LAB TOPIC 20

Plant Anatomy

Laboratory Objectives

After completing this lab topic, you should be able to:

1. Identify and describe the structure and function of each plant cell type and tissue type.
2. Describe the organization of tissues and cells in each plant organ.
3. Relate the function of an organ (root, stem, and leaf) to its structure.
4. Describe primary and secondary growth and identify the location of each in the plant.
5. Relate primary and secondary growth to the growth habit (woody or herbaceous).
6. Discuss adaptation of land plants to the terrestrial environment as illustrated by the structure and function of plant anatomy.
7. Apply your knowledge of plants to the kinds of produce you find in the grocery store.

Introduction

Vascular plants have been successful on land for over 425 million years, and their success is related to their adaptations to the land environment. Consider that aquatic algae live most often in a continuously homogeneous environment. The requirements for life are everywhere around it, so relatively minor structural adaptations have evolved for functions such as reproduction and attachment. In contrast, the terrestrial habitat, with its extreme environmental conditions, presents numerous challenges for the survival of plants. Consequently, land plants have evolved structural adaptations for functions such as the absorption of underground water and nutrients, the anchoring of the plant in the substrate, the elevation and support of aerial parts of the plant, and the transport of materials throughout the relatively large plant body. In angiosperms, the structural adaptations required for these and other functions are divided among three vegetative plant organs: stems, roots, and leaves. Unlike animal organs, which are often composed of unique cell types (for example, cardiac muscle fibers are found only in the heart, osteocytes only in bone), plant organs have many tissues and cell types in common, but they are organized in different ways. The structural organization of basic tissues and cell types in different plant organs is directly related to their different functions. For example, leaves function as the primary photosynthetic organ and generally have thin, flat blades that maximize light absorption and gas exchange. Specialized cells of the root epidermis are long extensions that promote one of the root functions, absorption. The interrelationship of structure and function is a major theme in biology, and you will continue to explore it in this lab topic.

Use the figures in this lab topic for orientation and as a study aid. Be certain that you can identify all items by examining the living specimens and microscope slides. These, and not the diagrams, will be used in the laboratory evaluations.

Summary of Basic Plant Tissue Systems and Cell Types

The plant body is constructed into **tissue systems** based on their shared structural and functional features. There are three tissue systems—**dermal, ground,** and **vascular**—that are continuous throughout the organs of roots, stems, and leaves (Figure 20.1). The plant tissues that actively and continuously divide by mitosis are called **meristematic tissues.** These are located in specific regions—for example the root tip. Following is a review of plant tissue systems and the most common types of cells seen in plant organs, as well as their functions. Other specialized cells will be described as they are discussed in lab. Refer back to this summary as you work through the exercises.

Dermal Tissue System: Epidermis

The **epidermis** forms the outermost layer of cells, usually one cell thick, covering the entire plant body. The epidermal cells are often flattened and rectangular in shape (Figure 20.2a and 2b). Specialized epidermal

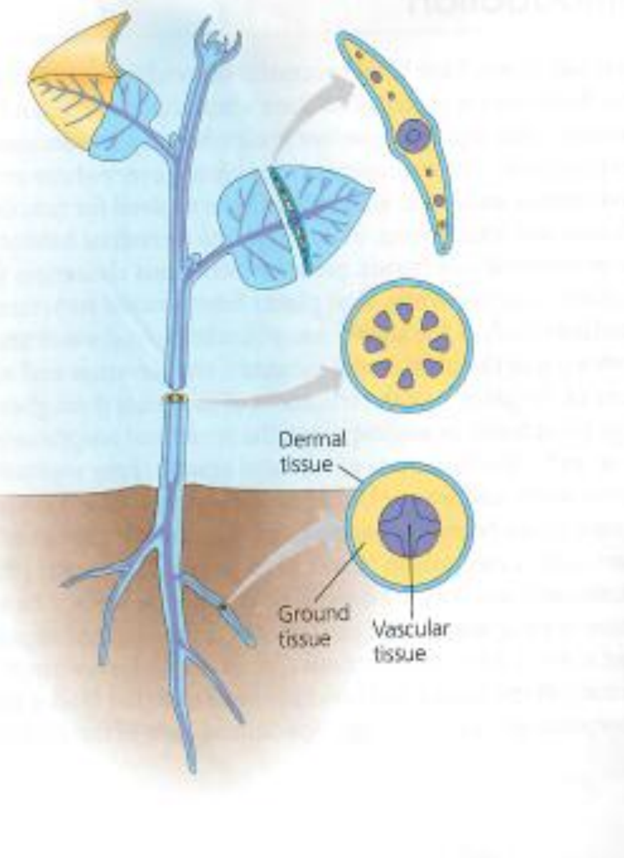
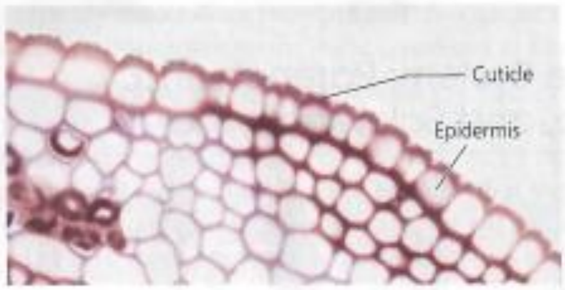
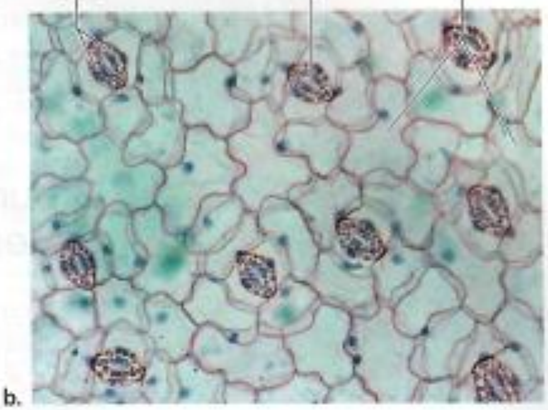
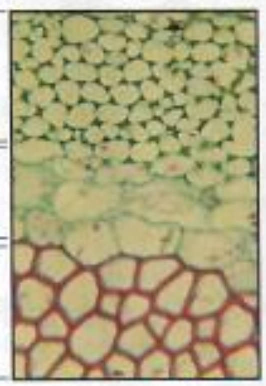


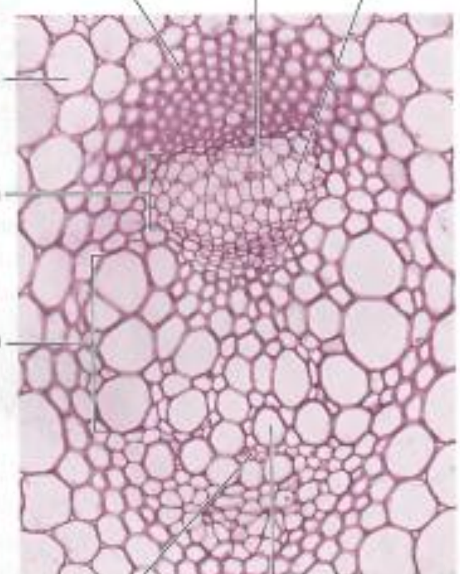
FIGURE 20.1

Three-tissue system. Roots, stems, and leaves are constructed of three basic tissue systems: dermal (blue), ground (yellow), and vascular (purple).









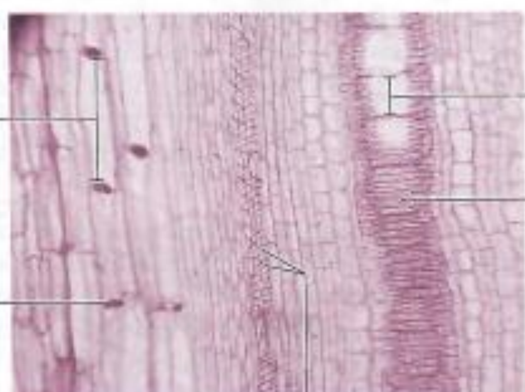


FIGURE 20.2

Plant tissue systems and cell types. (a) Dermal tissue—a single layer of epidermis covered by waxy cuticle. (b) Leaf surface showing epidermis with stomata and guard cells. (c) Ground tissue—cross section of pumpkin stem. (d) Vascular tissue—cross section of a vascular bundle in a buttercup stem. (e) Long section through xylem and phloem of pumpkin stem.

cells include the **guard cells** of the stomata, hairs called **trichomes,** and unicellular **root hairs.** Most epidermal cells on aboveground structures are covered by a waxy **cuticle,** which prevents water loss. The epidermis provides protection and regulates gas exchange and transpiration (water evaporation).

