SBI3U-C

UNIT
4

Plants: Anatomy, Growth, and Function

Table of Contents

Introduction

In this unit, you will be introduced to the diversity of vascular plants (plants with a system for transporting water and nutrients). You will explore their internal transport systems, reproductive cycles, and roles in creating and maintaining biodiversity. You will investigate the structures and functions of plant tissues using an online microscope. Through activities, you will determine the requirements for plant growth, and examine how the structure of leaves, stems, and roots are adapted to maximize energy capture. Finally, you will investigate the role that plants play in society and the environment. The importance of plants to bio-resources, sustainable agriculture, medicine, and biodiversity preservation will be explored.

Overall Expectations

After completing this unit, you will be able to

- demonstrate an understanding of the diversity of vascular plants, including their structures, internal transport systems, and their role in maintaining biodiversity
- investigate the structures and functions of plant tissues, and factors affecting plant growth
- evaluate the importance of sustainable use of plants to Canadian society and other cultures

SBI3U-C

Lesson 13

Plant Anatomy and Function

Introduction

We tend to take for granted how important plants are to maintaining life on earth, especially human life. Plants are so critical to human survival that future space exploration is dependent on our ability to grow plants in space. For example, NASA is working on using plants to create an Advanced Life Support (ALS) system to sustain human space travel and colonization of other planets, like Mars. Plants would provide our only means for generating food continuously and, while they do this, they would also supply oxygen, remove carbon dioxide, and help transform waste water into clean water. If we are ever to be successful at creating permanent space colonies on the moon or on Mars, we will need plants, especially vascular plants.

In this lesson, you will concentrate on the structure and function of vascular plants, the main type of plant on earth and the one most important to humans. Trees, crops like corn and rice, and flowering plants are all types of vascular plants. You will learn about the main parts of a plant: roots, stems, and leaves. You will also use an online microscope to view and draw specimens of specialized plant tissues.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (hours)	
Vascular Plants	½
Roots	½
Stems	½
Leaves	½
Activity: Examining Plant Tissues	1
Plant Tissue Types	½
Phytoremediation	¼
Key Questions	1

What You Will Learn

After completing this lesson, you will be able to

- use appropriate terminology related to plants
- identify, and draw biological diagrams of, the specialized plant tissues in roots, stems, and leaves
- compare and contrast monocot and dicot plants in terms of their structures
- describe the structures of the various types of tissues in vascular plants

Vascular Plants

Vascular plants are the type of plant you most commonly see in your daily life. They include trees, shrubs, flowering plants, ferns, and grasses. Vascular plants are critical to supporting life on earth, including our own. Vascular plants make up nearly all of our food crops, purify the water and air, provide fuel, and give us essential materials like wood and fibre.

Vascular plants consist of a root system and a shoot system (Figure 13.1). The root system penetrates the soil, absorbs water and minerals, and anchors the plant. The shoot system consists of the stems, leaves, and flowers. The stem serves as the structure for the positioning of the leaves, the principal site of photosynthesis. The places where the leaves join the stem are called nodes, and the parts of the stem between the nodes are called internodes.

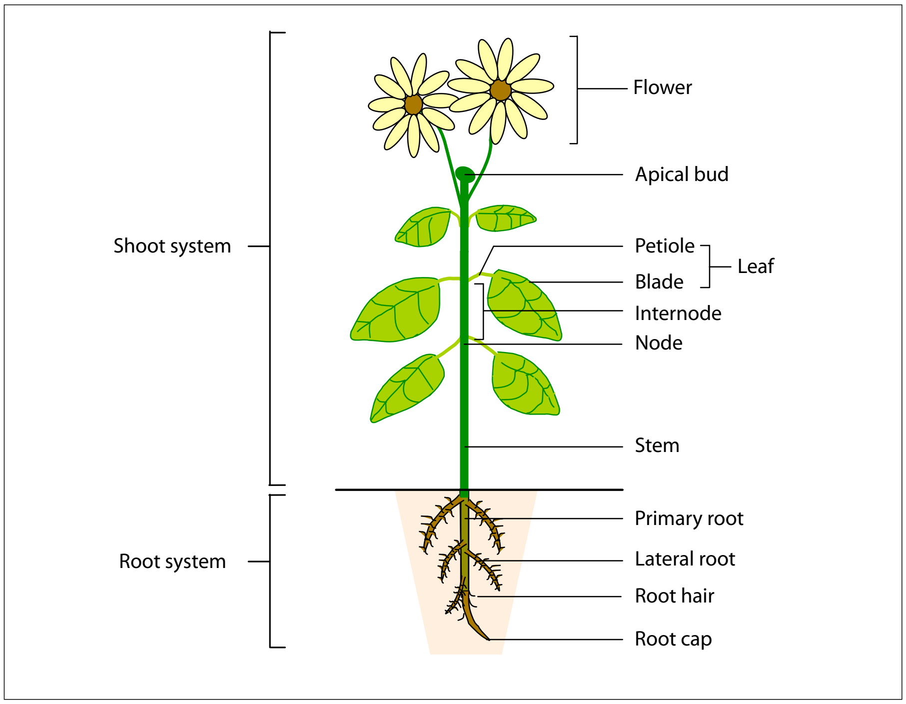


Figure 13.1: Diagram showing the main parts of a vascular plant

Vascular plants have three vegetative organs to carry out their functions: roots, stems, and leaves. Each of these organs has specialized tissue for their own particular function; however, they all contain vascular tissue that forms an interconnected network. The network extends from the leaves to the roots, and transports water and food (glucose) through the plant in a way that is similar to the circulatory system in mammals. The vascular network in plants contains two main types of tissue: xylem and phloem. They are to plants what veins and arteries are to humans and other animals. Xylem carries water throughout the entire plant. Phloem carries water and sugars. Xylem and phloem will be mentioned often as you study the roots, stems, and leaves of plants in this lesson.

Vascular plants are commonly divided into two large groups called angiosperms (flowering plants) and gymnosperms (non-flowering plants).

