CHAPTER 31

Plant Structure, Reproduction, and Development

Objectives

Introduction Explain how angiosperms impact human life.

31.1 Describe the scientific contributions of Dr. Katherine Esau.

Plant Structure and Function

31.2 Compare the structure of monocots and dicots.

31.3 Compare the structures and functions of root and shoot systems. Explain how "pinching back" a plant helps make the plant more bushy.

31.4 Define a taproot, runner, rhizome, tuber, and tendril.

31.5 Compare the structure and function of parenchyma, collenchyma, sclerenchyma, water-conducting cells, and food-conducting cells. Also compare the structure and function of xylem and phloem.

31.6 Compare the structures and functions of the epidermis, vascular tissue system, and ground tissue system of roots and shoots.

Plant Growth

31.7 Distinguish between (a) indeterminate versus determinate growth and (b) annuals, biennials, and perennials.

31.7, 31.8 Distinguish between primary and secondary growth.

Plant Reproduction

31.9 Describe the parts of a flower and their functions. Relate this structure to the overall life cycle of an angiosperm.

31.10 Describe the processes and events that lead to double fertilization.

31.11 Explain how a seed forms. Compare the structures of dicot and monocot seeds and explain the significance of seed dormancy.

31.12 Describe the formation and functions of fruit. Distinguish between simple fruits, aggregate fruits, and multiple fruits.

31.13 Describe the general process of germination and compare this process in pea and corn plants.

31.14 Describe four examples of vegetative reproduction in plants. Describe the advantages of this form of reproduction.

31.15 Explain how new plant varieties are produced by protoplast fusion and genetic engineering.

Key Terms

cotyledon
monocot
dicot
root system
root hair
shoot system
stem
node
internode
leaf
terminal bud
axillary bud
apical dominance
rhizome
tuber
parenchyma cell
collenchyma cell
sclerenchyma cell
fiber
sclereid
water-conducting cell
tracheid
vessel element
food-conducting cell
sieve-tube member
sieve plate
companion cell
xylem
phloem
tissue system
epidermis
cuticle
vascular tissue system
ground tissue system
cortex
endodermis
vascular bundle
pith
stoma
guard cell
mesophyll
vein
indeterminate growth
determinate growth
annual
biennial
perennial
meristem
apical meristem
primary growth
root cap
primary xylem
primary phloem
secondary growth
vascular cambium
secondary xylem
secondary phloem
wood
cork
cork cambium
bark
wood ray
heartwood
sapwood
sepal
petal
stamen
anther
carpel
stigma
ovary
ovule
germinate
sporophyte
gametophyte
embryo sac
pollination
double fertilization
endosperm
seed coat
seed dormancy
fruit
simple fruit
aggregate fruit
multiple fruit
vegetative reproduction
fragmentation
protoplast fusion
monoculture

Word Roots

apic- = the tip; **meristo-** = divided (*apical meristems:* embryonic plant tissue on the tips of roots and in the buds of shoots that supplies cells for the plant to grow)

bienn- = every 2 years (*biennial:* a plant that requires two years to complete its life cycle)

coll- = glue; **-enchyma** = an infusion (*collenchyma cell:* a flexible plant cell type that occurs in strands or cylinders that support young parts of the plant without restraining growth)

dorm- = sleep (*dormancy:* a condition typified by extremely low metabolic rate and a suspension of growth and development)

endo- = inner; **derm-** = skin (*endodermis:* the innermost layer of the cortex in plants roots)

epi- = over (*epidermis:* the dermal tissue system in plants; the outer covering of animals)

gamet- = a wife or husband (*gametophyte:* the multicellular haploid form in organisms undergoing alternation of generations, which mitotically produces haploid gametes that unite and grow into the sporophyte generation)

inter- = between (*internode:* the segment of a plant stem between the points where leaves are attached)

meso- = middle; **-phyll** = a leaf (*mesophyll:* the ground tissue of a leaf, sandwiched between the upper and lower epidermis and specialized for photosynthesis)

perenni- = through the year (*perennial:* a plant that lives for many years)

phloe- = the bark of a tree (*phloem:* the portion of the vascular system in plants consisting of living cells arranged into elongated tubes that transport sugar and other organic nutrients throughout the plant)

proto- = first; **-plast** = formed, molded (*protoplast:* the contents of a plant cell exclusive of the cell wall)

