12.3

Stems

Figure 1 The stems of trees are an important economic resource.

If you pass a building site or walk through a lumber yard, you will likely encounter one of the most common uses of stems. The stems of tree species are the source of wood (**Figure 1**). Any wooden boards, planks, and sheets you see come from the stems of a number of tree species, such as pine and ash. Stems in the form of tree trunks are worth a great deal to our economy. According to Statistics Canada, in 2009 the gross value of forestry and logging was $3.5 billion. The harvested wood is often converted to wood products, further contributing to our economy. For example, Industry Canada reported that Canadian pulp and paper was worth $9.8 billion in 2008.

The uses for stems go far beyond the lumber yard. The origins of these two common products might surprise you. Cinnamon, a popular spice, is powdered bark from a laurel tree. Chewing gum originally came to Europe from South America, where explorers saw Mayans chewing the sap of the chicle tree.

Figure 2 The green part of a cactus is its stem, modified to store water and nutrients and to perform photosynthesis.

Functions of Stems

Stems are certainly valuable to our economy, but what value are they to plants? Stems have several important roles. They connect the vascular tissue in the leaves to the vascular tissue in the root. This allows water and dissolved substances to be transported throughout the plant body. Stems also raise and support the leaves and reproductive organs. Raising leaves helps to maximize their exposure to sunlight, so they are able to photosynthesize more efficiently. Raising flowers or cones places them in an ideal position for pollination and the production of seeds and fruit. In some species, stems may also be modified to store water or carbohydrates. For example, cactus stems are highly modified to allow storage (**Figure 2**). Cacti, aspen trees, and many other plants have green stems that perform photosynthesis. The stems of many species have adaptations to help protect the plant from injury and herbivores. For example, thorns, such as those on the hawthorn tree, are modified branches that form sharp spikes that deter large herbivores.

Stem Structure

herbaceous describes plants with stems that do not have wood

woody describes plants with stems that contain wood

The plants in **Figure 3** show the diversity of stem types found among plant species. This diversity occurs in part because some species have herbaceous stems and some have woody stems. **Herbaceous** plants have stems that do not contain wood. Their stems are relatively pliable, carry out photosynthesis, and have a thin epidermis. As the name suggests, **woody** plants have stems that contain wood. Woody stems are relatively hard, have bark, and do not usually carry out photosynthesis. All gymnosperms have woody stems. Most woody angiosperms are eudicots. Monocots do not produce wood, but some have tissues that have a similar function, such as the stems of some palms and bamboos.

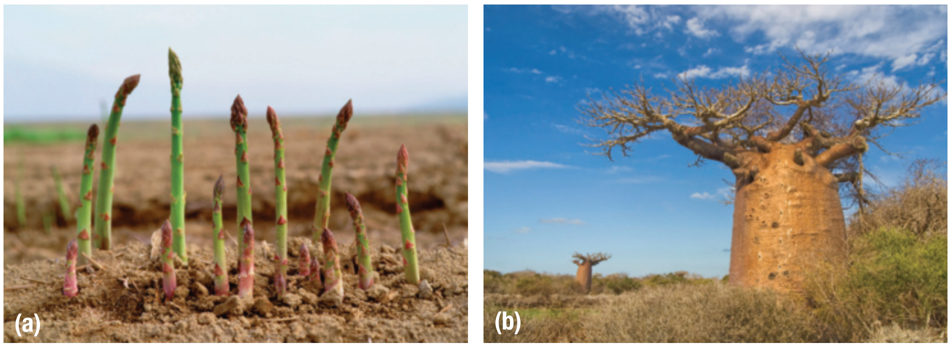
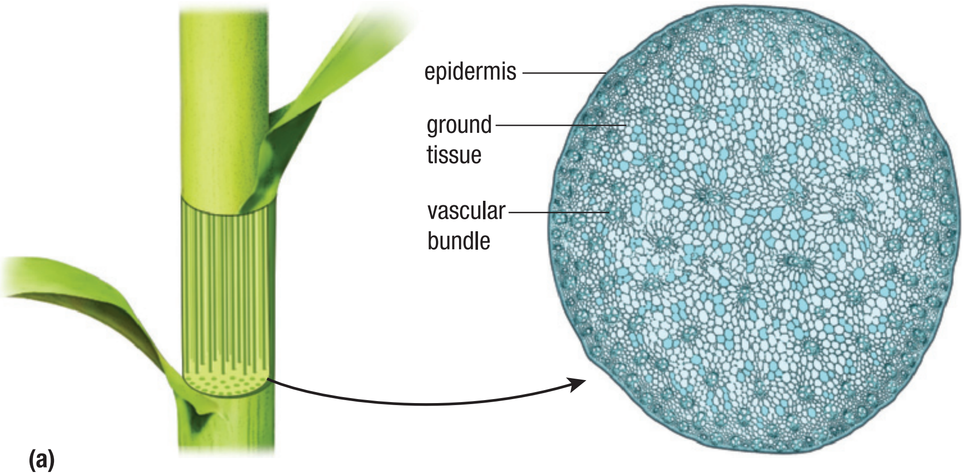