Angiosperms

Angiosperms, or flowering plants, are the dominant group within the vascular plant world. They are by far the most diverse group of vascular plants known, with over 275 000 named species, and it is estimated that there are at least that many more unknown to science. The basic food supply of the world is derived from the seeds and fruits of angiosperms (rice, wheat, corn). Angiosperms also produce fibres, wood, drugs, and other products of great economic value.

Angiosperms evolved more recently than gymnosperms, with the first flowering plant appearing around 140 million years ago. Flowering plants occur in a wide range of habitats, including both salt water and fresh water, and they come in a wide variety of shapes and sizes (Figure 13.2).

Figure 13.2: Photographs of some common angiosperms

Source: Wikimedia Commons

Angiosperms are named for the defining characteristic of flowering plants, namely, the enclosure of the seeds within a hollow ovary. The angiosperms are considered to be more advanced than the gymnosperms (conifers or cone-bearing plants) and other plants like ferns, all of which have "naked" seeds that are not enclosed in an ovary. In the 1700s, English naturalist John Ray discovered that angiosperms come in two different forms based on the structure of their seeds: monocotyledon (monocot) and dicotyledon (dicot).

Monocots and Dicots

A cotyledon is part of the embryo within the seed of a plant that contains stored food and serves as a food reservoir. Monocots have only one cotyledon; dicots have two cotyledons. The distinction between monocots and dicots is not always clear, but monocots have seeds that are in one piece, like corn, while dicot seeds can be easily split in half, like peas or beans.

There are other structures that distinguish monocots from dicots (Figure 13.3). Monocots, such as grasses and corn, have long, narrow leaves with parallel veins, and their vascular tissue (xylem and phloem) is arranged in long strands called vascular bundles, which are scattered throughout the stem. Dicots, such as maple and oak, have broad leaves with branched veins arranged in networks, and their bundles of vascular tissue are arranged within the stem to form a cylinder, appearing as a ring of spots when the stem is cut. The petals of monocot flowers are arranged in multiples of three; the petals of dicot flowers are arranged in multiples of four or five.

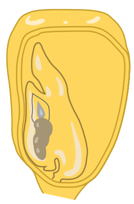
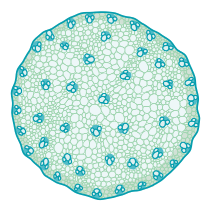
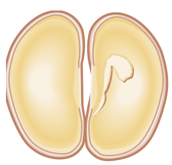
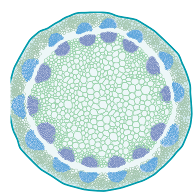
	Seed leaves	Veins in leaves	Vascular bundles in stems	Flower parts
Monocots	one cotyledon 	usually parallel 	scattered 	multiples of three 
Dicots	two cotyledons 	usually netlike 	arranged in ring 	multiples of four and five 

Figure 13.3: Table showing the differences between monocot and dicot plants

Source: McGraw-Hill Biology 11

Gymnosperms

The defining feature of gymnosperms is that their seeds are not enclosed in an ovary. The seeds look "naked" because they do not have any tissue like fruit or a thick skin around them. Gymnosperms include pines, spruce, fir, and many more trees, known as conifers, which are commonly called evergreen trees because they don't lose their leaves all at once, giving them the appearance of being green year-round. Since gymnosperms have several cotyledons inside their seeds, they are referred to as polycotyledons or polycots. Gymnosperms appeared early in the evolution of vascular plants; they have existed for at least 380 million years.

The white pine is one of the most famous conifer trees in Ontario (Figure 13.4). Because it grows so tall and straight, white pine was an ideal tree to use as masts for sailing ships during the eighteenth and nineteenth centuries.

Figure 13.4: Photograph showing white pine trees in the background with a close up of the needles and cone in the foreground. White pine needles grow in bunches of five.

Source: Wikipedia

Today, conifers like pine and spruce are the most commercially important trees in North America. The logging industry harvests these trees from the boreal and coastal forests to make lumber for construction and to make paper (Figure 13.5).

Figure 13.5: Photograph of a conifer logging area near Port Renfrew, B.C..

Source: Wikipedia

Plants, therefore, can be classified by type according to the chart shown in Figure 13.6, below.

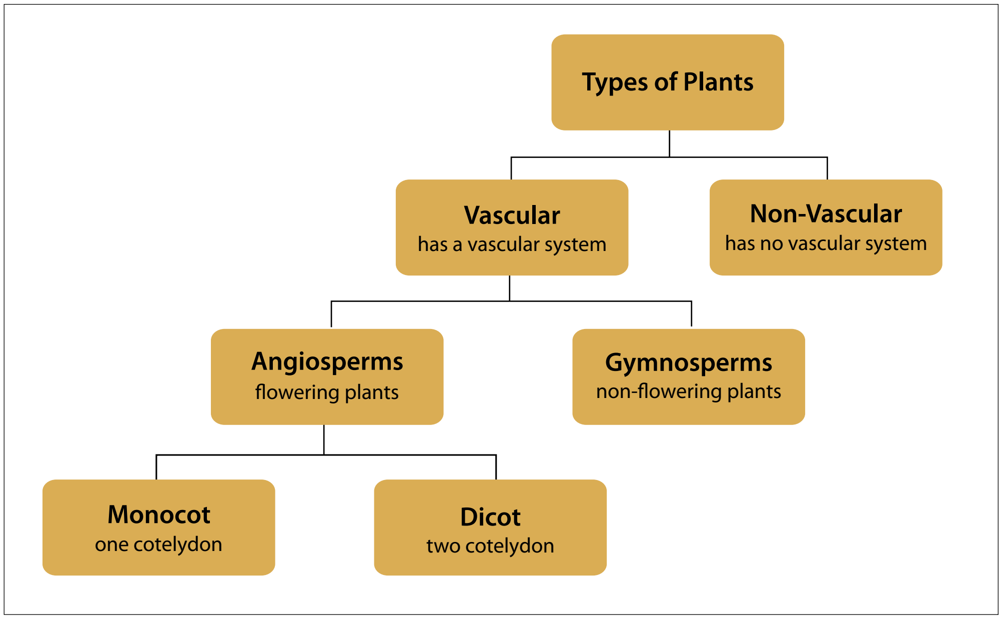


Figure 13.6: Chart summarizing the different types of plants

In the next sections, you will examine the three main parts of a vascular plant in detail: roots, stems, and leaves.

