CHAPTER 25 STRUCTURE AND ORGANIZATION OF PLANTS

Chapter Outline

25.1 Plant Organs

A. Diverse Flowering Plant Structure
   1. Structures of flowering plants are well-adapted to varied environments including water.
   2. Flowering plants usually have three vegetative organs: root, stem and leaf.
   3. The flower itself contains a number of organs.

B. Roots
   1. We speak of "a root" but it is more appropriate to call it a root system.
   2. The **root system** is the main root plus its **lateral** (side) **branches.**
   3. It is generally equal in size to the **shoot system**, the part above ground.
   4. Root systems have the following functions.
      a. Roots anchor a plant in soil and give support.
      b. Roots absorb water and minerals from soil; root hairs are central to this process.
         1) Root hair cells are in a zone near root tip.
         2) Root hairs are numerous to increase absorptive surface of a root.
         3) Transplanting plants damages a plant when the root hairs are torn off.
         4) Water and nutrients absorbed are distributed to the rest of the plant.
         5) Roots produce hormones that must be distributed to the plant
      c. Perennials "die back" to regrow the next season; roots of herbaceous perennials store food (e.g., carrots, sweet potatoes).

C. Stems
   1. The shoot system of a plant consists of the stem, the branches, and the leaves.
   2. The **stem** forms the main axis of the plant, along with lateral branches.
   3. Upright stems produce leaves and array them to be exposed to as much sun as possible.
   4. A **node** occurs where a leaf attaches to the stem and an **internode** is the region between nodes; nodes and internodes identify a stem even if it is underground.
   5. The stem has vascular tissue to transport water and minerals from roots and sugar from leaves.
   6. Nonliving cells form a continuous pipeline through vascular tissue.
   7. A cylindrical stem expands in girth and length; trees use woody tissue to strengthen stems.
   8. Stems function in storage: cactus stems store water and tubers are horizontal stems that store nutrients.

D. Leaves
   1. A **leaf** is the major organ of photosynthesis in most plants.
   2. Leaves receive water from roots by way of the stem.
   3. Broad, thin leaves have a maximum surface area to absorb CO_2 and collect solar energy.
   4. A **blade** is the wide portion of a leaf with most photosynthetic tissue.
   5. **Petiole** is a stalk that attaches a leaf blade to stem.
   6. The **leaf axil** is the upper acute angle between petiole and stem where an **axillary (lateral) bud** originates.
   7. Some leaves protect buds, attach to objects (tendrils), store food (bulbs), or capture insects.

25.2 Monocot Versus Eudicot Plants

A. Criteria for Monocots and Eudicots
   1. **Cotyledons** are embryonic seed leaves providing nutrition from the endosperm before the mature leaves begin photosynthesis.

2. Flowering plants are divided into **monocots** and **eudicots** based on these traits.

	Monocots	**Eudicots**
a. Number of **cotyledons** in seed	one	two
b. Distribution of root **xylem** and	root xylem and phloem in a ring	root phloem between **phloem** of xylem
c. Distribution of vascular bundles	scattered in stem	arranged in a distinct ring
d. Pattern of leaf veins	form a parallel pattern	form a net pattern
e. Number of flower parts	in threes and multiples of three	in fours and fives and multiples of four or five
f. Number of apertures in pollen grains	usually one	usually three
3. Representative members:	grasses, lilies, orchids, rice, wheat, corn	dandelions to oak trees and palm trees

4. The distinction between monocots and eudicots represents an important evolutionary division that relates to many structures.

25.3 Plant Tissues

A. Meristem Produces Tissue
   1. Plants continually grow due to **meristem** (embryonic tissue) in stem and root tips (apexes).
   2. Three types of **primary meristem** continually produce three types of specialized tissue.
      a. **Protoderm** is outermost primary meristem giving rise to **epidermis**.
      b. **Ground meristem** is inner meristem producing **ground tissue**.
      c. **Procambium** produces **vascular tissue**.
   3. Three specialized tissues are produced.
      a. **Epidermal tissue** forms outer protective covering.
      b. **Ground tissue** fills the interior.
      c. **Vascular tissue** transports water and nutrients and provides support.