Figure 3 (a) The herbaceous stems of the asparagus plant are a source of food for humans and other organisms. (b) The baobab tree is native to dry regions of Africa, Malaysia, and Australia. The wide, woody stem can store large amounts of water.

Anatomy of Herbaceous Stems

Figure 4 shows the general anatomical features of herbaceous stems of monocots and eudicots. The vascular tissue of herbaceous stems is arranged in distinct vascular bundles in ground tissue. A **vascular bundle** is a long, continuous strand of vascular tissue that consists of xylem and phloem. Vascular bundles run continuously from the root to the leaves. In each vascular bundle, the xylem is always closer to the centre of the stem, and the phloem is always closer to the outside of the stem. Vascular bundles are arranged differently in monocot and eudicot stems. In monocots, the vascular bundles are found throughout the ground tissue of the stem. In eudicots, the vascular bundles form a ring.

vascular bundle the arrangement of vascular tissue that consists of xylem and phloem



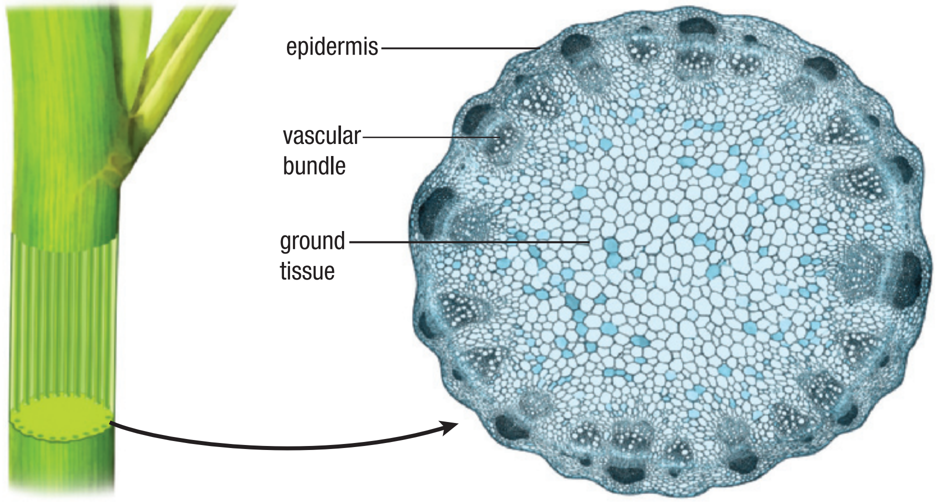


Figure 4 Stem structures of monocots and eudicots: (a) longitudinal view and a cross-section of a monocot stem (corn); (b) longitudinal view and a cross-section of a eudicot stem (alfalfa)

Investigation 12.3.1

Comparing Monocot and Eudicot Stem Cross-Sections (page 576)
Now that you have read about the structure and function of stems, you can complete Investigation 12.3.1.

In this observational study you will prepare and observe slides of cross-sections of monocot and eudicot stems.

Anatomy of Woody Stems

Woody stems have a more complex structure than herbaceous stems. Woody stems are able to grow thicker over the years due to the presence of vascular cambium. **Vascular cambium** is a layer of meristematic cells in the vascular tissue that divide to form new xylem and phloem cells. Each year, the vascular cambium produces a layer of xylem and phloem tissue. The xylem tissue is on the inside of the vascular cambium and the phloem tissue is on the outside.

vascular cambium the meristematic cell layer in vascular tissue

What we call "wood" is actually many layers of xylem tissue cells. Sapwood is the younger xylem through which water and minerals are transported to the leaves. Eventually, the cells in older xylem layers fill up with resins and oils and they no longer conduct water. These older xylem layers form the heartwood. Heartwood is very rigid and helps support the tree.

The anatomy of a typical woody stem is shown in **Figure 5**.