Support Questions

Be sure to try the Support Questions on your own before looking at the suggested answers provided.

1. Describe two ways that vascular plants could support human life in closed systems, such as space colonies. Suggested answer

2. Complete the following chart. Suggested answer

Type of plant	Characteristics
Vascular	
Non-vascular	
Angiosperm	
Gymnosperm	
Monocot	
Dicot	

3. What are the different types of vascular tissue? What function do they serve? Suggested answer

Roots

Roots serve several important functions in vascular plants, including absorption of water and minerals from the soil, storage of food, and anchorage in the ground. They also conduct materials to and from the stem. Roots are vital for the survival of vascular plants. When a seed germinates, the first structure to develop is the root. This allows the plant to anchor itself in the soil and take up water. The water is then used to convert the food stored in the seed as starch into a usable form, sugar, which the plant can live on until the leaves develop and the young seedling can make its own food through photosynthesis.

Root Function

Roots have four primary functions:

- to anchor the plant in one place for its entire life;
- to absorb large amounts of water and dissolved minerals from the soil;
- to transport water and dissolved nutrients to and from the shoot; and
- to store large amounts of energy.

Root Structure

Roots tend to grow downward, away from light and toward water. As a general rule, they do not contain leaves or buds. In most vascular plants, roots lie below the surface of the soil. Roots contain several structures that form what is called the root system. There are two main types of root systems: the taproot and the fibrous root.

Taproot

When a seed germinates, the root that is produced is called the primary root. If it enlarges to become the major root, the plant has a taproot system. The dandelion and carrot are two common plants with taproots (Figure 13.7).

Figure 13.7: Photograph of carrots, whose edible portion is the taproot

Source: Wikipedia

The taproot reaches deep into the soil for water, and anchors the plant firmly in the ground. For example, the taproot system of an oak tree helps it survive drought conditions by growing deep into the ground to find sources of water. The deep taproot of a dandelion makes it very hard to dig up this weed. Even if the top is pulled off, the plant will grow back from the taproot.

Fibrous Root

Other plants, such as grasses and maple trees, send out secondary roots that outgrow the primary root very quickly. These roots are called fibrous roots. They are characterized by a shallow mass of tangled roots that spread through a large area of soil (Figure 13.8). These root systems are very effective at water and mineral absorption as well as plant stabilization. Fibrous-rooted plants also help prevent soil erosion while promoting slope stability, because of the formation of fibrous root systems near the soil surface.

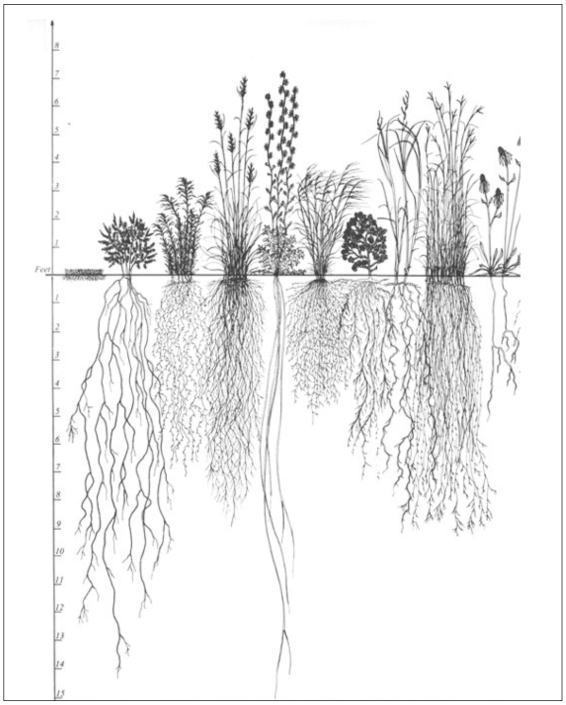


Figure 13.8: Drawing of plants with fibrous roots

Source: Wikipedia

How Roots Grow

The first organ of the seed to emerge and become established is the root. The growing part of the root is called the apical meristem. This consists of a large number of dividing cells located at the root tip. This meristem produces all the cells that will make up the main axis of the root as well as the cells of the protective root cap (Figure 13.9).

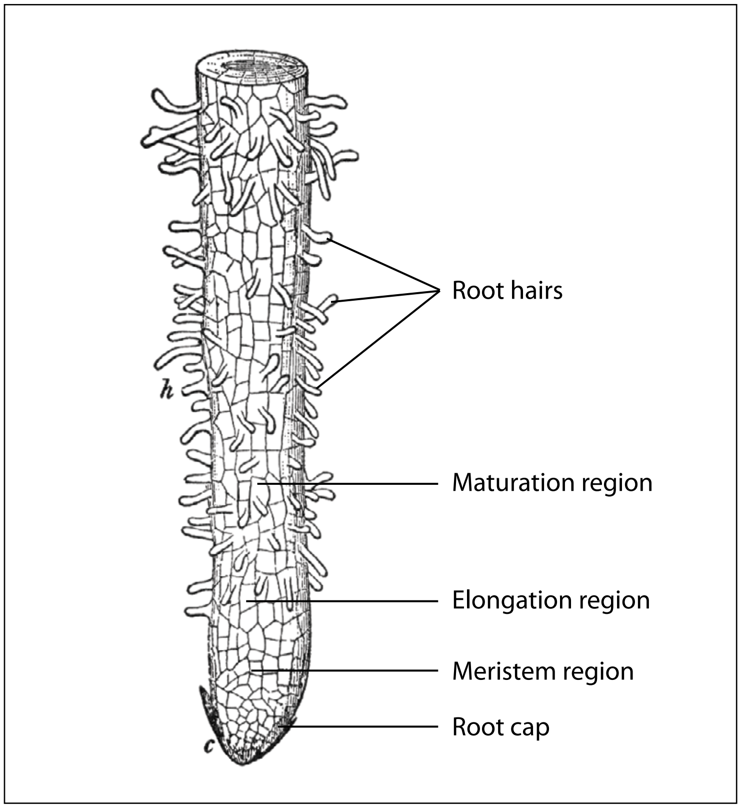


Figure 13.9: Drawing of the growing tip of a root

Source: Wikimedia Commons

Roots grow by increasing their length. Two factors contribute to the increase in root length:

- Reproduction: in the meristem region, continuous cellular reproduction adds new cells that help push the root cap through the soil. As the root cap cells die and are worn away, they are replaced by dividing meristematic cells.
- Elongation: in the elongation region, cells increase in length, forcing the root cap and meristem farther into the soil.