sclero- = hard (*sclereid:* a short, irregular sclerenchyma cell in nutshells and seed coats and scattered through the parenchyma of some plants)

sporo- = a seed; = **-phyto** = a plant (*sporophyte:* the multicellular diploid form in organisms undergoing alternation of generations that results from a union of gametes and that meiotically produces haploid spores that grow into the gametophyte generation)

stam- = standing upright (*stamen:* the pollen-producing male reproductive organ of a flower, consisting of an anther and filament)

xyl- = wood (*xylem:* the tube-shaped, nonliving portion of the vascular system in plants that carries water and minerals from the roots to the rest of the plant)

Lecture Outline

Introduction *A Gentle Giant*

A. Plants are unique organisms.
   Review: Basic characteristics of the plant kingdom (Module 17.1).
   1. Examining the giant sequoia, *Sequoiadendron gigantea,* helps underscore the unique capabilities and adaptations of plants. The tree known as General Sherman is the largest individual plant on Earth: 83 m tall, 10 m in diameter at the base, first branch at 40 m, weighing about 1400 tons, and alive for about 2500 years (chapter-opening photo, Figure 31.0).
   2. Humans depend on plants for a variety of needs (lumber, fabric, paper, food, etc.), and many other organisms depend on them for nutrition and shelter.
      NOTE: Despite the importance of plants, on a worldwide basis, slightly more photosynthesis is carried out by photosynthetic protists (algae) and bacteria of aquatic habitats.
   3. Giant sequoias are gymnosperms (naked seeds; Modules 18.8 and 18.9). Because angiosperms (covered seeds; Modules 18.11–18.15) make up 90% of the world's plant species, they are the focus here.
      Review: Module 17.3 discusses the basic differences between gymnosperms and angiosperms.

Module 31.1 Talking About Science: Plant scientist Katherine Esau was a preeminent student of plant structure and function.

A. Dr. Esau was born in Ukraine in 1898, studied in Moscow, and moved to Germany in 1918 and the United States in 1922. Her early research focused on plant viruses in sugar beets. She continued working into her nineties.

B. She is best known for her study of the structure and function of the food-conducting tissue (phloem) in plants and of plant anatomy in general. Among other discoveries, she first described plasmodesmata (open connections between plant cells, Figure 4.19A) and the transmission of plant viruses from cell to cell through these structures.

I. Plant Structure and Function

Module 31.2 The two major groups of angiosperms are the monocots and the dicots.

A. **Monocots** include orchids, bamboos, palms, lilies, and grasses (including most of the agricultural, grain-producing plants). They are distinguished by having one seed leaf **(cotyledon)** but also usually have parallel-veined leaves, scattered vascular bundles in stems, floral parts in multiples of three, and fibrous root systems (Figure 31.2).

B. Most angiosperms are **dicots.** Dicots include most shrubs and trees (except conifers) and many herbaceous plants, including many food plants and plants domesticated for their fibers. They are distinguished by having two cotyledons but also usually have net-veined leaves, vascular bundles in a ring in stems, floral parts in multiples of four or five, and taproot systems.

C. Careful analysis of plant structure often reveals its function. Conversely, function provides insight into the logic of a plant's structure.

Module 31.3 The plant body consists of roots and shoots.

A. These structural adaptations allow plants to function in terrestrial habitats without drying out. Functionally, plants need to take up water and minerals from the soil, absorb light and take in carbon dioxide from the air, and create their plant bodies with the molecules assembled from these raw materials and from those produced by photosynthesis.

B. The **root system** anchors the plant, absorbs and transports minerals and water, and stores food. The fibrous roots of monocots, and the taproot plus secondary roots of dicots, are effective in anchoring and absorption. The focal point of absorption is the **root hair,** an outgrowth of the epidermal cells, that increases the surface area for the absorption of water and minerals (Figure 31.3).
Preview: Most plants are also aided in nutrient uptake by mycorrhizal fungi (Module 32.11, Chapter 17 Opening Essay).

C. The **shoot system** consists of supporting **stems,** photosynthetic **leaves,** and reproductive structures (in angiosperms, flowers). Stems are composed of **nodes,** where leaves, flowers, or other stems are attached, and **internodes.** Leaves are composed of photosynthetic blades and short stalks that join the blade to the stem's nodes.