Ground Tissue System: Parenchyma, Collenchyma, and Sclerenchyma

The ground tissue system is distributed throughout the plant beneath the epidermis and surrounding the vascular tissues. Parenchyma, collenchyma, and/or sclerenchyma cells are typically found in ground tissue as seen in the cross section of a pumpkin stem (Figure 20.2c).

Parenchyma cells are the most common cell in plants and are characteristically thin-walled with large vacuoles. These cells may function in photosynthesis, support, storage of materials, and lateral transport.

Collenchyma cells are usually found near the surface of the stem, leaf petioles, and veins. These living cells are similar to parenchyma cells but are characterized by an uneven thickening of cell walls. They provide flexible support to young plant organs.

Sclerenchyma cells have thickened cell walls that may contain a strong polymer, lignin. They provide strength and support to mature plant structures and may be dead at functional maturity. The most common type of sclerenchyma cells are long, thin **fibers.**

Vascular Tissue System: Xylem and Phloem

The vascular tissue system functions in the transport of materials throughout the plant body. Xylem tissue and phloem tissue are complex tissues (composed of several cell types) seen in the cross section of a buttercup stem (Figure 20.2d) and a long section of a pumpkin stem (Figure 20.2e).

Xylem cells form a complex vascular tissue that functions in the transport of water and minerals throughout the plant and provides support. **Tracheids** and **vessel elements** are the primary water-conducting cells. Tracheids are long, thin cells with perforated tapered ends. Vessel elements are larger in diameter, open-ended, and joined end to end, forming continuous transport systems referred to as **vessels.** Parenchyma cells are present in the xylem and function in storage and lateral transport. Sclerenchyma fibers in the xylem provide additional support.

Phloem tissue transports the products of photosynthesis throughout the plant as part of the vascular tissue system. This complex tissue is composed of living, conducting cells called **sieve-tube elements** or sieve tube members, which lack a nucleus and have perforated sieve **plates** for end walls. The cells are joined end to end throughout the plant. Each sieve-tube element is associated with one or more adjacent **companion cells,** which are thought to regulate sieve-tube member function. Phloem parenchyma cells function in storage and lateral transport, and phloem fibers provide additional support.

Meristematic Tissue: Primary Meristem, Cambium, and Pericycle

Primary meristems consist of small, actively dividing undifferentiated cells located in buds of the shoot and in root tips of plants. These cells produce the primary tissues along the plant axis throughout the life of the plant. You will study primary meristems in the apical bud in Exercise 20.2 (Figure 20.4).

Pericycle is a layer of meristematic cells just outside the vascular cylinder in the root. These cells divide to produce lateral branch roots (Exercise 20.3 Lab Study B, Figure 20.7c).

Vascular cambium is a lateral meristem also composed of small, actively dividing cells that are located between the xylem and phloem vascular tissue. These cells divide to produce secondary growth, which results in an increase in circumference (Exercise 20.4, Figure 20.11).

Cork cambium is a lateral meristem located just inside the cork layer of a woody plant. These cells divide to produce secondary growth that replaces the primary epidermis as the root and stem expand (Exercise 20.4, Figure 20.11).

This lab topic begins with a study of the whole plant and then continues with investigations of the cells, tissues, and organs. You will investigate the structure and function of vascular plants in the following exercises:

- Study of the shape and form (morphology) of a herbaceous plant
- Investigation of the primary plant body derived from apical meristem
- Observation of the three organs, and the tissues and cells of the plant body: stems, roots, and leaves
- Investigation of secondary growth in stems of a woody plant
- Application of your knowledge of plant organs to plants commonly found in the grocery store

EXERCISE 20.1
Plant Morphology

Materials

living bean or geranium plant
squirt bottle of water
paper towel

Introduction

As you begin your investigation of the structure and function of plants, you need an understanding of the general shape and form (morphology) of the whole plant. In this exercise, you will study a bean or geranium plant, identifying basic features of the three vegetative organs: *roots, stems, and leaves*. In the following exercises, you will investigate the cellular structure of these organs and their tissues as viewed in cross sections. Refer to the living plant for orientation before you view your slides.

Procedure

1. Working with another student, examine a living **herbaceous** (non-woody) plant and identify the following structures in the *shoot (stems and leaves)*.
   a. **Nodes** are regions of the stem from which leaves, buds, and branches arise and that contain meristematic tissue (areas of cell division).
   b. **Internodes** are the segments of the stem located between the nodes.
   c. **Terminal buds** are located at the tips of stems and branches. They enclose the shoot apical meristem, which gives rise to leaves, buds, and all primary tissue of the stem. Only stems produce buds.
   d. **Axillary,** or **lateral, buds** are located in the leaf axes at nodes; they may give rise to lateral branches.
   e. Leaves consist of flattened **blades** attached at the node of a stem by a stalk, or **petiole.**
2. Observe the *root* structures by gently removing the plant from the pot and loosening the soil from the root structure. You may need to rinse a few roots with water to observe the tiny, active roots. Identify the following structures.
   a. **Primary** and **secondary roots.** The primary root is the first root produced by a plant embryo and may become a long taproot. Secondary roots arise from meristematic tissue deep within the primary root.
   b. Root tips consist of a **root apical meristem** that gives rise to a **root cap** (protective layer of cells covering the root tip) and to all the primary tissues of the root. A short distance from the root tip is a zone of **root hairs** (specialized epidermal cells), the principal site of water and mineral absorption.

Results

1. Label Figure 20.3.
2. Sketch in the margin of your lab manual any features not included in this diagram that might be needed for future reference. For example, your plant may have small green bracts (leaflike structures) at the base of the petiole. These are called stipules.

Discussion

1. Look at your plant and discuss with your partner the possible functions of each plant organ. Your discussion might include evidence observed in the lab today or prior knowledge. Describe proposed functions (more than one) for each organ.

   Stems:

   Roots:

   Leaves:

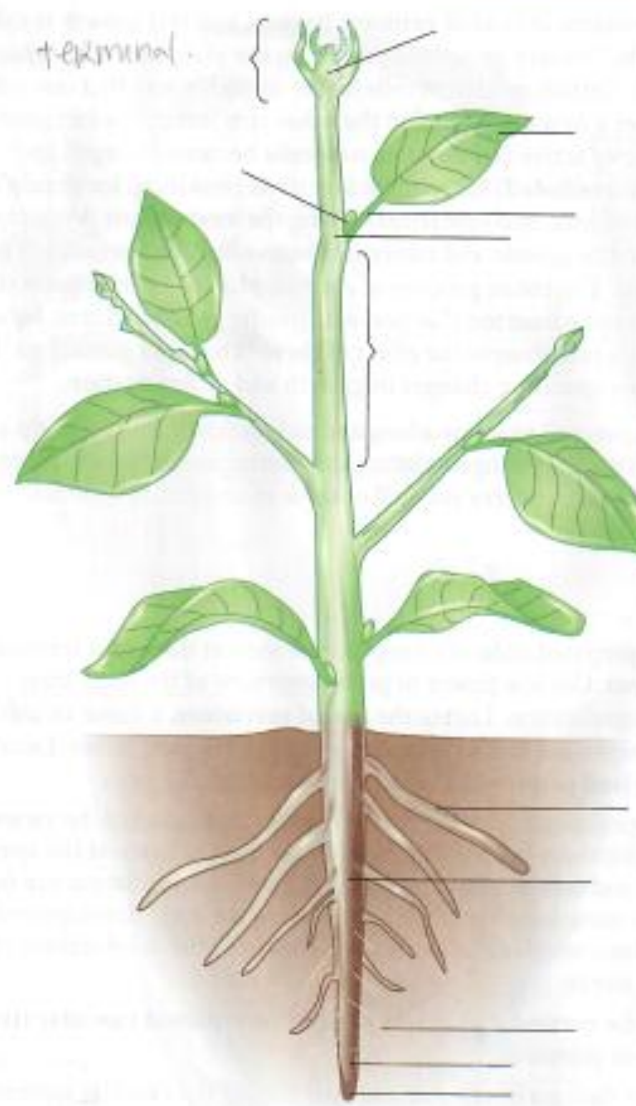


FIGURE 20.3

A herbaceous plant. The vegetative plant body consists of roots, stems, and leaves. The buds are located in the axils of the leaves and at the shoot tip. The roots also grow from meristem tissues in the root tip. Label the diagram based on your observations of a living plant and the structures named in Exercise 20.1.

