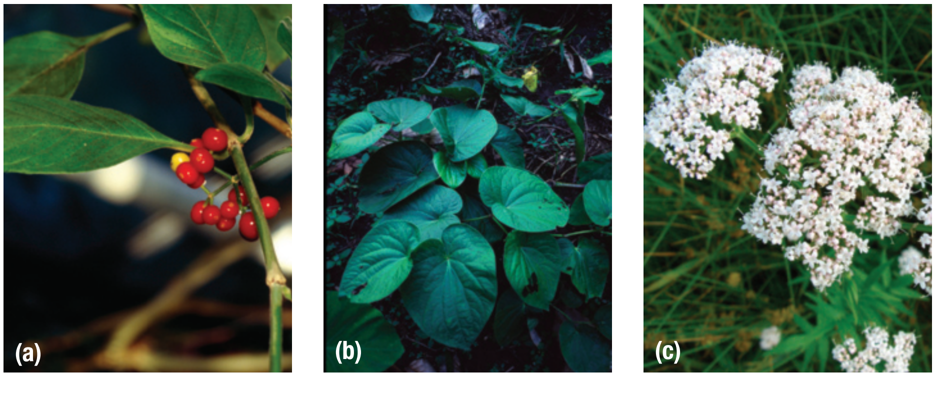

Figure 10 Chemicals in the roots of (a) ipecacuanha, (b) kava kava, and (c) valerian have medicinal uses that have been verified by scientific studies.

Mini Investigation

Identifying Starch in Roots

Skills: Questioning, Performing, Observing, Analyzing, Communicating — SKILLS HANDBOOK A2.1

Most of the roots eaten by humans are taproots. Taproots have many parenchyma cells, which store sugars and starch. Young roots tend to be sweeter, since they have not yet converted as much sugar to starch. Starch does not support bacterial growth as well as sugar, so roots can remain edible for a long time when stored properly. The presence of starch can be detected using an iodine solution known as Lugol's solution.

Equipment and Materials: knife; Petri dishes; Lugol's solution; starch; samples of roots

Caution: Lugol's solution is toxic if swallowed and may stain skin and clothing.

1. Bring small samples of roots, including some that you think might be starchy root vegetables, to class.
2. Copy **Table 1** into your notebook. Ensure that there is enough space for all your samples.

Table 1 Test for Starch Using Lugol's Solution

Sample	Appearance before test	Appearance after test
starch		

3. Place a small sample of starch in a Petri dish.
4. Place a small piece of each root sample in another Petri dish.
5. Observe the appearance of each substance, and record your observations in your table.
6. Carefully add one drop of Lugol's solution to each sample.
7. Observe the appearance of each substance and record your observations in your table.

A. Why was the known starch sample tested with Lugol's solution? T/I

B. Which of your samples contained starch? How did you determine this? T/I

C. Give two reasons why you would not taste an unknown food sample to determine whether it contains starch. A

Erosion Control

Figure 11 Special mixtures containing grass seeds may be sprayed on areas vulnerable to erosion.

Roots are extremely useful in helping to control erosion. Any area where soil is uncovered or sparsely covered is susceptible to wind and water erosion. Fibrous roots can be particularly useful in controlling erosion, since they form a mat that holds the upper soil layers in place during heavy rain, snow, or wind. You may have seen a strange green substance on piles of excavated soil on construction sites. This is actually an erosion control measure. It is mixture of grass seed, mulch, and synthetic additives that help the seeds grow quickly (**Figure 11**).

Trees may also be planted to control erosion. This is often done after an area of forest has been clear-cut, which involves harvesting all the trees in the area. Clear-cutting exposes the soil surface, making it vulnerable to erosion. However, even when tree seedlings are planted to replace the harvested trees, it takes many years for them to grow large enough to control erosion effectively.

Mangrove trees seem unusual to those of us who did not grow up around them. The roots of the mangrove arise from the above-ground portion of the stem (**Figure 12**). They are found at the shorelines of tropical seas, where they have an important role in controlling erosion. They also provide protected areas for the young of many marine organisms.

Figure 12 The characteristic roots of mangrove trees prevent erosion by waves.

12.4 Summary

- Roots anchor the plant, absorb water and minerals from the soil, and often store starch and sugars.
- All gymnosperms have taproots. Angiosperms may have either taproots or fibrous roots.
- All roots have a cortex and a vascular cylinder. Monocot roots have parenchyma cells in the centre of the vascular cylinder.
- Most plant species have symbiotic relationships with micorrhizal fungi that exchange water and nutrients with plant roots
- Some plants have mutualistic nitrogen-fixing bacteria living within specialized root nodules.
- The roots of woody gymnosperms and angiosperms have a similar structure.
- Humans use roots for many purposes.

12.4 Questions

1. What are the biological functions of plant roots? K/U
2. Draw a diagram of a fibrous root system. In what plant group are fibrous root systems found? K/U C
3. Draw a labelled diagram of a cross-section of a monocot root. Include the following labels: cortex, vascular cylinder, parenchyma, xylem, and phloem. K/U C
4. Can you tell the difference between monocots and eudicots by looking at root cross-sections? Why or why not? K/U
5. A student wants to test the effects of mycorrhizal fungi on the growth of a particular plant species. She has two identical plants and a solution containing the fungi in which roots may be dipped. Write a brief experimental design for the investigation. State the manipulated and responding variables, and any variables that must be controlled. T/I
6. Epiphytes are plants that live on other plants, usually trees. Use the Internet and other sources to find out more about these plants. K/U A
   (a) Are epiphytes common?
   (b) In what ecosystems are they most common and why?
   (c) What are some of the advantages and disadvantages of being an epiphyte?
7. The roots of legumes, such as peas and beans, have special nodules that are home to large numbers of bacteria. What benefit do these bacteria provide to the plant? What do they receive in exchange? K/U A
8. Mistletoe is a widely known parasitic plant that grows high in trees (**Figure 13**). Mistletoe gets water and minerals from its host plant. Predict which tissues in the host plant are infiltrated by the mistletoe roots. T/I A

Figure 13 Mistletoe is a parasitic plant.

9. List two human activities that are likely to result in an increase in erosion. Explain your choices. A
10. Plants store most of their starch in their roots rather than in their leaves. This storage is often at its maximum over winter. K/U A C
    (a) How might these adaptations benefit the plant?
    (b) Based on this information, which plant part is likely to supply the greatest amount of food energy to other species—leaves or roots?
    (c) Suggest a way that humans have taken advantage of this over-wintering adaptation.
11. Grizzly bears are famously powerful animals. Use the Internet and other sources to find out the connection between their powerful limbs and plant roots.

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