D. Buds are undeveloped shoots that contain potential nodes, internodes, and leaves. Two types occur: The **terminal bud** at the plant apex is the source of growth in height. The **axillary buds,** one in each angle formed by a leaf and the stem, are usually dormant but can produce new branches that add to a plant's width.

E. **Apical dominance** results from the release of hormones from terminal buds that inhibits the growth of the axillary buds. One can cause a plant to be bushier by pinching off the terminal bud, thereby stimulating (removing the inhibition of) the development of the axillary buds.

Module 31.4 Many plants have modified roots and shoots.

A. In many dicots (e.g., carrots, turnips, beets, sweet potatoes), food is stored in modified taproots (Figure 31.4A). Plants store food in these structures in the form of carbohydrates such as starch.
NOTE: Animals store food as the carbohydrate glycogen.

B. Stems can be modified for several purposes. Runners (e.g., strawberries) provide a means of asexual reproduction. **Rhizomes** (e.g., irises) and **tubers** (e.g., potatoes) are underground stems that store food in the form of starch (Figure 31.4B).

C. Leaves may also be modified from their photosynthetic function. Some leaf bases (e.g., celery) store food. Tendrils (e.g., cucumber) are modified for grasping and climbing. Spines (e.g., cactus) are modified for protection (Figure 31.4C).

Module 31.5 Plant cells and tissues are diverse in structure and function.

A. Plant cells have a unique combination of features. Many are photosynthetic and contain chloroplasts. They often have a large, central vacuole that helps support the cell (and plant tissues) by maintaining turgor (Module 5.16). All plant cells are bounded by a cell wall composed mainly of cellulose. Most plant cells that provide support have an additional, stronger secondary wall hardened with lignin that is laid down inside the primary wall. Pits with cytoplasmically continuous plasmodesmata (Module 4.19) often interconnect adjacent cells (Figure 31.5A).

B. Plant cells can be grouped into five types, depending on wall morphology and chemistry, shape, and function. Tissues made of the cells may be simple (bearing the cell type name) or complex (composed of several cell types).

C. **Parenchyma cells** are abundant, unspecialized cells, with only primary walls, and generally with equal-sided shapes. They function in food storage, photosynthesis, and aerobic respiration (Figure 31.5B).

D. **Collenchyma cells** resemble parenchyma cells but lack secondary walls and have thicker primary walls. They provide support for young parts of plants that are still growing (Figure 31.5C).

E. **Sclerenchyma cells** have rigid secondary walls, hardened with lignin, and function in support and protection. Lignin is the main chemical component of wood. The elongated **fibers** that strengthen many plants are a type of sclerenchymal cell. The resistant cells in many seed coats and the stone cells of pears are made of sclerenchymal cells called **sclereids** (Figure 31.5D).

F. **Water-conducting cells** have elongated shapes and secondary walls, and function only when dead and connected end to end. **Tracheids** have tapered ends, covered with open pits. **Vessel elements** are wider and shorter and have completely open ends. **Xylem** tissue is largely composed of these water-conducting cells, with parenchyma and sclerenchyma cells for support and storage (Figure 31.5E, F).
Preview: Flow of water through xylem (Module 32.3).

G. **Food-conducting cells** (aka **sieve-tube members**) are also arranged end to end but have relatively thin primary walls and no secondary walls. They are alive, but lack nuclei and ribosomes, when they function. The end of each cell forms a **sieve plate** containing numerous pits with plasmodesmata. Each food-conducting cell is found in association with at least one **companion cell** that makes certain proteins for it. **Phloem** tissue is largely composed of these food-conducting cells, with parenchyma and sclerenchyma cells for support and storage.
Preview: Phloem function (Module 32.5).

Module 31.6 Three tissue systems make up the plant body (Figure 31.6A).

A. The **epidermis** is the skinlike first defense against damage or infection. This tissue system is composed of a single, surrounding layer of cells.

B. The **vascular tissue system** is composed of xylem and phloem and conducts water and nutrients throughout the plant.

C. The **ground tissue system** fills the spaces between the epidermis and vascular tissue system, is mainly composed of parenchyma, and functions variously in photosynthesis, storage, and support.