B. Epidermal Tissue
   1. **Epidermis** is an outer protective covering tissue of plant roots, leaves, and stems of nonwoody plants.
   2. It contains closely packed epidermal cells.
   3. Waxy **cuticle** covers the walls of epidermal cells, minimizing water loss and protecting against bacteria.
   4. In roots, certain epidermal cells are modified into **root hairs** that increase surface area of the root for absorption of water and minerals and help to anchor plants in the soil.
   5. Different protective hairs are produced by epidermal cells of stems and leaves.
   6. Epidermal cells are modified as glands to secrete protective substances.
   7. On the lower epidermis of eudicot leaves, and both surfaces of monocot leaves, special **guard cells** form microscopic pores (**stomata**) and regulate gas exchange and water loss.
   8. In older woody plants, the epidermis of the stem is replaced by cork tissue which si park of bark.
      a. **Cork** is outer covering of the bark of trees; composed of dead cork cells that may be sloughed off.
      b. **Cork cambium** is lateral meristem that produces new cork cells.
      c. As cork cells mature, they encrust with the lipid **suberin** that renders them waterproof and inert.
      d. Cork protects a plant and makes it resistant to attack by fungi, bacteria, and animals.

C. Ground Tissue
   1. **Ground tissue** fills the inside of plants with parenchyma, collenchyma and sclerenchyma cells.
   2. **Parenchyma** are the least specialized of all plant cell types.
      a. Cells of this type contain plastids (e.g., chloroplasts or colorless storage plastids).
      b. They are found in all organs of a plant.
      c. They divide to form more specialized cells (e.g., roots develop from stem cuttings in water).
   3. **Collenchyma** resemble parenchyma but has thicker primary cell walls.
      a. Collenchyma cells are uneven in the corners.
      b. They usually occur as bundles of cells just beneath epidermis.
      c. They give flexible support to immature regions of plants (e.g., a celery stalk is mostly collenchyma).

4. **Sclerenchyma** cells have thick secondary cell walls.
    a. They are impregnated with **lignin** that makes the walls tough and hard.
    b. They provide strong support to mature regions of plants.
    c. Most cells of this type are nonliving.
    d. Sclerenchyma cells form fibers (used in linen and rope) and shorter sclereids (found in seed coats, nut shells, and gritty pears).

D. Vascular Tissue
    1. **Xylem** passively conducts water and mineral solutes upward through a plant from roots to leaves.
        a. Xylem contains tracheids and vessel elements.
        b. **Tracheids**
            1) Tracheids are smaller, hollow, thin, long nonliving cells with tapered overlapping ends.
            2) Water moves across end and sidewalls because of pits or depressions in secondary cell wall.
        c. **Vessel Elements**
            1) Vessel elements are hollow non-living cells lacking tapered ends.
            2) They are larger than tracheids.
            3) They lack transverse end walls.
            4) They form a continuous pipeline for water and mineral transport.
        d. Xylem also contains sclerenchyma cells to add support.
        e. Vascular rays are flat ribbons of parenchyma cells between rows of tracheids; they conduct water and minerals across the width of the plant.
    2. **Phloem** is vascular tissue that conducts the organic solutes in plants, from the leaves to the roots; it contains **sieve-tube cells** and **companion cells**.
        a. **Sieve-tube Cells**
            1) Sieve-tube cells contain cytoplasm but no nucleus.
            2) They are arranged end to end.
            3) They have channels in their end walls (thus, the name "sieve-tube"), through which plasmodesmata extend from one cell to another.
        b. **Companion Cells**
            1) Companion cells are closely connected to sieve-tube cells by numerous plasmodesmata.
            2) They are smaller and more generalized than sieve-tube cells.
            3) They have a nucleus which may control and maintain the function of both cells.
            4) They are also thought to be involved in the transport function of phloem.
    3. Vascular tissue extends from root to leaves as vascular cylinder (roots), vascular bundles (stem) and leaf veins.

25.4 Organization of Roots

A. Eudicot Root Tip
    1. The eudicot root tip, a site of **primary growth**, is organized into zones of cells in various stages of differentiation.
    2. Cells are continuously added to a **root cap** below and **zone of elongation** above by contributions from the **zone of cell division**.
    3. The **root cap** is a protective cover; its cells are replaced constantly because they are soon ground off.
    4. The **zone of elongation** is above the **zone of cell division** where cells become longer and more specialized.
    5. The **zone of cell division** contains meristematic tissue and adds cells to root tip and zone of elongation.
    6. The **zone of maturation** is above the zone of elongation; cells are mature and differentiated and it has root hairs.

B. Tissues of a Eudicot Root
    1. **Epidermis** is a single layer of thin-walled, rectangular cells.
        a. The epidermis forms the protective outer layer of the root.
        b. In the region of maturation, there are many root hairs.
        c. Root hairs project as far as 5–8 mm into the soil.
    2. **Cortex** is a layer of large, thin-walled, irregularly shaped parenchyma cells.
        a. These cells contain starch granules; the cortex functions in food storage.
        b. The cells are loosely packed; water and minerals can diffuse through the cortex without entering cells.