Above the elongation region, in the maturation region, the elongated cells that originally came from the meristem begin to differentiate. Vascular tissue forms inside the root, while epidermal tissue forms on the outside. Specialized epidermal cells form extensions called root hairs that greatly increase the surface area for water and mineral absorption. As the root grows, the hairs farthest from the tip die and fall off while new hairs form closer to the tip.

Root Adaptations

An adaptation is anything that helps an organism survive and reproduce in an ecosystem. It is important to remember that mere survival is not enough for evolution to occur; a species must also reproduce to be considered successful as an organism. Roots have adapted and evolved to fulfill a variety of other functions including storage, support, and aeration.

Here are three types of root adaptations:

1. Aerial roots are exposed to the air for at least part of the day. Epiphytes, which are plants that grow on other plants but are not parasitic, have aerial roots. For example, some rainforest orchids are epiphytes that grow perched high on tree trunks and branches, where they attach themselves with aerial roots. They absorb the water they need directly from the moist air and they obtain their mineral requirements from the leaves, dust, and bark that fall and decompose near their roots.
2. Pneumatophores are specialized aerial roots enabling plants to grow in waterlogged soil. For example, mangrove trees grow in mud along ocean shorelines. The mud is anaerobic (oxygen-poor) and unstable, so the mangroves produce exposed roots that are not completely submerged in order to obtain oxygen in an otherwise anaerobic substrate.
3. Adventitious roots do not grow from a plant's root system, but sprout above ground, most commonly from stems. These root structures often increase plant stability or allow the plant to reproduce by sprouting. Prop roots are adventitious roots that are found in corn and some tropical trees, such as the banyan. Prop roots originate from the lower stem and grow downward into the soil or mud, where they function to support (or "prop up") the plant.

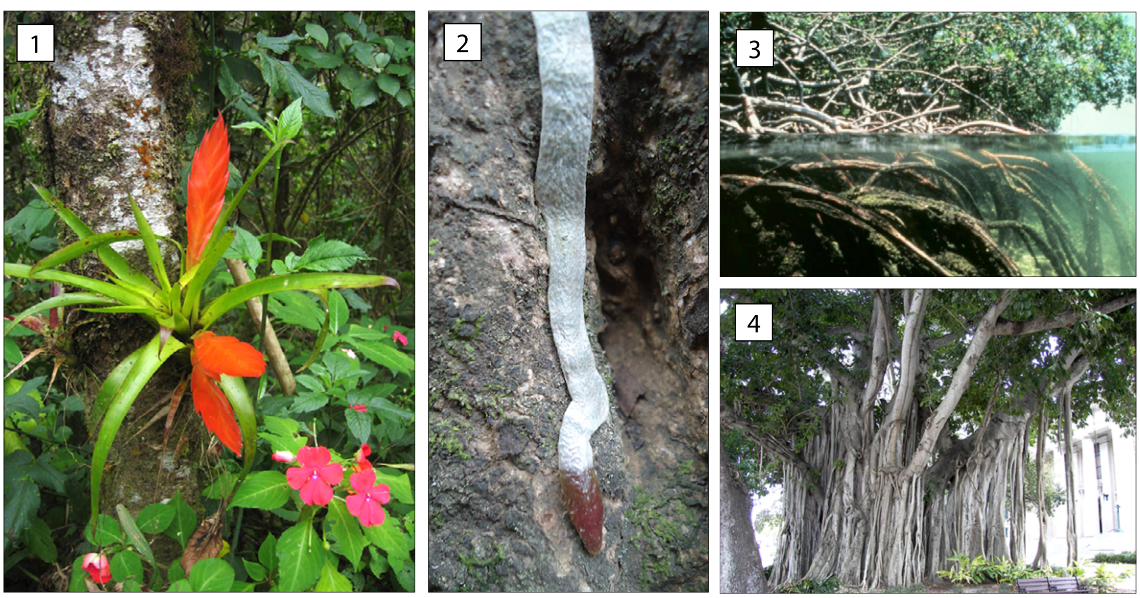


Figure 13.10: Examples of root adaptations: 1) epiphyte growing on a tree in Costa Rica; 2) orchid root clinging to a tree; 3) mangrove roots above and below water; 4) prop roots on a banyan tree

Support Questions

4. State the four major functions of roots in plants. Suggested answer

5. Describe how a growing root can travel downward into the soil. Suggested answer

6. Explain what an aerial root is. Suggested answer

Stems

Stems are the main structural part of the plant lying above ground. A plant can have one or many stems. Stems can be short or very tall, depending on the plant's need to escape the shadows of other plants. Tree trunks are actually stems; if you look around you, chances are you will see products or structures made of tree stems, which we call wood.

Stem Function

Stems have four primary functions:

- They provide the framework to physically support the leaf canopy and expose the leaves to sunlight.
- They serve as a transport system that connects the roots with the leaves.
- They store surplus food for continued growth during the warm season, and over winter to support spring growth.
- They may be able to carry out photosynthesis.

Stem Structure

The vascular tissue present in roots extends upward through the stems with modifications that allow the stems to grow above the surface of the soil. The vascular tissue of roots and stems is interconnected. The xylem transports water and nutrients up the stem to the leaves, while the phloem transports sugars manufactured by the leaves to all the growing parts of the plant including the roots. As mentioned earlier, xylem and phloem are referred to as vascular bundles. The vascular bundles are surrounded by supporting tissues. In the stem, the supporting tissues can be quite thick and strong, especially in trees.