D. Each **tissue system** is continuous from organ to organ throughout the plant.

E. Roots are surrounded by epidermal cells with root hairs and without a cuticle. The ground tissue **(cortex cells)** functions in conducting materials from the root surface into the central vascular tissue and in food storage. The inner layer of the cortex (the **endodermis**) provides a selective barrier, regulating flow into the vascular tissue (Figure 31.6B).
Preview: Solute uptake is controlled by the plasma membranes of root cells (Module 32.2).

F. On most stems and leaves, the epidermal cells have a waxy coating **(cuticle).** Stems of dicots and monocots differ in the relative distributions of ground tissue and vascular tissue systems. A dicot has bundles of vascular tissue in an outer ring supported in a ring of ground tissue cortex that surrounds a parenchyma **pith.** Monocots have **vascular bundle** tissues scattered in a more uniform ground tissue (Figure 31.6C).

G. Leaves have a complex arrangement of the three tissue types that perfectly fits their function of photosynthesis. The lower epidermal tissue includes **guard cells** that form a pore or **stomata** (Module 32.4). The ground tissue is arranged in **mesophyll** layers, a lower, loose layer specialized for gas exchange and an upper, more compact layer specialized for photosynthesis. Tiny branches **(veins)** of the vascular tissue of stems enter each leaf and provide contact to and from photosynthetic cells and gas-exchange surfaces (Figure 31.6D).

II. Plant Growth

Module 31.7 Primary growth lengthens roots and shoots.

A. Unlike animals that have a **determinate growth,** plants have **indeterminate growth;** that is, they continue to grow during their entire lives. To get to other places in their environments (up and out), individual plants must grow.

B. Three seasonal growth patterns occur in plants. **Annuals** complete their life cycle in one year. **Biennials** complete their life cycle in two years. **Perennials** continue to live and reproduce for many years.

C. Indeterminate growth is the result of plants having **meristems,** embryonic tissues composed of unspecialized cells that continue to give rise to new cells. **Apical meristems** are found at the root and shoot tips and in axillary buds. The lengthwise growth produced by these regions is **primary growth.** Differentiation within these regions has been recently shown to be regulated by master control (homeotic) genes, as in animals (Figure 31.7A).
Review: Cell differentiation (Module 11.2–11.4) and homeotic genes (Module 11.12).

D. The apical meristem in the root divides cells downward, forming a **root cap** that is sloughed off during growth through abrasive soil. Other cells from the meristem grow upward and form three concentric rings of embryonic tissue that will form the epidermis, cortex, and central vascular cylinder. Just above the meristem, these tissues elongate, pushing the root tip downward. Above that region, the three tissue systems differentiate; the cells of the vascular cylinder differentiate into **primary xylem** and **primary phloem** (Figure 31.7B).

E. The apical meristem in shoots forms three downward-developing cylinders of embryonic tissues, also with zones of elongation and differentiation. Some of the apical meristem cells remain in lateral positions and develop the apical meristems in axillary buds (Figure 31.7C).
Preview: The hormonal basis of shoot growth is discussed in Module 33.2.

Module 31.8 Secondary growth increases the girth of woody plants.

A. **Secondary growth** involves meristems that grow laterally in stems and is most evident in trees, shrubs, and vines.

B. The **vascular cambium** is a cylindrical meristem that develops from parenchyma cells between the xylem and phloem of shoots. As cells in this meristem divide inward, they form new layers of **secondary xylem** to the outside of the primary xylem. As cells of the vascular cambium divide outward, they form new layers of **secondary phloem** inside the primary phloem. The increase in thickness of the stem (forming the wood of a tree, shrub, or vine) is mostly layers of secondary xylem (Figure 31.8A).

C. In regions that have distinct seasons, secondary xylem cells are larger in diameter during periods of favorable growth and smaller at other times. This results in distinct annual growth rings.

D. The new layers of phloem external to the vascular cambium do not accumulate but are sloughed off in **bark** at about the same rate they are produced. Within the secondary phloem, meristematic regions **(cork cambium)** divide off **cork** cells outward. Mature cork cells are dead and have waxy, thick walls that protect the stem surface from damage and infection, much like epidermal cells. However, they eventually slough off as new cork cambium develops in layers below (Figure 31.8B).
NOTE: This also provides a way for a woody plant to increase the circumference of its protective layer as the diameter of the stem increases.