2. Imagine that you have cut each organ—roots, stems, and leaves—in cross section. Sketch the overall shape of that cross section in the margin of your lab manual. Remember, you are not predicting the internal structure, just the overall shape.

EXERCISE 20.2
Plant Primary Growth and Development

Materials

prepared slides of *Coleus* stem (long section)
compound microscope

Introduction

Plants exhibit **indeterminate growth,** as they produce new cells throughout their lifetime as a result of cell divisions in meristems. Tissues produced from apical meristems are called **primary tissues,** and this growth is called **primary growth.** Primary growth occurs along the plant axis at the shoot and the root tip. Certain meristem cells divide in such a way that one cell product becomes a new body cell and the other remains in the meristem. Beyond the zone of active cell division, new cells become enlarged and specialized (**differentiated**) for specific functions (resulting, for example, in vessels, parenchyma, and epidermis). Using the model plant *Arabidopsis,* research into the genetic and molecular basis of cell differentiation has rapidly advanced. The entire genome of *Arabidopsis* has been sequenced, and mutations can be inserted that prevent specific gene functions. Subsequently, scientists can observe the effect of these "knockout mutations" by studying the corresponding changes in growth and differentiation.

In this exercise, you will examine a longitudinal section through the tip of the stem, observing the youngest tissues and meristems at the apex, then moving down the stem, where you will observe more mature cells and tissues.

Procedure

1. Examine a prepared slide of a longitudinal section through a terminal bud of *Coleus.* Use low power to get an overview of the slide; then increase magnification. Locate the **apical meristem,** a dome of tissue nestled between the **leaf primordia,** young developing leaves. Locate the axillary **bud primordial** between the leaf and the stem.
2. Move the specimen under the microscope so that cells may be viewed at varying distances from the apex. The youngest cells are at the apex of the bud, and cells of increasing maturity and differentiation can be seen as you move away from the apex. Follow the early development of vascular tissue, which differentiates in relation to the development of primordial leaves.
   a. Locate the narrow, dark tracks of **undifferentiated vascular tissue** in the leaf primordia.
   b. Observe changes in cell size and structure of the vascular system as you move away from the apex and end with a distinguishable vessel element of the **xylem,** with its spiral cell wall thickening in the older leaf primordia and stem. You may need to use the highest power on the microscope to locate these spiral cell walls.

Results

1. Label Figure 20.4, indicating the structures visible in the young stem tip.
2. Modify the figure or sketch details in the margin of the lab manual for future reference.

Discussion

1. Describe the changes in cell size and structure in the stem tip. Begin at the youngest cells at the apex and continue to the xylem cells.

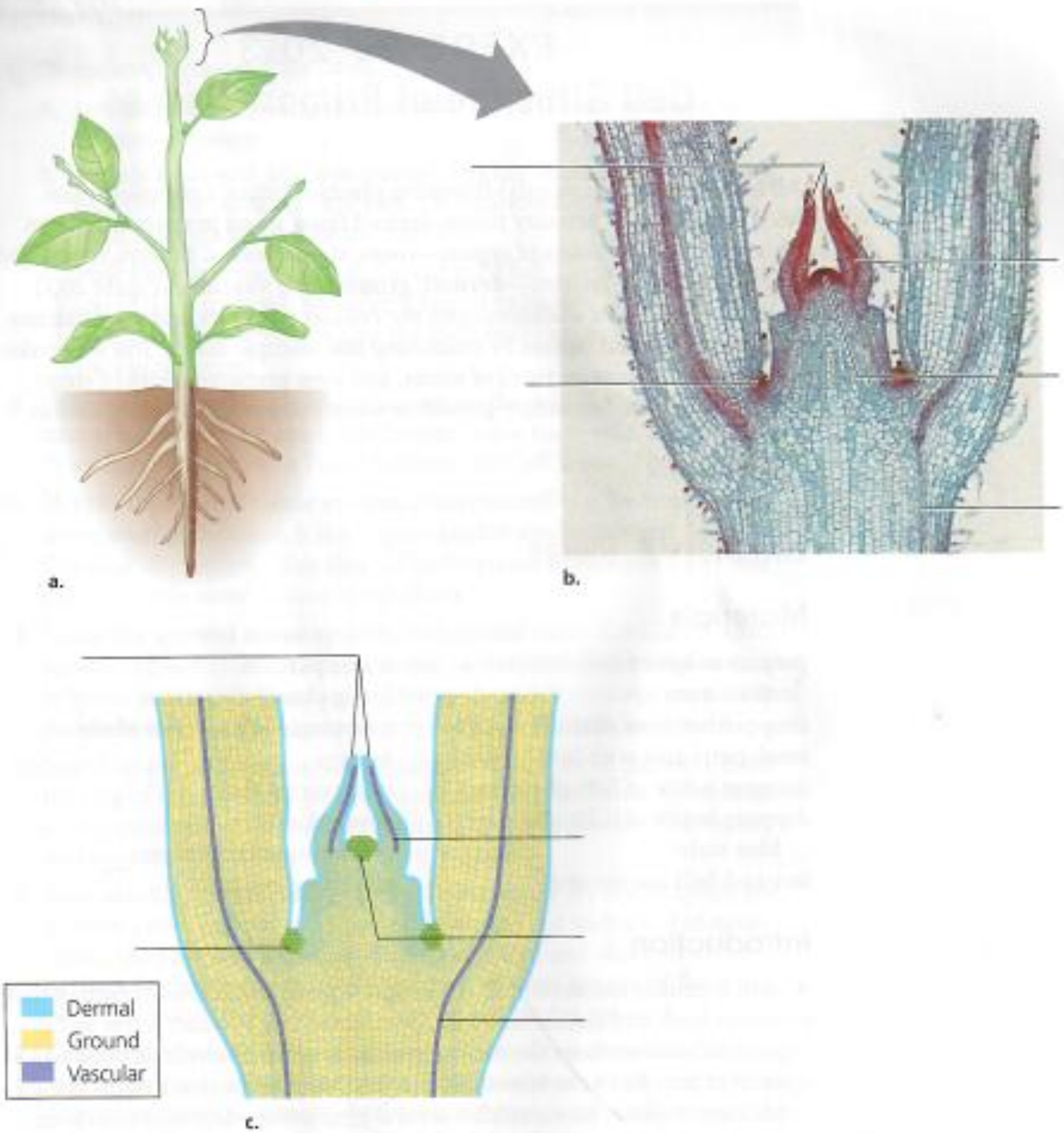


FIGURE 20.4

***Coleus* stem tip.** (a) Diagram of entire plant body. (b) Photomicrograph of a longitudinal section through the terminal bud. (c) Line diagram of the growing shoot tip with primordial leaves surrounding the actively dividing apical meristem. The most immature cells are at the tip of the shoot and increase in stages of development and differentiation farther down the stem. Label the cells and structures described in Exercise 20.2.

2. The meristems of plants continue to grow throughout their lifetime, an example of indeterminate growth. Imagine a 200-year-old oak tree, with active meristem producing new buds, leaves, and stems each year. Contrast this with the growth pattern in humans.

EXERCISE 20.3
Cell Structure of Primary Tissues

All **herbaceous** (nonwoody) flowering plants produce a complete plant body composed of primary tissue, derived from apical primary meristem. This plant body consists of *organs*—roots, stems, leaves, flowers, fruits, and seeds—and *tissue systems*—**dermal, ground,** and **vascular** (Figure 20.1). In this exercise, you will investigate the cellular structure and organization of plant organs and tissues by examining microscopic slides. You will make your own thin cross sections of stems, and view prepared slides of stems, roots, and leaves. Secondary growth in woody stems will be examined in Exercise 20.4.