The xylem is always positioned closer to the centre of the stem, while the phloem is closer to the outside of the stem. As shown earlier in Figure 13.3, the vascular bundles of herbaceous monocots like corn are scattered throughout the stem while, in herbaceous dicots, the bundles are arranged in a ring. In dicots, there is a thin layer of tissue between the xylem and the phloem called the vascular cambium.

There are two main types of stems: herbaceous and woody.

Herbaceous Stems

Herbaceous stems are green and usually soft. They do not survive the winter and will grow again each year. Most flowers you are familiar with, such as tulips and dandelions, have herbaceous stems. Most crops, such as wheat and corn, also have herbaceous stems. The stems of many herbaceous dicots are hollow.

Woody Stems

Woody stems contain tough, hard tissue commonly called wood. All trees and many shrubs, such as dogwood and sumach, have woody stems. These stems survive the winter and grow thicker over time.

All angiosperms with woody stems are classified as dicots because they have a ring of cambium between the xylem and phloem. The meristematic tissue in the vascular cambium produces new layers of xylem and phloem each year. The new phloem crushes the old phloem against the outer bark. More xylem is produced than phloem, so the central part of the stem develops a thicker core. This thick layer is called wood. In temperate plants, the xylem vessels produced in the spring, when water is more plentiful, are referred to as spring wood; they are much larger than the xylem vessels formed in the drier summer months, called summer wood. Summer wood terminates with the end of the growing season and the onset of winter dormancy. The spring xylem forms a light-coloured band, whereas the summer xylem forms a dark-coloured band; together, they make up the annual growth rings that can be seen when a tree is cut. Tropical woody plants also produce growth rings, but they do not correspond to years, since tropical trees grow year-round. Thus, the age of tropical trees is difficult to determine.

Only the most recently formed xylem bands actually transport materials upward. This xylem is called sapwood because it is saturated with tree sap. The older, inner xylem that functions only as support is called heartwood. The outer bark on the stem is formed by a second layer of meristematic tissue that develops around the outside of the stem. As the stem grows, the outer layers of cells die. At maturity, these thick-walled, non-living cells make up the outer bark, which helps protect the tree from dehydration, disease, and herbivores.

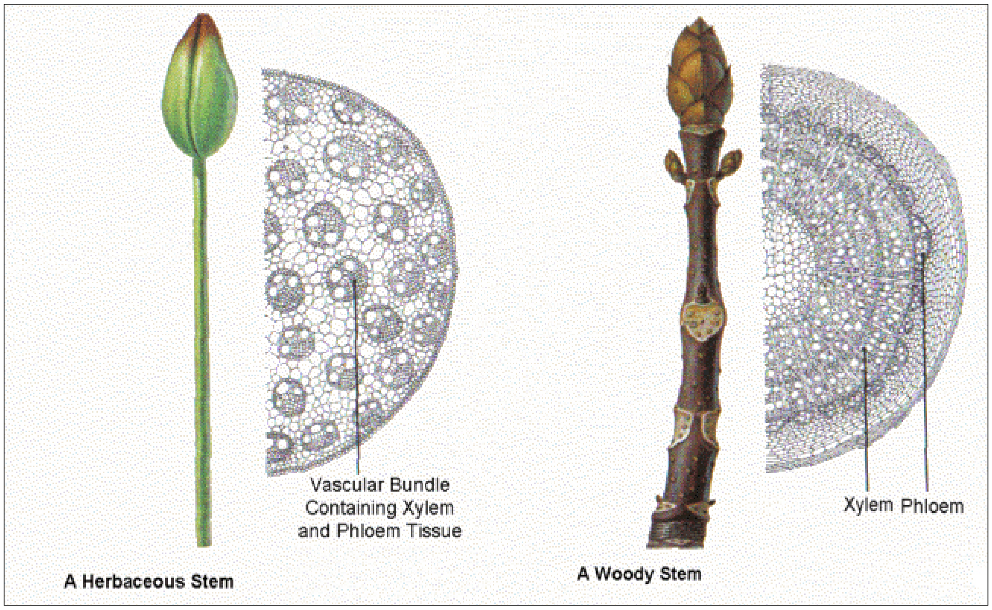


Figure 13.11: This image compares a herbaceous (monocot) stem to a woody (dicot) stem.

Stem Growth

Stems grow from their tips. Meristematic tissue located at the tip of the stem (apical meristem) forms new cells. Plant stems increase in length and thickness by laying down successive layers of cells, similar to the way bricks are laid in building a wall. Woody stems grow in thickness because of cell division in a thin layer of cells called the cambium. The cambium lies just under the protective bark layer, and becomes active in the spring in response to warm weather. Most of the tissue in a woody stem is accumulated xylem. Xylem cells are produced on the inside of the cambium, and phloem cells on the outside. The phloem and bark do not accumulate, and are sloughed off as the stem increases in diameter. Stem length increases as active cells produce new cells at the stem tips (apical buds). The new cells then differentiate into xylem, cambium, and phloem.

Stem Adaptations

Some stems have structural adaptations that enable them to survive and reproduce.

Here are five types of stem adaptations:

1. Rhizomes are stems that grow horizontally underground and live year-round. The two main functions of rhizomes are reproduction and food storage. Under favourable conditions, as in spring, they send up new shoots. Many common Ontario weeds such as bind-weed, quack grass, and horse nettle have rhizomes, thus making them particularly difficult to eliminate. Other plants with rhizomes include iris, asparagus, rhubarb, and most ferns.

2. Corms superficially resemble bulbs but, unlike bulbs, they consist mostly of stem tissue bearing a few small, scaly leaves. Like bulbs, corms store food, but it is located in their stem tissue rather than their leaves. Corms are also reproductive structures. Plants with corms include crocus, banana, and taro.

3. Tubers are short, very thick, underground stems filled with stored food in the form of starch. A familiar example of a tuber is a potato. The eyes of a potato are actually buds from which conventional, aerial stems and leaves will grow. Potato fields are planted by placing pieces of tuber with one or two eyes into the ground.