E. Wood itself can be divided into central **heartwood,** xylem that no longer functions in transport because it is plugged with resins, and **sapwood,** younger secondary xylem that actually conducts water. **Wood rays** are collections of parenchyma cells that extend laterally from heartwood into the sapwood, providing channels between these two regions. The heartwood of trees acts as an endoskeleton, providing a strong, rigid, yet flexible core upon which the living plant substance is supported.

F. Wood is the source of many products useful to humans. As a building material, it is unmatched for its combination of strength, hardness, lightness, insulating properties, durability, workability, and beauty.

III. Plant Reproduction

Review: Features of angiosperms (Modules 17.11–17.14).

Module 31.9 Overview: The sexual life cycle of a flowering plant.

A. A flower is actually a compressed shoot with highly modified leaves (sepals, petals, stamens, and carpels) inserted at nodes separated by greatly reduced internodes (Figure 31.9A).

B. **Sepals** are usually green and protect flower buds. **Petals** are usually large and showy and attract pollinators.

C. **Stamens** are male structures with pollen-bearing **anthers** at their tip. Pollen grains deliver sperm nuclei to females.

D. **Carpels** are female structures composed of **stigma** and **ovule**-bearing **ovaries.** Ovules carry the female egg.

E. Pollination occurs when pollen is delivered to the stigma of another flower. Fertilization occurs in the ovule. The fertilized egg develops into an embryo, and the ovule develops into a seed that holds the embryo. The ovary develops into a fruit that aids in seed dispersal. The seed **germinates** in a favorable environment to complete the life cycle (Figure 31.9B).

Module 31.10 The development of pollen and ovules culminates in fertilization.

A. *Review:* Alternation of generations. Like all plants, angiosperms alternate between diploid sporophytes that produce spores by meiosis (spores then divide mitotically and develop into a gametophyte) and haploid gametophytes that produce gametes by mitosis. The gametes unite by fertilization to form a diploid zygote, which is the first cell of the next sporophyte generation (Modules 16.26 and 17.4).

B. The mature plant we see is the **sporophyte.** Angiosperm gametophytes are microscopic and are found inside the flower parts (Figure 31.10).

C. The male **gametophyte** is the two-celled pollen grain. It develops following meiosis of cells in the anther. The resulting "spores" divide mitotically to produce two haploid cells, a tube cell and a generative cell. The outer wall of the pollen grain is thick and resistant.

D. The female gametophyte develops inside the ovule, a central cell surrounded by a coating of smaller cells. The central cell undergoes meiosis, but only one of the resulting haploid nuclei develops into a spore. The nucleus in the haploid spore enlarges and divides mitotically, forming the embryo sac. (The **embryo sac,** housed in and protected by the sporophyte, is the female gametophyte. The embryo sac contains a large central cell with two haploid nuclei. Another of the cells is the haploid egg.) All this happens in specialized ovary tissue at the base of the carpel.
NOTE: There is a similarity between the one-functional-cell result of meiosis producing female "spores" in flowering plants and the result during egg formation in mammals.

E. **Pollination** is the delivery of a male pollen grain to a receptive stigma of the female carpel. Pollen is usually wind- or animal-dispersed (Module 17.13).

F. After pollination, the pollen grain germinates and grows into the stigma and ovary. The generative cell divides mitotically, forming two sperm nuclei. At the base of the ovule, the pollen tube releases both sperm nuclei.

G. The **double fertilization** that follows is a hallmark of the angiosperms. One sperm nucleus fertilizes the egg, forming the zygote that will develop into the embryo. The other sperm nucleus fuses with the two central nuclei, forming a triploid nucleus that will develop into tissue that nourishes the embryo.

Module 31.11 The ovule develops into a seed.

A. Within the ovule, the triploid cell develops into a nutrient-rich **endosperm,** and repeated division of the diploid zygote leads to the development of an embryo (Figure 31.11A).
NOTE: Be sure to point out that the ovule includes everything inside the original coating of small cells that surrounded the cell that underwent meiosis to form, ultimately, the eight haploid nuclei, including the egg. All nuclei other than the zygote and endosperm do not develop further.

B. The embryo first develops an anchor cell and very soon differentiates into a shoot with cotyledons. The old ovule coat develops into a resistant **seed coat.**

C. The seed develops up to a point and then becomes **dormant.** This allows time for dispersal and for the seasonal occurrence of conditions favorable for independent growth.