Lab Study A. Stems

Materials

prepared slide of herbaceous dicot stem
dropper bottle of distilled water
small petri dish with 50% ethanol
dropper bottle of 50% glycerine
dropper bottle of 0.2% toluidine blue stain
nut-and-bolt microtome
warm paraffin
living plant for sections
new single-edged razor blade
forceps
microscope slides
coverslips
compound microscope
dissecting needles

Introduction

A stem is usually the main stalk, or axis, of a plant and is the only organ that produces buds and leaves. Stems support leaves and conduct water and inorganic substances from the root to the leaves and carbohydrate products of photosynthesis from the leaves to the roots. Most herbaceous stems are able to photosynthesize. Stems exhibit several interesting adaptations, including water storage in cacti, carbohydrate storage in some food plants, and thorns that reduce herbivory in a variety of plants.

You will view a prepared slide of a cross section of a stem, and, working with another student, you will use a simple microtome—an instrument used for cutting thin sections for microscopic study—to make your own slides. You will embed the stem tissue in paraffin and cut thin sections. You will stain your sections with toluidine blue, which will help you distinguish different cell types. This simple procedure is analogous to the process used to make prepared slides for subsequent lab studies.

Read through the procedure and set up the materials before beginning.

Procedure

1. Embed the sections of the stem.
   a. Using a new single-edged razor blade, cut a 0.5-cm section of a young bean stem.
   b. Obtain a nut-and-bolt microtome. The nut should be screwed just into the first threads of the bolt. Using forceps, carefully hold the bean stem upright inside the nut.
   c. Pour the warm paraffin into the nut until full. Continue to hold the top of the stem until the paraffin begins to harden. While the paraffin completely hardens, continue the exercise by examining the prepared slide of the stem.
2. Examine a prepared slide of a cross section through the herbaceous dicot stem (Figure 20.6). As you study the stem tissues and cells, refer back to "Summary of Basic Plant Tissue Systems and Cell Types," Figure 20.2.
3. Identify the **dermal tissue system,** characterized by a protective cell layer covering the plant. It is composed of the **epidermis** and the **cuticle.** Occasionally, you may also observe multicellular **trichomes** (hairs and glands) on the outer surface of the plants.
4. Locate the **ground tissue system,** background tissue that fills the spaces between epidermis and vascular tissue. Identify the **cortex region** located between the vascular bundles and the epidermis. It is composed mostly of **parenchyma,** but the outer part may contain **collenchyma** as well.
5. Next find the **pith region,** which occupies the center of the stem, inside the ring of vascular bundles; it is composed of parenchyma. In herbaceous stems, these cells provide support through turgor pressure. This region is also important in storage of water and materials.
6. Now identify the **vascular system,** a continuous system of xylem and phloem providing transport and support. In your stems and in many stems, the **vascular bundles** (clusters of xylem and phloem) occur in rings that surround the pith; however, in some groups of flowering plants, the vascular tissue is arranged in a complex network.
7. Observe that each bundle consists of *phloem tissue toward the outside and xylem tissue toward the inside*. A narrow layer of vascular cambium, which may become active in herbaceous stems, is situated between the xylem and the phloem. Take note of the following information as you make your observations.

   Phloem tissue is composed of three cell types:

   a. Dead, fibrous, thick-walled **sclerenchyma cells** that provide support for the phloem tissue and appear in a cluster as a **bundle cap.**
   b. **Sieve-tube elements,** which are large, living, elongated cells that lack a nucleus at maturity. They become vertically aligned to form sieve tubes, and their cytoplasm is interconnected through sieve plates located at the ends of the cells. Sieve plates are not usually seen in cross sections.
   c. **Companion cells,** which are small, nucleated parenchyma cells connected to sieve-tube cells by means of cytoplasmic strands.

   Xylem tissue is made up of two cell types:

   a. **Tracheids,** which are elongated, thick-walled cells with closed, tapered ends. They are dead at functional maturity, and their interior spaces are interconnected through pits in the cell walls.

FIGURE 20.5
Using the nut-and-bolt microtome. A piece of stem is embedded in paraffin in the bolt. As you twist the bolt up, slice thin sections to be stained and viewed. Slide the entire blade through the paraffin to smoothly slice thin sections. Follow the directions in Exercise 20.3, Lab Study A carefully.

b. **Vessel elements,** which are cylindrical cells that are large in diameter and dead at functional maturity. They become joined end to end, lose their end walls, and form long, vertical vessels.

Vascular cambium is a type of meristematic tissue that is located between the xylem and the phloem and which actively divides to give rise to secondary tissues (You will study these tissues in woody stems in Exercise 20.4).

8. *Complete the Results section on the next page for this slide, then return to step 9 to prepare and observe your own handmade sections of stem preparations.*
9. Cut the stem sections in the hardened paraffin.
   a. Support the nut-and-bolt microtome with the bolt head down and, using the razor blade, carefully slice off any excess paraffin extending above the nut. Be careful to slice in a direction away from your body and to keep your fingers away from the edge of the razor blade (Figure 20.5).

Be careful to keep fingers and knuckles away from the razor blade. Follow directions carefully.

   b. Turn the bolt *just a little,* to extend the stem/paraffin above the edge of the nut.
   c. Produce a thin section by slicing off the extension using the full length of the razor blade, beginning at one end of the blade and slicing to the other end of the blade (see Figure 20.5). *Use the entire blade surface, not a sawing action.*
   d. Transfer each section to a small petri dish containing 50% ethanol.
   e. Continue to produce thin sections of stem in this manner. The thinnest slices may curl, but this is all right if the stem section remains in the paraffin as you make the transfer. Cell types are easier to identify in very thin sections or in the thin edges of thicker sections.
10. Stain the sections.
   a. Leave the sections in 50% ethanol in the petri dish for 5 minutes. The alcohol *fixes,* or preserves, the tissue. Using dissecting needles and forceps, carefully separate the tissue from the surrounding paraffin.
   b. Using forceps, move the stem sections, free of the paraffin, to a clean slide.
   c. Add several drops of toluidine blue to cover the sections. Allow the sections to stain for 10 to 15 seconds.
   d. Carefully draw off the stain by placing a piece of paper towel at the edge of the stain.
   e. Rinse the sections by adding several drops of distilled water to cover the sections. Draw off the excess water with a paper towel. Repeat this step until the rinse water no longer looks blue.
   f. Add a drop of 50% glycerine to the sections and cover them with a coverslip, being careful not to trap bubbles in the preparation.
   g. Observe your sections using a compound microscope. Survey the sections at low or intermediate power, selecting the specimens with the clearest cell structure. You may have to study more than

one specimen to see all structures. The thinnest edges of sections will provide the clearest view, particularly of the cells in vascular bundles.

11. Follow steps 3–7 above and identify *all structures and cells.* Incorporate your observations into the Results section (step 4 below).