4. Bulbs consist of a small stem surrounded by numerous fleshy leaves. Bulbs store food in the fleshy leaves, usually in the form of sugar. They are also reproductive structures. Plants with bulbs include onions, garlic, daffodils, and tulips.

5. Stolens, or runners, are stems running horizontally above ground. This structure allows the plant to explore its environment and put down new roots in favourable locations. An example of a plant with stolens is the strawberry.

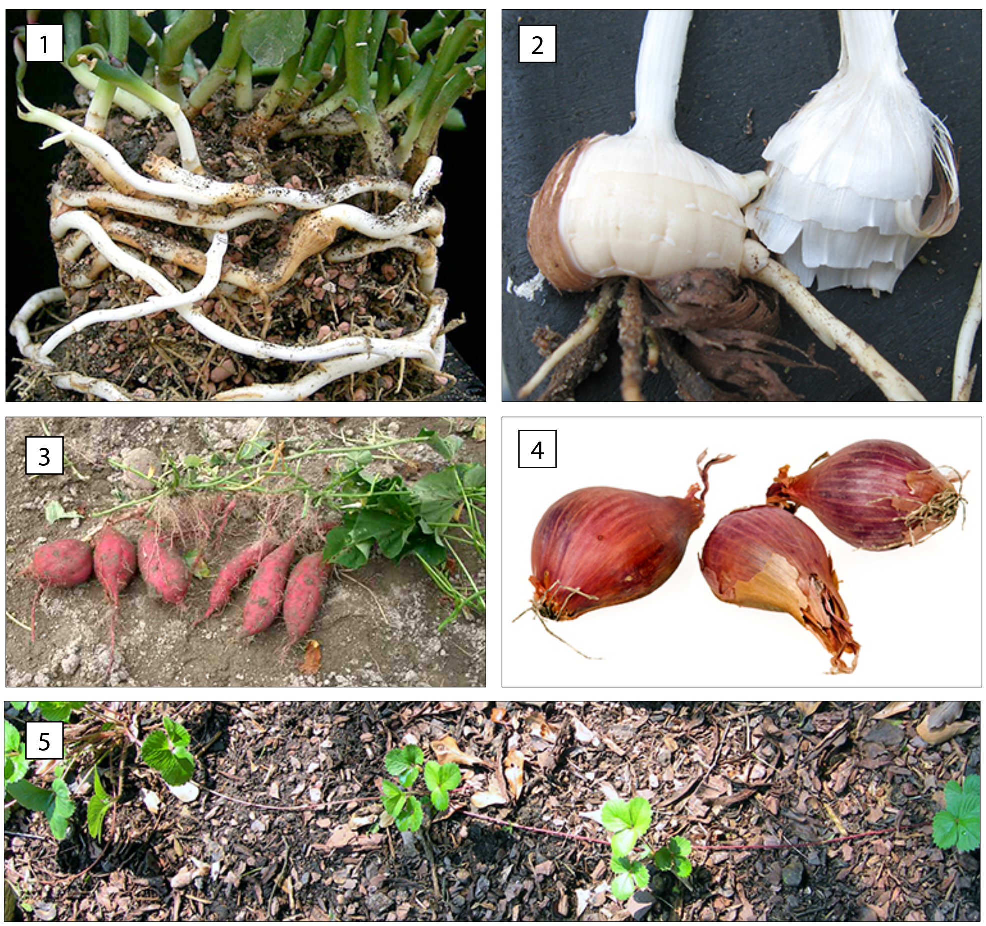


Figure 13.12: Images of different stem adaptations: 1) *Euphorbia* plant sending out rhizomes; 2) *Crocosmia* corms; 3) sweet potato tubers; 4) shallot bulbs; and 5) strawberry stolens

Support Questions

7. Match the term to the definition.

Suggested answer

Stem	Definition
1. Stolens or runners	A. These resemble bulbs but, unlike bulbs, they consist mostly of stem tissue bearing a few small, scaly leaves.
2. Bulbs	B. These are greatly enlarged, short underground stems filled with stored food in the form of starch.
3. Tubers	C. These store food in the fleshy leaves, usually in the form of sugar. They are also reproductive structures.
4. Corms	D. These are stems that grow horizontally underground.
5. Rhizomes	E. These are stems running horizontally above ground.

Leaves

Often, the most noticeable feature of plants is their leaves. Leaves are the structures where most photosynthesis takes place. Photosynthesis is the process by which plants are able to capture energy from light and use that energy to make glucose, the building block of all food. Chlorophyll is a green pigment located in the chloroplasts of the plant's mesophyll cells. It captures energy from sunlight and stores it as chemical energy, which is later used to make glucose from carbon dioxide and water. Oxygen is a byproduct of photosynthesis and is released through the stomata. If it weren't for leaves, we wouldn't have oxygen to breathe.

Leaves are usually green because they absorb all the other colours of light needed for photosynthesis. The green wavelengths of light get reflected, which makes them appear green. All the food required by animals (including you) ultimately comes from the photosynthesis that takes place in leaves.

Leaf Function

Leaves have four primary functions:

- to absorb sunlight to manufacture sugars through a process called photosynthesis;
- to control transpiration (the release of water from the plant);
- to release oxygen; and
- to absorb and store carbon dioxide.

Leaf Structure

There are many different kinds of leaves. Most leaves are designed to provide the maximum exposure to sunlight, so their surfaces are flattened to present a large area for efficient light absorption (Figure 13.13). Leaves are attached to the stem by the petiole. A thick vascular bundle called the midrib runs along the centre of the leaf, which also gives it support. Veins branch off from the midrib to transport water and sugars. The blade is the thin, expanded structure on either side of the midrib. The blade is where the majority of photosynthesis takes place.