3. **Endodermis** is single layer of rectangular cells that forms the boundary between cortex and inner vascular cylinder.
    a. Its cells fit closely together and are bordered on four sides by the **Casparian strip.**
    b. It regulates the entrance of minerals into the vascular cylinder.
    c. The **Casparian strip** is an impermeable lignin and suberin layer that excludes water and mineral ions.
    d. The only access to the vascular bundle is through endodermal cells.
4. **Vascular cylinder** is an arrangement of vascular tissues as a cylinder.
    a. The **pericycle** is the first layer of cells within vascular cylinder
        1) Its cells have retained the capacity to divide.
        2) It can start the development of branch or secondary roots.
    b. **Vascular tissue** forms main portion of a vascular bundle; it is composed of
        1) xylem, whose cells are arranged in a star-shaped pattern; and
        2) phloem, whose cells are located in regions between arms of xylem.

C. Organization of Monocot Roots
1. Monocot roots have the same zones as a eudicot root but do not undergo secondary growth.
2. The monocot root has a ring of vascular tissue where alternating bundles of xylem and phloem surround **pith.**
3. Monocot roots also have pericycle, endodermis, cortex, and epidermis.

D. Root Diversity
1. Roots have adaptations to help anchor plants, absorb water and minerals, and store carbohydrates.
2. There are three general root types.
    a. **Taproot** is common in eudicots; the first or **primary root** grows straight down and remains dominant root of a plant; often fleshy and adapted to store food (e.g., carrots, beets).
    b. The **fibrous root system** of monocots is a mass of slender roots and lateral branches that hold the plant secure in the soil.
    c. **Adventitious roots** develop from underground stems or from the base of above-ground stems.
        1) A **prop root's** main function is to anchor a plant (e.g., corn and mangrove plants).
        2) **Pneumatophores** of mangrove plants project above the water from roots to acquire oxygen.
        3) Ivy has holdfast roots to anchor aerial shoots.
3. **Haustoria** are rootlike projections from stems on parasitic plants (e.g., dodders and broomrapes).
        1) Haustoria grow into the host plant.
        2) They contact vascular tissue from which they extract water and nutrients.
4. **Mycorrhizae** are an association between fungus and roots.
        1) In this mutualism, fungus receives sugars and amino acids from plant.
        2) Plant receives water and minerals from the fungus.
5. Legumes (e.g., peas and beans) have **root nodules** containing nitrogen-fixing bacteria.
    a. Bacteria extract nitrogen from air and reduce it to a form that can be used by plant tissues.
    b. Legumes are often planted to bolster nitrogen supply of soil.

25.5 Organization of Stems

A. Primary Growth
1. The stem tip is the site of **primary growth** where cell division extends length of stems or roots.
2. **Shoot apical meristem** produces new leaves and primary meristems, increasing stem length.
3. Shoot apical meristem is protected within a terminal bud of **leaf primordia** (**immature leaves**).
4. **Bud scales** are scalelike coverings protecting terminal buds during winters when bud growth stops.
5. Three specialized types of primary meristem develop from shoot apical meristem.
    a. **Protoderm** is outermost primary meristem that gives rise to **epidermis.**
    b. **Ground meristem** produces two tissues composed of parenchyma cells: the pith and the cortex.
    c. **Procambium** is inner meristem that produces **primary xylem** and **primary phloem.**
6. Differentiation continues; cells become first tracheids or vessel elements within vascular bundle.
7. First sieve-tube cells are short-lived and do not have companion cells.
8. Mature phloem develops later after all surrounding cells have stopped expanding and **vascular cambium** has developed.

B. Herbaceous Stems
1. **Herbaceous stems** are mature nonwoody stems that exhibit only primary growth.
2. The outermost tissue of herbaceous stems is epidermis covered by a waxy cuticle to prevent water loss.

3. Xylem and phloem are in distinctive **vascular bundles.**
    a. In each bundle, xylem is found to the inside of the stem; phloem is found to the outside.
    b. In the eudicot herbaceous stem, vascular bundles are arranged in a ring towards outside of the stem and separating the cortex from the central pith.
    c. In monocot stem, vascular bundles are scattered throughout the stem; there is no well-defined cortex or pith.
4. Cortex sometimes carries on photosynthesis; pith may function as a storage site.