D. Seeds of dicots (common bean) have two fleshy cotyledons that have absorbed the endosperm nutrients and taken over the role of nourishment. The seeds of monocots (corn) have one cotyledon, a protective sheath over the embryonic root and shoot, and contain a large endosperm (Figure 31.11B).

Module 31.12 The ovary develops into a fruit.

A. A **fruit** houses and protects seeds and helps disperse them. During development, hormonal changes make the ovary grow and thicken.

B. Fruits are highly varied in organization, depending on how many ovules, how many ovaries, how many carpels, or how many flowers are involved in the formation, and on the ultimate means of dispersal (wind, water, or animal).

C. A pea pod is an example of a **simple fruit** (Figure 31.12A, B).

D. A blackberry is an example of an **aggregate fruit,** fruit that develops from many united carpels.

E. A pineapple is an example of a **multiple fruit,** fruit that develops from many united flowers (Figure 31.12C).
NOTE: Plums and avocados are fruits with single seeds. The winged maple "seed" and plumed dandelion "seed" are examples of fruits modified for wind dispersal. The seed of each is at the heavy end of the fruit.

Module 31.13 Seed germination continues the life cycle.

A. New plant life does not start with seed germination. Dormancy is broken, and a previously developing embryo starts developing again. The seed takes up water, expands, and ruptures its coat. Endosperm or cotyledons begin to enzymatically digest stored nutrients, and the nutrients are transported to the growing parts.

B. In dicots, the embryonic root emerges first, followed by young shoots that leave the seed in a hooked shape that protects the terminal meristem from abrasion by soil particles. Once the shoot clears the soil surface, light stimulates the hook to straighten, and the first foliage leaves develop at the tip and begin photosynthesis (Figure 31.13A). In the pea, the cotyledons, having provided food for the germinating embryo, remain in the soil and decompose.

C. In monocots, the embryonic root emerges first, followed by young shoots that do not develop a hook. However, the shoots are protected from abrasion by a sheath that surrounds them until they break through the soil surface. The corn cotyledon remains in the soil and decomposes (Figure 31.13B).

Module 31.14 Asexual reproduction produces plant clones.

Review: Asexual and sexual reproduction (Chapter 8, *Opening Essay,* and Module 27.1).

A. **Vegetative reproduction** is an extension of the capacity of plants for indeterminate growth, and it is common among plants. It involves **fragmentation** into separate parts, each that regenerates into a new whole plant.
Review: Animal reproduction by fragmentation is discussed in Module 27.1.

B. There are advantages to asexual reproduction. Offspring are suited to their immediate environments. Early life for vegetative offspring is less hazardous for the young because they are closer to being mature than seedlings and the parent may nurture them before separation.

C. A garlic clove is part of an underground stem (bulb) (Figure 31.14A). A root sprout of a coast redwood will grow to take the place of the parent, if the parent is lost (Figure 31.14B). The creosote bush of southwestern deserts reproduces vegetatively from its roots, forming very old clones (the one in Figure 31.14C is estimated at 12,000 years old). Dune grass propagates by underground runners (Figure 31.14D).

Module 31.15 Connection: Vegetative reproduction is a mainstay of modern agriculture.

A. Many ornamental trees and shrubs and houseplants are propagated by stem or leaf cuttings.

B. Plant tissue culture provides another way to grow offspring from a few meristematic cells (Figure 31.15A), and this technique has been adapted to propagate genetically engineered plant cells.

C. A new technique uses plant culture methods in conjunction with enzymatic treatment of a plant cell to remove the cell wall. The result is a protoplast that can fuse with another protoplast from a different species, making a new hybrid. **Protoplast fusion** is used to make plants with certain desirable characteristics (Figure 31.15B).

D. Vegetative propagation has one main disadvantage: Crop plants developed from cloning processes have inherently low levels of genetic diversity, which exposes them to potential devastation from disease, especially when planted in **monoculture.**

Class Activities

1. A thought experiment: Ask your students to consider what might be the evolutionary basis of the differences between monocots and dicots. Under what conditions might one be at an advantage over the other?

2. There really is no such thing as a vegetable. Have your students properly classify plant parts that are considered vegetables. For example, cucumbers are fruits, lettuce is a leaf, etc.