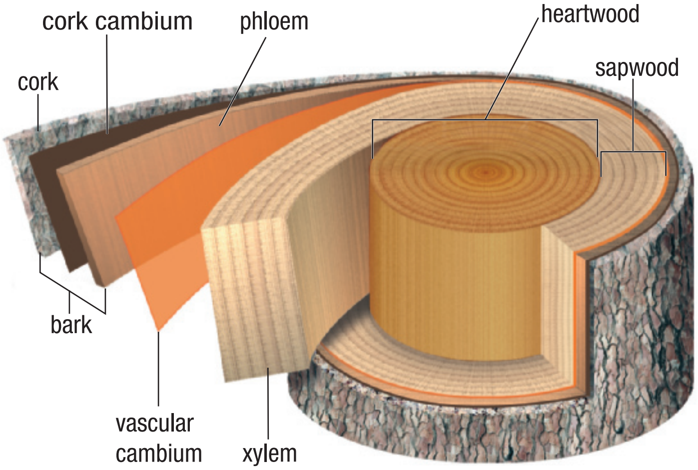


Figure 5 Cross-section of a typical woody stem. The light and dark rings in the heartwood and softwood are xylem, organized into growth rings.

bark the protective outermost layer of the stems and roots of woody plants; consists of phloem, cork cambium, and cork

cork cambium the meristematic layer in a woody plant that produces cork

Bark consists of all the tissues found outside the vascular cambium. It includes phloem, cork cambium, and cork. The phloem transports sugars made in the leaves throughout the plant. The **cork cambium** is a layer of meristematic tissue that produces cork, the tough, outer layer of the tree that prevents water loss from the stem. As the stem increases in size, the cork often cracks and may flake off the tree. Bark protects plants from some herbivores and, in the case of certain tree species, including Ontario's red and white pine, can even offer protection from low-temperature fires.

GROWTH RINGS

In temperate regions, growth only happens in the spring and summer. In spring, the vascular cambium grows rapidly, producing large xylem cells that have relatively thin walls (**Figure 6**). This forms a layer of lighter-coloured wood, known as spring wood. In summer, fewer xylem cells are produced and they have thicker cell walls that form a layer of darker-coloured wood, known as summer wood. Together, these layers form a growth ring. Each ring has light wood on one side and dark wood on the other.

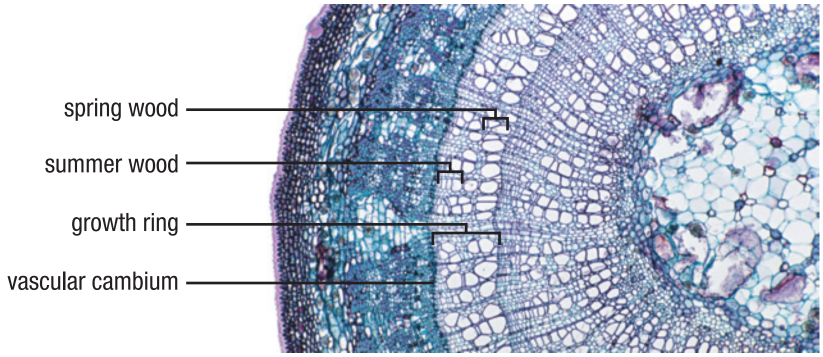


Figure 6 A two-year-old woody stem. Within the growth ring, the xylem cells are larger in spring wood than in summer wood.

Cell Types in Vascular Tissues

The structure of cells in both the xylem and phloem tissues helps the vascular tissue carry out its functions of transport and support. Xylem cells are thick walled and dead at maturity. The cell walls of xylem are rich in lignin, a carbohydrate that makes the cells very strong. Phloem cells are living at maturity and contain cytoplasm. Both phloem and xylem cells may be stacked to form long, continuous tubes.

There are two types of xylem cells: tracheids and vessel elements. A **tracheid** is a long, cylindrical cell with tapered ends (**Figure 7(a)**). All the cell walls of a tracheid have pits (small holes) that allow water and solutes to pass up or across to neighbouring xylem cells. A **vessel element** is shorter and wider than a tracheid and has less-tapered ends (**Figure 7(b)**). Only the side cell walls of vessel elements have pits. The other walls are **perforation plates**, which are end walls with one or more openings to allow water and solutes to pass through.