Results

1. Label the stem section in Figure 20.6b and 20.6c.
2. Were any epidermal trichomes present in your stem?

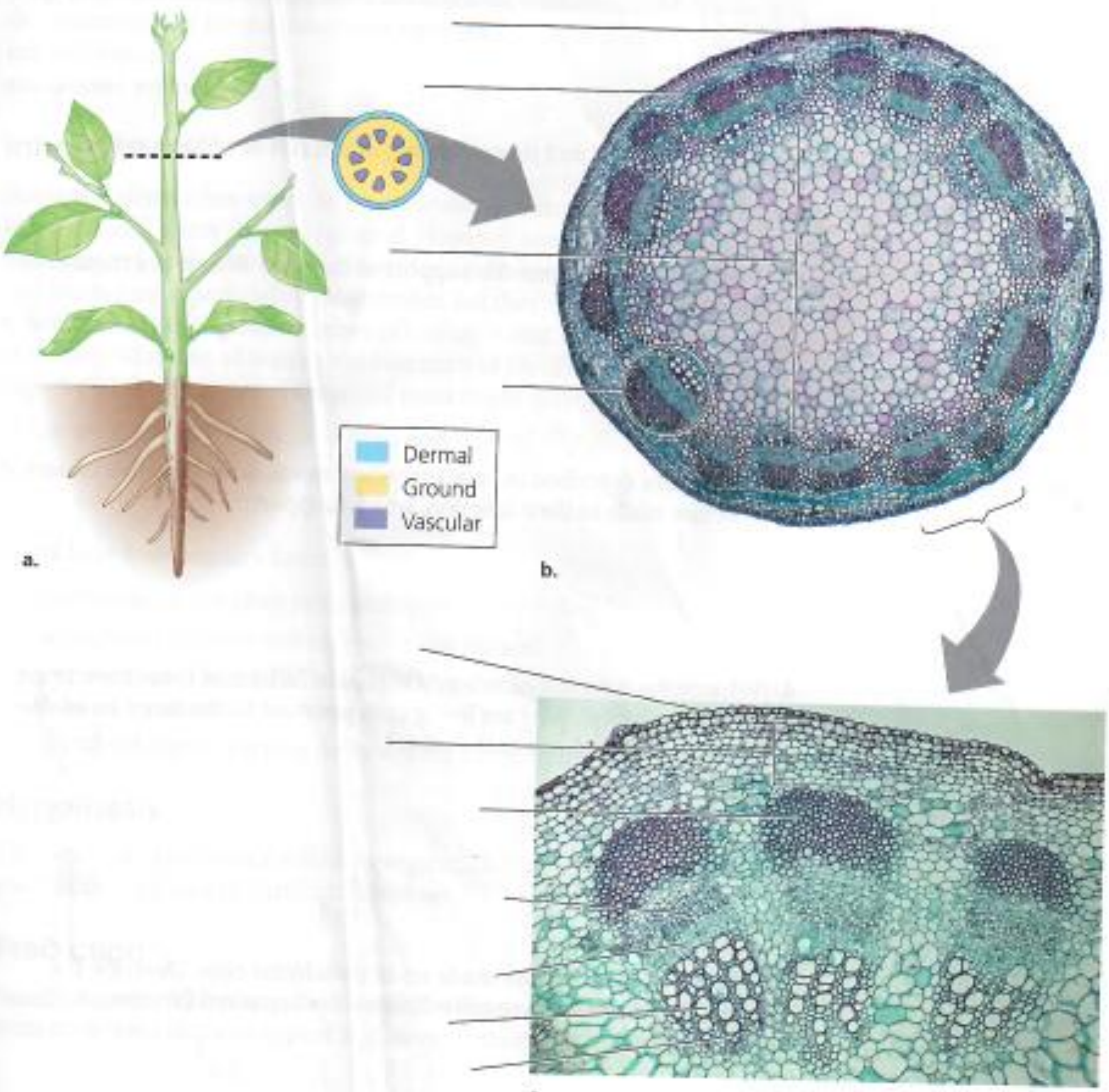


FIGURE 20.6

Stem anatomy. (a) Diagram of whole plant. (b) Photomicrograph of cross section through the stem portion of the plant. (c) Enlargement of one vascular bundle as seen in cross section of the stem.

3. Note any features not described in the procedure. Sketch these in the margin of your lab manual for future reference. Return to Procedure step 9 in this lab study and complete the preparation of hand sections of the bean stem.
4. Compare your hand sections with the prepared slide. Modify Figure 20.6 or sketch your hand section in the margin. Is there any evidence of vascular cambium and secondary growth (Exercise 20.4)? Compare your results with those of other students.

The functions of cells were described in the Summary of Basic Plant Tissue Systems and Cell Types, which appeared near the beginning of this lab topic (Figure 20.2).

Discussion

1. Which are larger and more distinct, xylem cdls or phloem cells?

2. What types of cells provide support of the cem? Where are these cells located in the stem?

3. For the cells described in your preceding aswer, how does their observed structure relate to their function, which isupport?

4. What is the function of xylem? Of phlcm? Which of these have living cells at maturity? Why are living cells iiportant to the function of one type of tissue and not to the other?

5. The pith and cortex are made up of prenchyma cells. Describe the many functions of these cells. Relatearenchyma cell functions to their observed structure.

6. What differences did you observe in the prepared stem sections and your hand sections? What factors might be responsible for these differences?

Lab Study B. Roots

Materials

prepared slide of butterc ıp (*Ranunculus*) root (cross section)
demonstration of fibrous roots and taproots
colored pencils
compound microscope

Introduction

Roots and stems often appea: to be somewhat similar, except that roots grow in the soil and stems above th ground. However, some stems (rhizomes) grow underground, and some roots (adventitious roots) grow aboveground. Roots and stems may superficially apıear similar, but they differ significantly in their functions. One of the major thımes of biology is that structure and function are closely related at all levels o the hierarchy of life. Therefore, we would expect that the structure of stens and roots might differ in important ways.

What are the primary function of stems?

Roots have four primary functicns:

1. anchorage of the plant in th soil
2. absorption of water and mirerals from the soil
3. conduction of water and mirerals from the region of absorption to the base of the stem
4. starch storage to varying degees, depending on the plant

Hypothesis

The working hypothesis for this ivestigation is that the *structure* of the plant body is related to particular *unctions*.

Prediction

Based on the hypothesis, make a pediction about the similarity of root and stem structures that you expect to ıbserve (if/then).

You will now test your hypothesis ard predictions by observing the external structure of roots and their interal cellular structure and organization in a prepared cross section. This investigation is an example of collecting evidence from observations rather than conducting a controlled experiment.

Procedure

1. Examine the external root structure. When a seed germinates, it sends down a **primary root,** or **radicle,** into the soil. This root sends out side branches called lateral roots, and these in turn branch out until a root system is formed.

   If the primary root continues to be the largest and most important part of the root system, the plant is said to have a **taproot** system. If many main roots are formed, the plant has a **fibrous root** system. Most grasses have a fibrous root system, as do trees with roots occurring within 1 m of the soil surface. Carrots, dandelions, and pine trees are examples of plants having taproots.

   a. Observe examples of fibrous roots and taproots on demonstration in the laboratory.

   b. Sketch the two types of roots in the margin of your lab manual.

2. Examine the internal root structure.

   a. Study a slide of a cross section through a buttercup (*Ranunculus*) root. Note that the root lacks a central pith. The vascular tissue is located in the center of the root and is called the **vascular cylinder** (Figure 20.7b).

   b. Look for a cortex located between the vascular cylinder and the epidermis. The **cortex** is primarily composed of large parenchyma cells filled with numerous purple-stained organelles. Which of the four functions of roots listed in the introduction to this lab study do you think is related to these cortical cells and their organelles?

   c. Identify the following tissues and regions and label Figure 20.7b and 20.7c accordingly: **epidermis,** parenchyma of **cortex, vascular cylinder, xylem, phloem, endodermis,** and **pericycle.** The endodermis and the pericycle are unique to roots. The endodermis is the innermost cell layer of the cortex. The walls of endodermal cells have a band called the **Casparian strip**—made of **suberin,** a waxy material—that extends completely around each cell, as shown in Figure 20.8. This strip forms a barrier to the passage of anything moving between adjacent cells of the endodermis. All water and dissolved materials absorbed by the epidermal root hairs and transported inward through the cortex must first pass through the living cytoplasm of endodermal cells before entering the vascular tissues. The pericycle is a layer of dividing cells immediately inside the endodermis; it gives rise to lateral roots. Refer to "Summary of Basic Plant Tissue Systems and Cell Types" and Figure 20.2.

Results

1. Review Figure 20.7 and note comparable structures in Figure 20.8.
2. Using a colored pencil, highlight the structures or cells found in the root but not seen in the stem.