3. Bring in a variety of fruits and vegetables, and discuss the developmental source of the tissues in each, and their specific functions. Strawberries are separate fruits (the "seeds") on a modified flower receptacle (the red part). Coconuts have liquid endosperm. Some fruits have been bred without seeds (bananas, navel oranges, seedless grapes) and are propagated vegetatively. There is no end of interesting trivia in the produce section of your local grocery. Consult a botany text for further details.

4. The three-dimensional arrangements of tissue layers in roots, stems, and leaves are sometimes difficult to grasp from overhead transparencies alone. For smaller classes, the use of large models of these organs (available in most departments) will help show the three-dimensional arrangement of all the basic tissues, and their potential continuity from structure to structure. Secondary growth from the vascular and cork cambiums is also easier to demonstrate with models that show these structures. If you have a color video camera attachment on a dissecting microscope, cross sections of twigs of different age and of wood can be examined in front of a smaller lecture section (depending on your monitor size). This is particularly valuable once you have discussed the function of the two types of cambium using transparencies.

5. An interesting demonstration of the continuity of root and stem (and perhaps even leaf) vascular systems can be made by allowing a squash plant to decompose over winter. Pull up the old squash plant in your garden at the end of the summer and let it lie on the surface of the ground through the fall and into the following spring. Bacteria and fungi will decompose away the softer, cellulose walls first, leaving the pattern of the vascular bundles. At the junction of root and stem, quite a tangle occurs, but it is clear that the vascular systems of each part are completely connected. Be sure to discuss the biological process that resulted in this preparation.

Transparency Acetates

Figure 31.2	A comparison of monocots and dicots
Figure 31.3	The body plan of a flowering plant (a dicot)
Figure 31.4A	The modified root of a sugar beet plant
Figure 31.4B	Three kinds of modified stems
Figure 31.5A	The structure of a plant cell
Figure 31.5B	Parenchyma cell
Figure 31.5C	Collenchyma cell
Figure 31.5D	Sclerenchyma cells: fibers (left) and sclereids (right)
Figure 31.5E	Water-conducting cells
Figure 31.5F	Food-conducting cells (sieve-tube members)
Figure 31.6A	The three tissue systems
Figure 31.6B	Tissue systems in a young root (a dicot)
Figure 31.6C	Tissue systems in young stems
Figure 31.6D	Tissue systems in a dicot leaf
Figure 31.7A	Locations of apical meristems, responsible for primary growth
Figure 31.7B	Primary growth of a root
Figure 31.7C	Primary growth of a shoot
Figure 31.8A	Secondary growth of a woody stem
Figure 31.8B	Anatomy of a log
Figure 31.9A	The structure of a flower
Figure 31.9B	Life cycle of a generalized angiosperm
Figure 31.10	An angiosperm life cycle (Layer 1)
Figure 31.10	An angiosperm life cycle (Layer 2)
Figure 31.10	An angiosperm life cycle (Layer 3)
Figure 31.11A	Development of a dicot plant embryo
Figure 31.11B	Seed structure
Figure 31.12B	The correspondence between flower and fruit in the pea plant
Figure 31.13A	Pea germination (a dicot)
Figure 31.13B	Corn germination (a monocot)

Media

See the beginning of this book for a complete description of all media available for instructors and students. Animations and videos are available in the Campbell Image Presentation Library. Media Activities and Thinking as a Scientist investigations are available on the student CD-ROM and web site.

Animations and Videos	File Name
Root Growth in a Radish Seed Time-Lapse Video	31-07B-RootTimeLapseVideo-B.mov
Root Growth in a Radish Seed Time-Lapse Video	31-07B-RootTimeLapseVideo-S.mov
Plant Fertilization Animation	31-10-AngiospmLifeCycleAnim.mov
Seed Development Animation	31-11-SeedDevelopmentAnim.mov
Fruit Development Animation	31-12-FruitDevelopmentAnim.mov

Activities and Thinking as a Scientist	Module Number
Web/CD Activity 31A: *Root, Stem, and Leaf Sections*	31.6
Web/CD Thinking as a Scientist: *What Are the Functions of Monocot Tissues?*	31.6
Web/CD Activity 31B: *Primary and Secondary Growth*	31.8
Web/CD Activity 31C: *Angiosperm Life Cycle*	31.10
Web/CD Activity 31D: *Seed and Fruit Development*	31.12
Web/CD Thinking as a Scientist: *What Tells Desert Seeds When to Germinate?*	31.13