Phloem cells are living at maturity and contain cytoplasm. Three types of phloem cells are found in vascular plants: sieve cells, sieve tube elements, and companion cells. **Sieve cells** have narrow pores in all their cell walls and contain all the organelles found in most cells, including a nucleus. **Sieve tube elements** have cytoplasm but lack many cell organelles, including a nucleus. The end walls of these cells are called **sieve plates**, which are cell walls with perforations to allow sugar solutions to pass to the neighbouring phloem cells. The third type of phloem cell is a **companion cell**, which is always associated with a sieve tube element. It has a nucleus and all the other organelles that the sieve tube element lacks. The sieve tube elements and their associated companion cells form long conducting tubes (**Figure 7(c)**).

tracheid an elongated, tapered xylem cell with thick cell walls containing small pits; tracheids overlap one another at the ends to form continuous tubes from root to shoot

vessel element a shorter, blunt-ended xylem cell with thick cell walls containing small pits; vessel elements are stacked end to end to form vessel tubes that run from root to shoot

perforation plate the perforated end wall of a vessel element

sieve cell a phloem cell with pores in its cell walls; contains all necessary cell organelles

sieve tube element a phloem cell with pores in its side cell walls and a sieve plate at the end walls; sieve tube elements lack organelles and depend on associated companion cells

sieve plate the perforated end wall of a sieve tube element

companion cell a small, nucleated phloem cell that is always associated with a sieve tube element

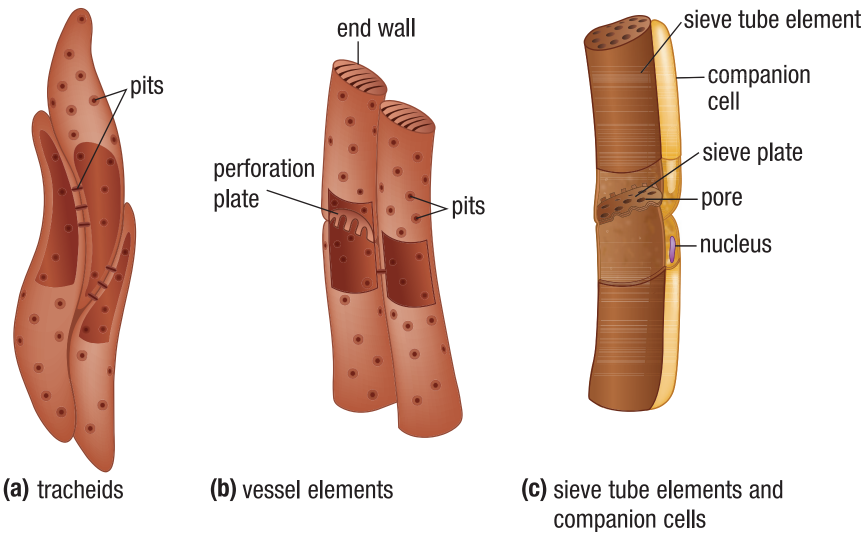


Figure 7 (a) Tracheids have pits in the cell walls that allow transport between neighbouring xylem cells. (b) Vessel elements have a perforation plate at each end of the cell in addition to pits in the side walls. (c) The phloem of angiosperms includes sieve tube elements and their associated companion cells. The companion cells direct the metabolic functions of the sieve tube elements. Each end wall of a sieve tube element contains a sieve plate, which has pores to allow transport between other sieve tube elements.

Not all vascular plants contain all the different types of xylem and phloem cells. **Table 1** shows the cell types most commonly found in the vascular tissue of gymnosperms and angiosperms.

Table 1 Xylem and Phloem Cell Types in Gymnosperms and Angiosperms

Plant group	Xylem tissue cell types	Phloem tissue cell types
gymnosperms	tracheids	sieve cells
angiosperms	tracheids vessel elements	sieve tube elements companion cells

Stem Specializations

All stems connect the vascular tissue of the plant shoot and root, but not all types of stems hold plants upright. Some stems grow underground and are modified to store food and water. Underground stems can also give rise to a new plant.

Figure 8 shows examples of the three types of underground stems: tubers, corms, and rhizomes.

Figure 8 Underground stems: (a) potato tuber, (b) gladiolus corm, and (c) iris rhizome

Stolons are modified stems that grow along the soil instead of upright. Spider plants produce new plants on the ends of stolons (**Figure 9(a)**). Vines are plants with modified stems that take advantage of other objects, including other plants, to raise and support their leaves. Vine stems may be woody, such as grape stems (**Figure 9(b)**), or herbaceous, such as sweet pea stems (**Figure 9(c)**). The tendrils that hold up sweet pea vines are modified leaves.