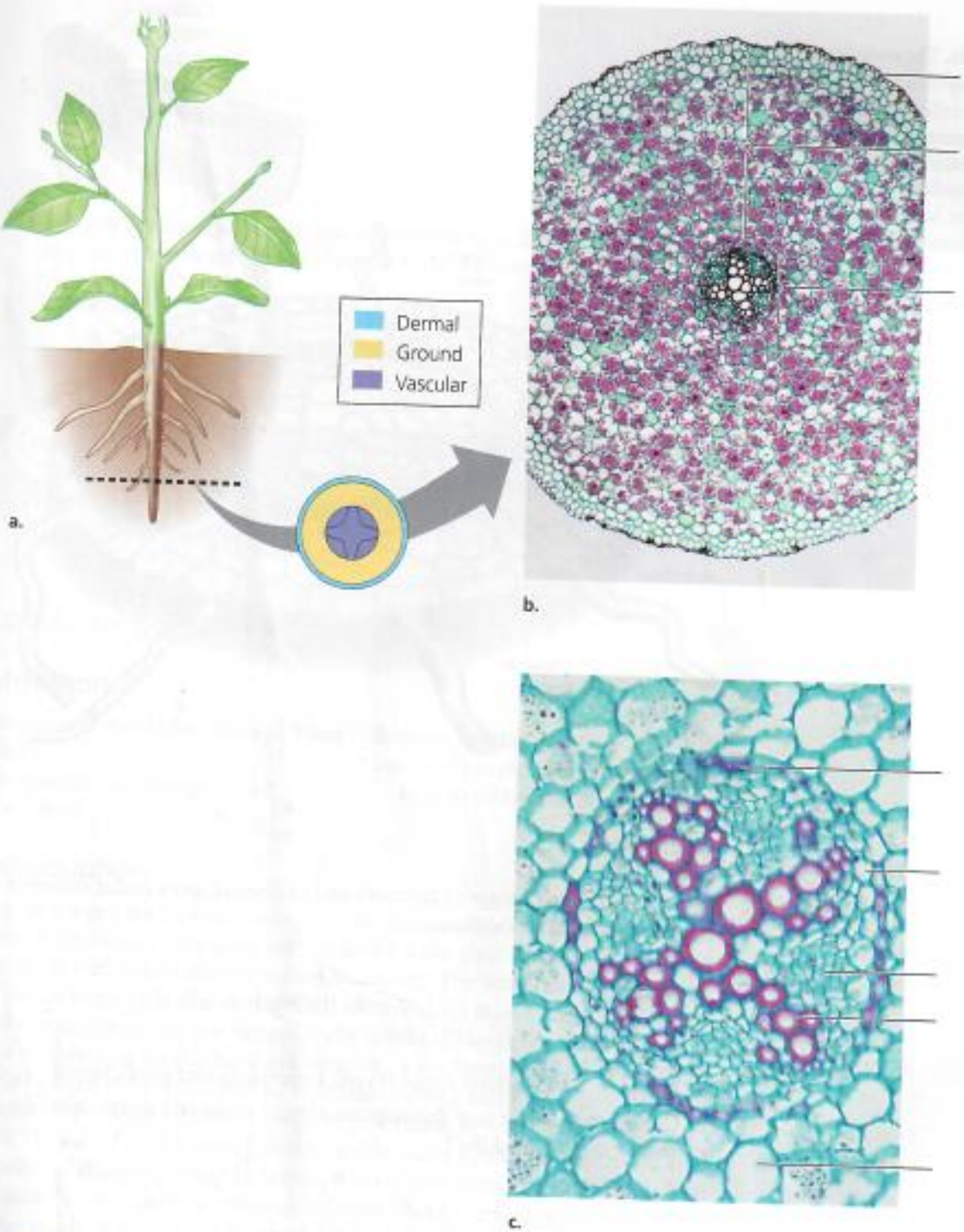


FIGURE 20.7

Cross section of the buttercup root. (a) Whole plant. (b) Photomicrograph of a cross section of a root. (c) Enlargement of the vascular cylinder. Label the root based on your observations of a prepared microscope slide.

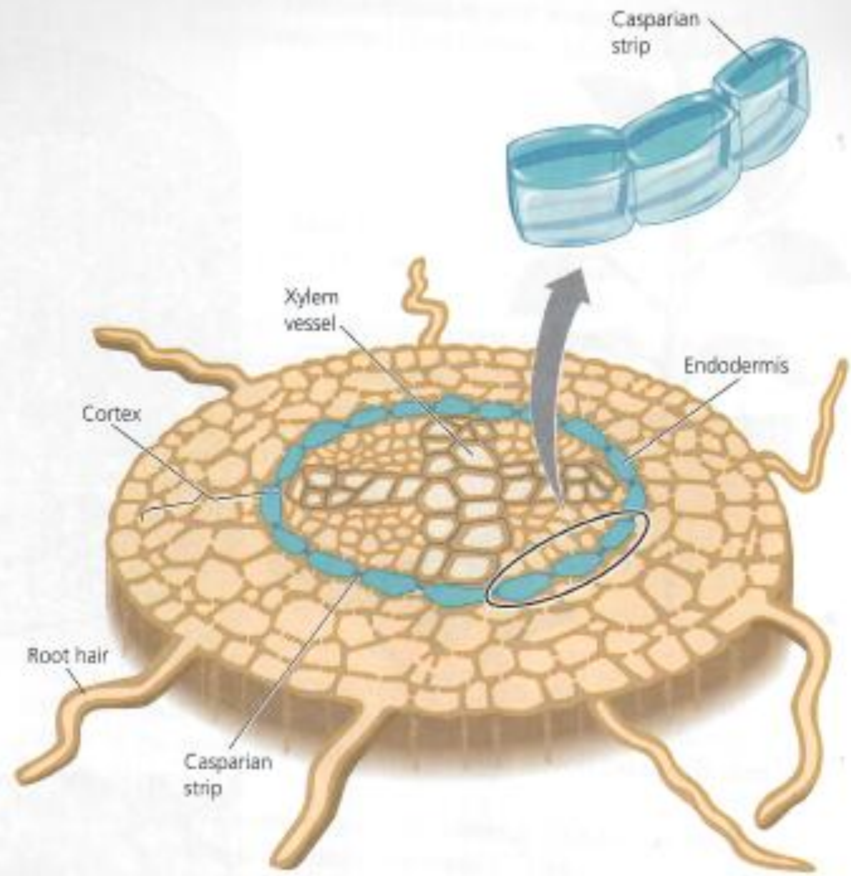


FIGURE 20.8
Root endodermis. The endodermis is composed of cells surrounded by a band containing *suberin,* called the *Casparian strip* (seen in enlargement), that prevents the movement of materials along the cells' walls and intercellular spaces into the vascular cylinder. Materials must cross the cell membrane before entering the vascular tissue.

Discussion

1. Suggest the advantage of taproots and of fibrous roots under different environmental conditions.

2. Did your observations support your hypothesis and predictions?
3. Compare the structure and organization of roots and stems. How do these two organs differ?

4. Explain the relationship of structure and function for two structures or cells found only in roots.

5. Note that the epidermis of the root lacks a cuticle. Can you explain why this might be advantageous?

6. What is the function of the endodermis? Why is the endodermis important to the success of plants in the land environment?

MB Student Media Video—Ch. 35: Root Growth in a Radish Seed (time-lapse)

Lab Study C. Leaves

Materials

prepared slide of lilac (*Syringia*) leaf
slides
compound microscope
coverslips
dropper bottles of water
leaves of purple heart (*Setcreasia*) kept in saline and DI water

Introduction

Leaves are organs especially adapted for photosynthesis. The thin blade portion provides a very large surface area for the absorption of light and the uptake of carbon dioxide through stomata. The leaf is basically a layer of parenchyma cells (the **mesophyll**) between two layers of epidermis. The loose arrangement of parenchyma cells within the leaf allows for an extensive surface area for the rapid exchange of gases. Specialized epidermal cells called **guard cells** surround the stomatal opening and allow carbon dioxide uptake and oxygen release, as well as evaporation of water at the leaf surface. Guard cells are photosynthetic (unlike other epidermal cells), and are capable of changing shape in response to complex environmental and physiological factors. Current research indicates that the opening of the stomata is the result of the active uptake of K^+ and subsequent changes in turgor pressure in the guard cells.

In this lab study, you will examine the structure of a leaf in cross section. You will observe stomata on the leaf epidermis and will study the activity of guard cells under different conditions.

Procedure

1. Before beginning your observations of the leaf cross section, compare the shape of the leaf on your slide with Figure 20.9a and 20.9b.
2. Observe the internal leaf structure.