C. Woody Stems
1. Woody plants have both primary and secondary tissues.
2. Primary tissues are new and form each year from primary meristem right behind the apical meristem.
3. Secondary tissues develop from second year onward from growth of lateral meristem.
4. **Primary growth** increases the length of a plant; **secondary growth** increases its girth.
5. As secondary growth continues, it is not possible to distinguish individual vascular bundles.
6. The woody eudicot stem has a different organization with three distinct areas: bark, wood, and pith.
7. Bark of a tree contains cork, cork cambium, and phloem.
    a. Secondary phloem is produced each year by vascular cambium but does not build up.
    b. This phloem tissue is soft; therefore it is easy to remove the bark of a tree.
8. **Cork cambium** is meristem beneath the epidermis that produces new cork cells when needed.
    a. Cork cambium begins to divide, producing cork that disrupts epidermis replacing it with cork cells.
    b. Cork cells become impregnated with suberin, causing them to die but making them waterproof.
    c. Consequently, cork forms an impervious barrier, even to gas exchange, except at **lenticels**.
9. Wood
    a. Wood is secondary xylem which builds up each year; the **vascular cambium** is dormant during the winter.
    b. **Spring wood** is composed of wide xylem vessel elements with thin walls, necessary to conduct sufficient water and nutrients to supply abundant growth that occurs during spring.
    c. **Summer wood** forms when moisture is scarce; composed of a lower proportion of vessels, it contains thick-walled tracheids and numerous fibers.
    d. An **annual ring** is one ring of spring wood followed by a ring of summer wood; this equals one year's growth.
    e. **Sapwood** is outer annual rings where transport occurs.
    f. **Heartwood** is inner annual rings of older trees.
        1) Vessels no longer function in transport; they become plugged with resins and gums that inhibit growth of bacteria and fungi.
        2) Heartwood may help to support a tree.
10. Woody Plants
    a. The first flowering plants were probably woody shrubs; herbaceous plants evolved later.
    b. It is advantageous to be woody when there is adequate rainfall; woody plants can grow taller and have adequate tissue to support and service leaves.
    c. It takes energy to support secondary growth and prepare plant for winter in temperate zones.
    d. Long-lasting plants need more defense mechanisms against attack by herbivores and parasites.
    e. Trees need years to mature before reproducing; they are more vulnerable to accident or disease.

D. Stem Diversity
1. **Stolons** are stems that grow along the ground; new plants grow where the nodes contact the soil.
2. The succulent stems of cacti are modified for water storage.
3. Tendrils of grapes and morning glories are stems adapted for wrapping around support structures.
4. **Rhizomes** are underground horizontal stems.
    a. Rhizomes are long and thin in grasses and thick and fleshy in irises.
    b. Rhizomes survive winter and contribute to asexual reproduction because each node bears a bud.
    c. Some rhizomes have **tubers** that function in food storage (e.g., potatoes).
5. **Corms** are bulbous underground stems that lie dormant during winter, like rhizomes.
6. Humans use stems: sugarcane is primary source of table sugar, cinnamon and quinine are from bark, wood is from paper, etc.

25.6 Organization of Leaves

A. Leaf Structure
   1. Leaves are organs of photosynthesis in plants; they are made of a flattened blade and a petiole.
   2. The **leaf veins** reveal the presence of vascular tissue within the leaves.
   3. The vascular tissues of leaves transport water and nutrients.
   4. Leaf veins have a net pattern in eudicot leaves and a parallel pattern in monocot leaves.
   5. A **petiole** is a stalk that attaches a leaf blade to the plant stem.
   6. **Epidermis** is the layer of cells that covers the top and bottom sides of a leaf.
      a. The epidermis often bears protective hairs or glands; epidermal glands produce irritating substances.
      b. The epidermis is covered by a waxy **cuticle** that keeps the leaf from drying out.
      c. The epidermis, particularly lower epidermis, contains **stomata** that allow gases to move into and out of the leaf.
   7. **Mesophyll** is the inner body of a leaf and the site of most of photosynthesis.
      a. **Palisade mesophyll** is the layer of mesophyll containing elongated parenchyma cells with many chloroplasts.
      b. **Spongy mesophyll** contains loosely packed parenchyma cells that increase the surface area for gas exchange.

B. Leaf Diversity
   1. **Simple leaves** have margins not deeply lobed or divided into smaller leaflets.
   2 **Compound leaves** are divided into smaller leaflets, and each leaflet may have its own stalk.
   3. Leaves are variously modified.
      a. Shade plants have broad leaves while desert plants have reduced leaves with sunken stomata.
      b. Cactus spines are modified leaves; succulents have fleshy leaves to hold moisture.
      c. Onion bulbs have leaves surrounding a short stem.
      d. The tendrils of peas and cucumbers are leaves.
      e. The Venus's-flytrap has leaves to trap and digest insects.