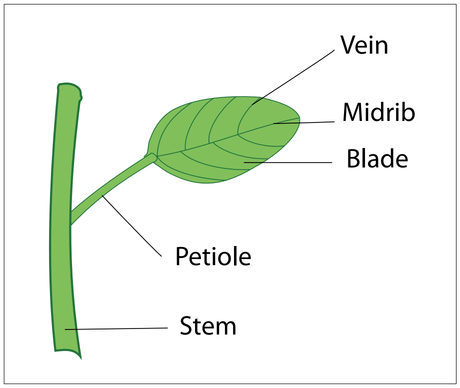


Figure 13.13: Diagram showing the parts of a leaf

The blade of a leaf is composed of several layers, as seen in the follwing cross-section (Figure 13.14).

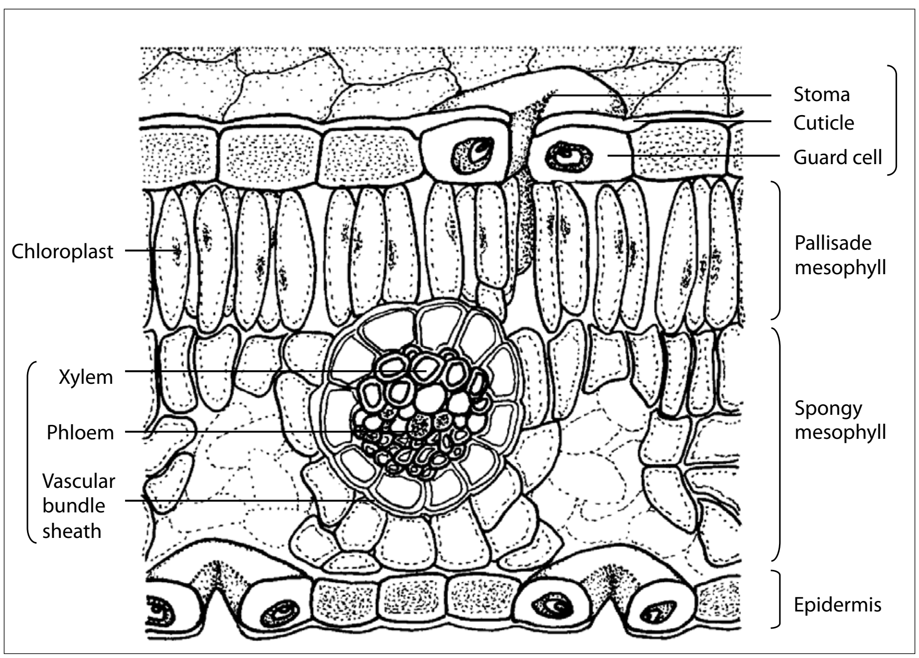


Figure 13.14: Cross-section of a leaf

Source: Biodidac

On the top and bottom is a layer of thick, tough cells called the epidermis. Its primary function is to protect the other layers of leaf tissue. The cuticle is part of the epidermis. It produces a waxy layer called cutin, which helps protect the leaf against dehydration and bacterial, viral, or fungal infection. The amount of cutin on a leaf increases with the amount of light it receives, as protection against burning and drying out. For this reason, when plants are moved from shade into full sunlight, it should be done over a period of a few weeks. This gradual exposure to sunlight allows the cutin layer to build up, protecting the leaves from rapid water loss or sunburn. The waxy cutin also repels water, which is why many pesticide sprays contain an additive to help the pesticide chemical stick to, or penetrate, the cutin layer.

In the lower epidermis, special epidermal cells called guard cells open and close tiny openings called stomata (singular: stoma). The guard cells open and close the stomata in response to environmental stimuli, such as changes in weather and light. The stomata regulate the passage of water, oxygen, and carbon dioxide into and out of the leaf. Conditions that would cause plants to lose a lot of water (high temperature, low humidity) stimulate guard cells to close. In mild weather, they remain open. Guard cells also close in the absence of light. In most species, the majority of the stomata are located on the underside of leaves.

Transpiration is the evaporation of water from plants. This occurs especially through the stomata, in the leaves, but also from the stems. Transpiration is important in cooling the plant and enabling the flow of mineral nutrients from its roots to its shoots.

Located between the upper and lower epidermis is a layer of cells called the mesophyll. It is divided into a dense upper layer (palisade mesophyll) and a lower layer that contains lots of air space (spongy mesophyll). Located within the mesophyll cells are chloroplasts, where photosynthesis takes place. The palisade mesophyll layer is where most of the photosynthesis takes place. In the spongy mesophyll, the cells are irregular in shape, loosely packed, and have fewer chloroplasts than in the palisade mesophyll. Their main function seems to be the temporary storage of glucose that has been synthesized in the palisade layer. They also aid in the exchange of gases between the leaf and the environment. During the day, these cells release oxygen and water vapour into the air spaces that surround them. These large air spaces promote the rapid diffusion of carbon dioxide into the cells. The air spaces are interconnected, and eventually open up to the outside of the leaf through the stomata.

Types

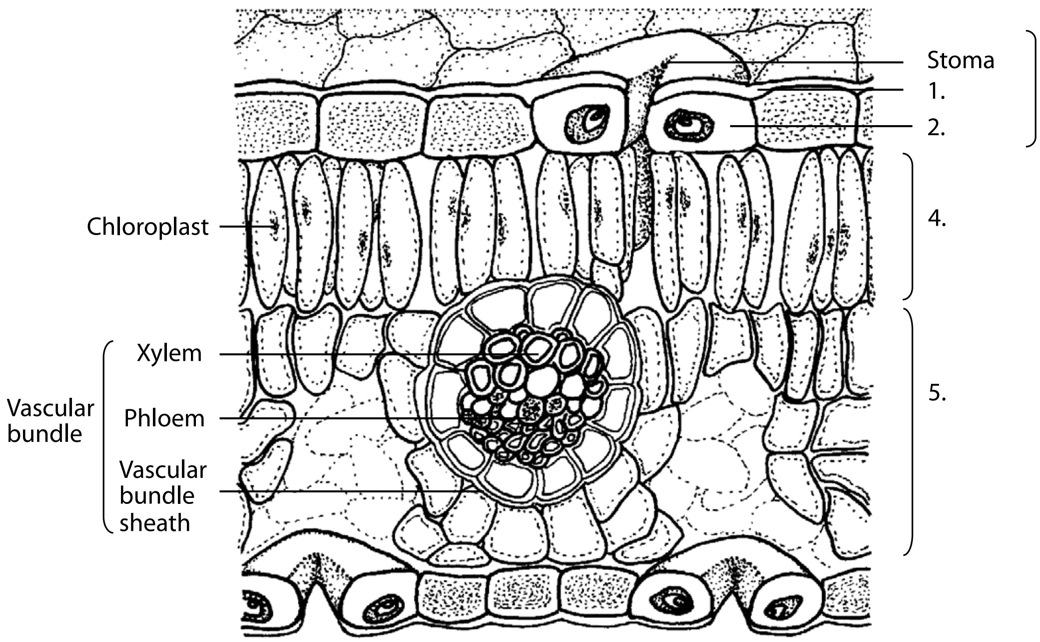
Leaves come in many forms, from the small round needles of spruce trees to the broad thick leaves of palm trees. All leaves have the same function of performing photosynthesis, but they also have to deal with water loss and gas exchange. Plants are often forced to make a tradeoff between having a large enough surface to catch light for photosynthesis and a small enough surface to prevent excessive water loss during dry conditions.