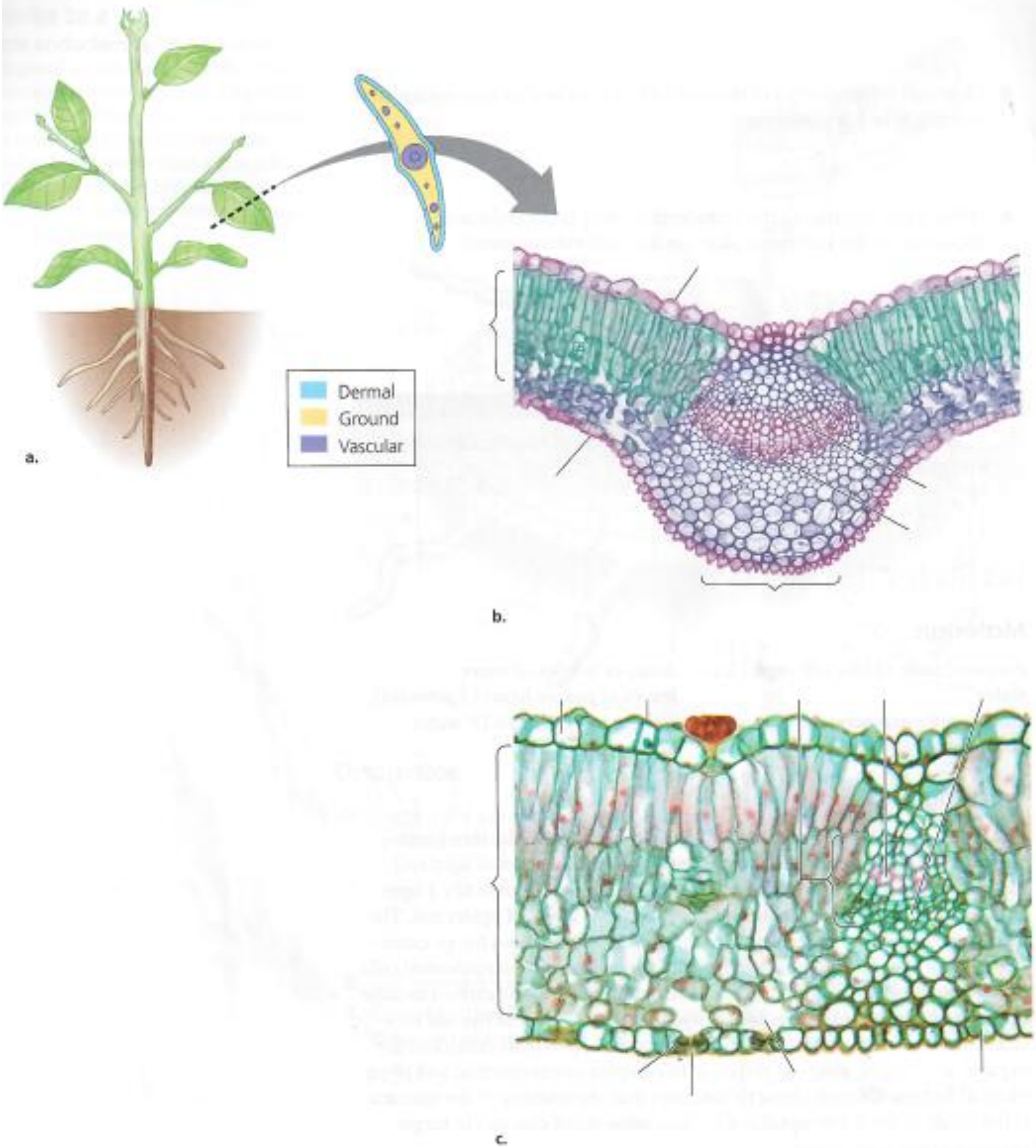


FIGURE 20.9
Leaf structure. (a) Whole plant. (b) Photomicrograph of a leaf cross section through the midvein. (c) Photomicrograph of a leaf cross section near the midvein.

a. Examine a cross section through a lilac leaf and identify the following cells or structures: **cuticle** (a waxy layer secreted by the epidermis), **epidermis** (upper and lower), parenchyma with chloroplasts (**mesophyll**), **vascular bundle** with **phloem** and **xylem,** and **stomata** with **guard cells** and **substomatal chamber.** Refer to "Summary of Basic Plant Tissue Systems and Cell Types" and Figure 20.2.

b. The vascular bundles of the leaf are often called **veins** and can be seen in both cross section and longitudinal sections of the leaf. Observe the structure of cells in the central midvein. Is xylem or phloem on top in the leaf?

c. Observe the distribution of stomata in the upper and lower epidermis. Where are they more abundant?

d. Label the cross section of the leaf in Figure 20.9.

3. Observe the leaf epidermis and stomata.

a. Obtain two *Setcreasia* leaves, one placed in saline for an hour and the other placed in distilled water for an hour.

b. Label two microscope slides, one "saline" and the other "H_2O."

c. To remove a small piece of the lower epidermis, fold the leaf in half, with the lower epidermis to the inside. Tear the leaf, pulling one end toward the other, stripping off the lower epidermis (Figure 20.10). If you do this correctly, you will see a thin purple layer of lower epidermis at the torn edge of the leaf.

d. Remove a small section of the epidermis from the leaf in *DI water* and mount it in water on the appropriate slide, being sure that the outside surface of the leaf is facing up. View the slide at low and high power on your microscope, and observe the structure of the stomata. Sketch your observations in the margin of your lab manual.

e. Remove a section of the epidermis from the leaf in *saline* and mount it on the appropriate slide in a drop of the *saline*. Make sure that the outside surface of the leaf is facing up. View the slide with low power on your microscope, and observe the structure of the stomata. Sketch your observations in the margin of your lab manual.

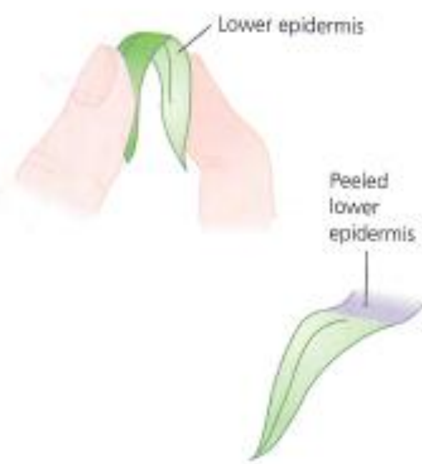


FIGURE 20.10
Preparation of leaf epidermis peel. Bend the leaf in half and peel away the lower epidermis. Remove a small section of lower epidermis and make a wet mount.

Results

1. Review the leaf cross section in Figure 20.9.
2. Describe the structure of the stomata on leaves kept in DI water.

3. Describe the structure of the stomata on leaves kept in saline.

Discussion

1. Describe the functions of leaves.

2. Provide evidence from your observations of leaf structure to support the hypothesis that structure and function are related. Be specific in your examples.

3. Explain the observation that more stomata are found on the lower surface of the leaf than on the upper.

4. Explain the differences observed, if any, between the stomata from leaves kept in DI water and those kept in saline. Utilize your knowledge of osmosis to explain the changes in the guard cells. (In this activity, you stimulated stomatal closure by changes in turgor pressure due to saline rather than K^+ transport.)

EXERCISE 20.4
Structure of Tissues Produced by Secondary Growth

Materials

prepared slides of basswood (*Tilia*) stem
compound microscope

Introduction

Secondary growth is responsible for the increase in circumference in woody plants and arises from meristematic tissue called **cambium.** Vascular cambium and cork cambium are two types of cambium. The **vascular cambium** is a single layer of meristematic cells located between the secondary phloem and secondary xylem. Dividing cambium cells produce a new cell at one time toward the xylem, at another time toward the phloem. Thus, each cambial cell produces files of cells, one toward the inside of the stem, another toward the outside, resulting in an increase in stem circumference. The secondary phloem cells become differentiated into sclerenchyma fiber cells, sieve-tube elements, and companion cells. Secondary xylem cells become differentiated into tracheids and vessel elements. Certain cambial cells produce parenchyma ray cells that can extend radially through the xylem and phloem of the stem.

The **cork cambium** is a type of meristematic tissue that divides, producing cork tissue to the outside of the stem and other cells to the inside. The cork cambium and the secondary tissues derived from it are called **periderm.** The periderm layer replaces the epidermis and cortex in stems and roots with secondary growth. These layers are continually broken and sloughed off as the woody plant grows and expands in diameter.