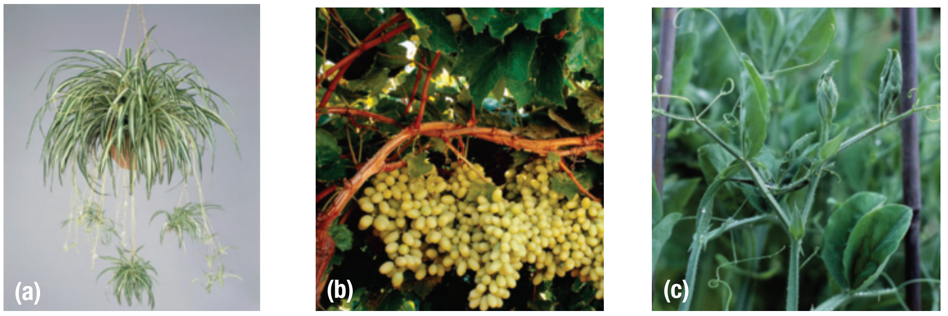


Figure 9 Above-ground modified stems are found on (a) spider plants, (b) grape vines, and (c) sweet peas.

Human Uses of Stems

The most obvious use of stems is in the many wood-based products we use, from furniture, to kitchen cabinetry, to the paper in books. However, humans use vascular plant stems, and the chemicals they contain, for a variety of other purposes (**Table 2**).

Table 2 Some Uses of Plant Stems

Use	Examples	Use	Examples
fuel	• ethanol • wood	dyes	• indigo, used to dye jeans • hematoxylin, a stain used to prepare microscope slides
food	• sugar cane • potatoes • yams • maple syrup • asparagus	other chemicals	• tannin, an ingredient in wood stains • turpentine, a solvent • latex rubber, used for many products, including gloves, tubing, and erasers
textiles	• flax (used to manufacture linen) • hemp (used to produce textiles) • bamboo (used to make clothing; often blended with other natural fibres such as cotton)	medicine	• salicylic acid, a pain reliever made from willow bark • taxol, an anti-cancer drug made from the bark and needles of yew trees

CAREER **LINK**

Engineering Technologist
The pulp and paper industry employs engineering technologists to help apply the plans of professional engineers to the production process. To learn more about this career,

GO TO NELSON SCIENCE

UNIT TASK **BOOKMARK**

You can apply your knowledge of the many ways we use plant stems to the Unit Task described on page 630.

Research This

Willow Bark and Modern Medicine

Skills: Researching, Analyzing, Communicating, Defining the Issue, Defending a Decision

SKILLS HANDBOOK A5.1

A number of Canada's Aboriginal peoples found that willow bark could be used medicinally to ease pain and fever.

1. Conduct research to find out how this traditional use of a plant stem eventually led to the production of one of the most widely known and life-saving medicines, acetylsalicylic acid (ASA).

A. How did Aboriginal peoples prepare and use willow bark? K/U

B. Willow grows in many places on Earth. Identify any other culture that used willow medicinally. K/U T/I

C. What is the active ingredient in willow bark? Why did the Bayer company chemically modify this substance? K/U T/I

D. How is ASA of benefit to people suffering from cardiovascular disease? T/I

E. The active ingredient in willow bark was first isolated in 1828. In 1899, the Bayer company completed clinical trials of ASA and made it available to physicians. Why was it important to conduct this research on willow bark? T/I A

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12.3 Summary

- Stems connect the vascular tissue from shoot to root and raise and support leaves and reproductive structures; they may perform photosynthesis, store water and/or carbohydrates, and have protective features.
- The structure of xylem and phloem cells helps the vascular tissue perform its transport role.
- Gymnosperms have woody stems; angiosperm stems may be woody or herbaceous.
- The vascular bundles are arranged randomly in herbaceous monocot stems and in a circle in herbaceous eudicot stems.
- Woody stems produce new xylem and phloem cells each year.
- Humans use stems for many purposes, such as for wood products, food, textiles, dyes, medicines, chemicals, and fuel.

12.3 Questions

1. What functions do plant stems fulfill for the plant? K/U
2. (a) What is cork cambium and what does it do? K/U
   (b) Do all plants have cork cambium? Explain. K/U A
3. In a table, compare and contrast the vascular tissue of gymnosperms and angiosperms. Consider the types of stems, the xylem and phloem cells, and the arrangement of the tissue within the stem. K/U C
4 (a) Do mature cells of xylem tissue have nuclei? Explain. K/U
   (b) Do mature cells of phloem tissue in angiosperms have nuclei? Explain. K/U
5. Using the information in this section, give your opinion on the economic value of stems to Canadian society. K/U A
6. The rubber tree is grown for its sap and wood (**Figure 10**). The collected sap is processed to produce natural rubber. The companies that own these plantations sometimes advertise their products as environmentally sustainable. Use the Internet and other sources to check this claim. Report on your findings. C A

Figure 10 Natural rubber is a renewable resource.

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