Trees have come up with two solutions to this problem. Deciduous trees, like maples and oaks, have large leaves that are excellent at gathering light for photosynthesis. But during the cold, dry winter months, these leaves would cause too much water loss, so deciduous trees drop their leaves and regrow them the next spring. Evergreen trees, like pines and cedars, have small needle-shaped leaves that are very good at preventing water loss, so these trees can keep their needles throughout the winter. The tradeoff for evergreens is that photosynthesis is a bit slower than in deciduous trees, so evergreens are generally slower-growing trees.

Support Questions

8. Identify the structures labelled 1 to 5 on the following cross-section of a leaf.

Suggested answer



9. What is the sun's role in photosynthesis? Suggested answer

10. What structure in plants allows them to absorb carbon dioxide? Suggested answer

11. What is chlorophyll, and what does it do? Suggested answer

12. How is glucose created? Suggested answer

13. Why do plants release oxygen? Suggested answer

Activity: Examining Plant Tissues

Follow this link to the activity Examining Plant Tissues. There, you will use an online microscope to view slides of various plant tissues including stems, roots, and leaves. When you have reviewed all the material, answer the Support Question below.

Support Questions

14. Draw a cross-section of either a stem or a leaf based on one of the slide images. Be sure to label the main structures including xylem, phloem, epidermis, cuticle, and vascular bundle.

Suggested answer

Phytoremediation

The presence of plants helps prevent wind, rain, and groundwater from carrying pollution away from one area to another. In addition, plants can actually help clean up many kinds of pollution in the environment, including metals, pesticides, explosives, and oil, through a process called phytoremediation.

Phytoremediation works best at sites with low to medium amounts of pollution. Plants remove harmful chemicals from the ground when their roots take in water and nutrients from polluted soil, streams, and groundwater. Plants can therefore clean up harmful chemicals lying as deep as their roots can grow. Tree roots grow deeper than those of smaller plants, so they are used to reach pollution deeper in the ground.

Once inside the plant, the chemicals can be

- stored in the roots, stems, or leaves;
- changed into less harmful chemicals within the plant; or
- changed into gases that are released into the air as the plant transpires (breathes).

Phytoremediation can occur even if the chemicals are not taken into the plant by the roots. For example, chemicals can stick to a plant's roots, or they can be converted into less harmful chemicals by insects or microbes that live near the roots.

As a method of cleaning up polluted sites, phytoremediation has many advantages. It takes advantage of natural plant processes. It requires less equipment and labour than other methods, since plants do most of the work. The site can be cleaned up without removing polluted soil or pumping polluted groundwater. This allows workers to avoid contact with harmful chemicals. Trees and plants can make a site more attractive as well.

Phytoremediation also has some disadvantages. It can take many growing seasons to clean up a site using this method. Its use must be restricted to sites with contamination only as deep as the roots of the plants being used. Plants that absorb toxic materials may contaminate the food chain, and the air could be also contaminated by the burning of leaves or limbs of plants containing dangerous chemicals.

Support Questions

15. What is phytoremediation? Suggested answer

16. What happens to pollutants when they are incorporated into a plant? Suggested answer

17. The area around a remote mine site in northern Ontario needs to have its toxic topsoil cleaned up so it can gradually be returned to natural forest. You are a consultant hired to investigate the best way to do this. What strategy would you suggest for cleaning up the site? Give two reasons for your choice. Suggested answer

Key Questions

Now work on your Key Questions in the online submission tool. You may continue to work at this task over several sessions, but be sure to save your work each time. When you have answered all the unit's Key Questions, submit your work to the ILC.

(17 marks)

39. Name the specific type of plant tissue or cell that performs the following functions:

a) waterproofing the surface layer

b) rapidly dividing into new cells

c) transporting sugars throughout the plant

(3 marks: 1 mark each)

40. Maple syrup is produced from the sap moving in the xylem of maple trees in the early spring. How would taking too much sap in the spring harm the maple tree? **(2 marks)**

41. A number of plants are currently being studied for use in cleaning up land sites containing toxic substances.

a) Name the technique of using plants for this purpose. **(1 mark)**

b) Describe one way plants can clean up toxic substances. **(1 mark)**

c) List two advantages and two disadvantages of this technique. **(4 marks)**

42. You are exploring the beach on a tropical island and come across a strange-looking plant that washed ashore. It has been at sea for many weeks, but it still has clear features. You think it may be new to science, so you want to classify it. It has the following five features:

- long leaves with narrow blades **(60 cm × 3 cm)**
- parallel veins on the leaves
- a taproot
- a short thick stem covered in a tough waxy epidermis
- one cotyledon

a) Is the plant an angiosperm or a gymnosperm? Explain your answer. **(3 marks)**

b) Based on these five features, explain whether you think it came from a desert island or a tropical rainforest jungle. **(3 marks)**

Now go on to Lesson 14. Send your answers to the Key Questions to the ILC when you have completed Unit 4 (Lessons 13 to 16).