Procedure

1. Examine a cross section of a woody stem (Figure 20.11).
   a. Observe the cork cambium and periderm in the outer layers of the stem. The outer **cork** cells of the periderm have thick walls impregnated with a waxy material called **suberin.** These cells are dead at maturity. The thin layer of nucleated cells that may be visible next to the cork cells is the **cork cambium.** The **periderm** includes the layers of cork and associated cork cambium. The term **bark** is used to describe the periderm and phloem on the outside of woody plants.
   b. Observe the cellular nature of the listed tissues or structures, beginning at the periderm and moving inward to the central pith region. **Sclerenchyma fibers** have thick, dark-stained cell walls and are located in bands in the phloem. **Secondary phloem** cells with thin cell walls alternate with the rows of fibers. The **vascular cambium** appears as a thin line of small, actively dividing cells lying between the outer phloem tissue and the extensive secondary xylem. **Secondary xylem** consists of distinctive open cells that extend in layers to the central **pith** region. Lines of parenchyma cells one or two cells thick form **lateral rays** that radiate from the pith through the xylem and expand to a wedge shape in the phloem, forming a **phloem ray.**
2. Note the **annual rings** of xylem, which make up the **wood** of the stem surrounding the pith. Each annual ring of xylem has several rows of **early wood,** thin-walled, large-diameter cells that grew in the spring and, outside of these, a few rows of **late wood,** thick-walled, smaller-diameter cells that grew in the summer, when water is less available.
3. By counting the annual rings of xylem, determine the age of your stem. Note that the phloem region is not involved with determining the age of the tree.

Results

1. Review Figure 20.11.
2. Sketch in the margin of your lab manual any details not represented in the figure that you might need for future reference.
3. Indicate on your diagram the region where primary tissues can still be found.

Discussion

1. What has happened to the several years of phloem tissue production?

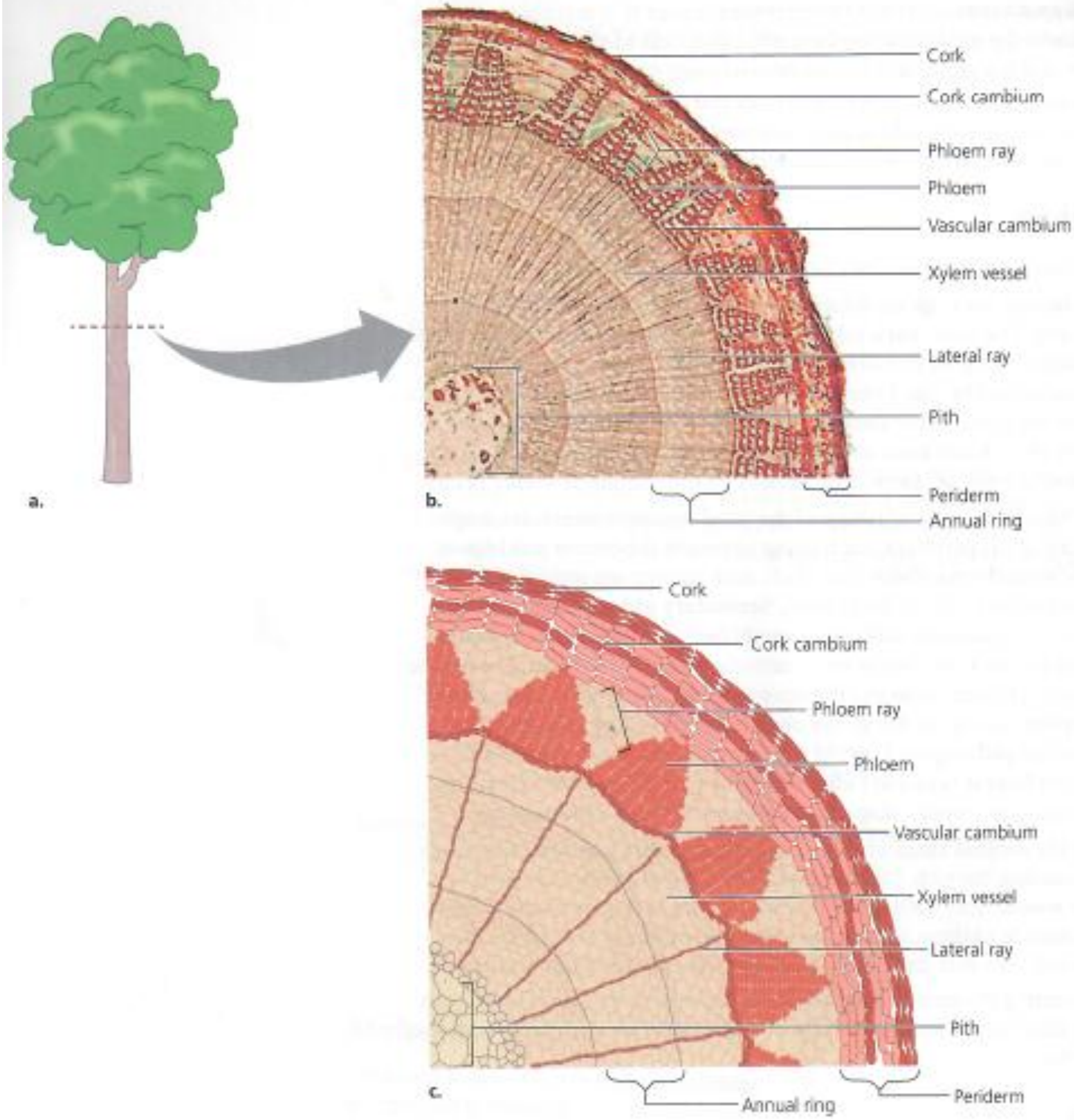


FIGURE 20.11

Secondary growth. (a) Whole woody plant. (b) Photomicrograph of a cross section of a woody stem. (c) Compare the corresponding diagram with your observations of a prepared slide. If necessary, modify the diagram to correspond to your specimen.

2. Based on your observations of the woody stem, does xylem or phloem provide structural support for trees?

3. What function might the ray parenchyma cells serve?

4. How might the structure of early wood and late wood be related to seasonal conditions and the function of the cells? Think about environmental conditions during the growing season.

EXERCISE 20.5

Grocery Store Botany: Modifications of Plant Organs

Materials

variety of produce: squash, lettuce, celery, carrot, white potato, sweet potato, asparagus, onion, broccoli, and any other produce you wish to examine

Introduction

Every day you come into contact with the plant world, particularly in the selection, preparation, and enjoyment of food. Most agricultural food plants have undergone extreme selection for specific features. For example, broccoli, cauliflower, cabbage, and brussels sprouts are all members of the same species that have undergone selection for different characteristics. In this exercise, you will apply your botanical knowledge of plant organs and tissues to the laboratory of the grocery store.

Procedure

1. Working with another student, examine the numerous examples of root, stem, and leaf modifications on demonstration. (There may be some reproductive structures as well. Refer to Lab Topic 15 Plant Diversity II, if needed.)
2. For each grocery item, determine the type of plant organ, its modification, and its primary function. How will you decide what is a root, stem, or leaf? Review the characteristics of these plant organs and examine your produce carefully.

Results

Complete Table 20.1.

Discussion

1. What feature of the white potato provided key evidence in deciding the correct plant organ?

2. Based on your knowledge of the root, why do you think roots have been selected so often as food sources?

TABLE 20.1 Grocery Store Botany

Name of Item	Plant Organ (Root, Stem, Leaf, Flower, Fruit)	Function/Features (Storage, Support, Reproduction, Photosynthesis)

Reviewing Your Knowledge

1. Use Table 20.2 to describe the structure and function of the cell types seen in lab today. Indicate the location of these in the various plant organs examined. Refer to "Summary of Tissue Systems and Cell Types" and Figures 20.2, 20.6, 20.7, 20.9, and 20.11.
2. Some tissues are composed of only one type of cell; others are more complex. List the cell types observed in xylem and in phloem.
   Xylem:

   Phloem:

3. What characteristic of sieve-tube structure provides a clue to the role of companion cells?

TABLE 20.2 Structure and Function of Plant Cells

Cell Type	Structure	Function	Plant Organ
Epidermis			
Guard cells			
Parenchyma			
Collenchyma			
Sclerenchyma			
Tracheids			
Vessels			
Sieve tubes			
Endodermis			
Primary meristems			
Vascular cambium			
Pericycle			
Periderm			
Ray parenchyma			