

Chapter 35

Plant Structure, Growth, and Development

Lecture Outline

Overview: Plastic Plants?

- The fanwort, an aquatic weed, demonstrates the great **developmental plasticity** that is characteristic of plants.
 - The fanwort has feathery underwater leaves and large, flat, floating surface leaves.
 - Both leaf types have genetically identical cells, but the dissimilar environments in which they develop cause different genes involved in leaf formation to be turned on or off.
- In addition to plastic structural responses of individual plants to specific environments, plant species have adaptations in **morphology** that benefit them in their specific environments.
 - For example, cacti have leaves that are reduced to spines and a stem that serves as the primary site of photosynthesis. These adaptations minimize water loss in desert environments.
- The form of any plant is controlled by environmental and genetic factors. As a result, no two plants are identical.
- Angiosperms make up 90% of plant species and are at the base of the food web of nearly every terrestrial ecosystem.
- Most land animals, including humans, depend on angiosperms directly or indirectly for sustenance.

Concept 35.1 The plant body has a hierarchy of organs, tissues, and cells.

- Plants, like multicellular animals, have organs that are composed of different tissues, and tissues that are composed of different cell types.
 - A **tissue** is a group of cells with common structure and function.
 - An **organ** consists of several types of tissues that work together to carry out particular functions.

Vascular plants have three basic organs: roots, stems, and leaves.

- The basic morphology of vascular plants reflects their evolutionary history as terrestrial organisms that inhabit and draw resources from two very different environments.
 - Vascular plants obtain water and minerals from the soil.
 - Vascular plants obtain CO₂ and light above-ground.
- To obtain the resources they need, vascular plants have evolved two systems: a subterranean **root system** and an aerial **shoot system** of stems and leaves.
- Each system depends on the other.

- Lacking chloroplasts and living in the dark, roots would starve without *photosynthates*, the sugar and other carbohydrates imported from the shoot system.
- Conversely, the shoot system depends on water and minerals that roots absorb from the soil.

Roots provide anchorage, absorption, and storage.

- A **root** is an organ that anchors a vascular plant in the soil, absorbs minerals and water, and stores sugars and starches.
- Most eudicots and gymnosperms have a *taproot system*, consisting of one large vertical root (the taproot) that develops from an embryonic root.
- The taproot produces many small lateral, or branch, roots.
 - In angiosperms, taproots often store sugars and starches that later support flowering and fruit production.
 - Taproot systems generally penetrate deeply and are well adapted to deep soils.
- In seedless vascular plants and most monocots, including grasses, the embryonic root dies and does not form a main root.
- Instead, many small roots grow from the stem. Such roots are *adventitious*, a term describing a plant organ that grows in an unusual location.
- Each small root forms its own lateral roots, giving rise to a *fibrous root system*—a mat of thin roots that spread out below the soil surface.
 - A fibrous root system is usually shallower than a taproot system and is best adapted to shallow soils with light rainfall.
 - Grass roots are concentrated in the upper few centimeters of soil. As a result, grasses make excellent ground cover for preventing erosion.
- The root system helps anchor a plant.
- In both taproot and fibrous root systems, absorption of water and minerals occurs near the root tips, where vast numbers of tiny **root hairs** enormously increase the surface area.
 - Root hairs are short-lived, tubular extensions of individual root epidermal cells.
- Some plants have modified roots. Some arise from roots, while others are adventitious, arising above-ground from stems or even from leaves.
- Some modified roots provide additional support and anchorage. Others store water and nutrients or absorb oxygen from the air.

Stems consist of alternating nodes and internodes.

- A **stem** is an organ consisting of alternating **nodes**, the points at which leaves are attached, and **internodes**, the stem segments between nodes.
- At the angle formed by each leaf and the stem is an **axillary bud** with the potential to form a lateral shoot or branch.
- The growth of a young shoot is usually concentrated at its apex, where there is an **apical bud**, or terminal bud, with developing leaves and a compact series of nodes and internodes.
- The presence of a terminal bud is partly responsible for inhibiting the growth of axillary buds, a phenomenon called **apical dominance**.
 - By concentrating resources on growing taller, apical dominance is an evolutionary adaptation that increases the plant's exposure to light.
- In the absence of a terminal bud, the axillary buds break dormancy and give rise to lateral shoots complete with their own apical buds, leaves, and axillary buds.
 - This is why pruning trees and shrubs makes them bushier.

- Modified shoots with diverse functions have evolved in many plants.
 - These shoots, which include stolons, rhizomes, tubers, and bulbs, are often mistaken for roots.

Leaves are the main photosynthetic organs of most plants.

- The **leaf** is the primary site of photosynthetic organs of most plants, although green stems are also photosynthetic.
- Although leaves vary extensively in form, they generally consist of a flattened **blade** and a stalk, the **petiole**, which joins the leaf to a stem node.
 - Grasses and other monocots lack petioles. In these plants, the base of the leaf forms a sheath that envelops the stem.
- Monocots and eudicots differ in the arrangement of **veins**, the vascular tissue of leaves.
- Most monocots have parallel major veins that run the length of the blade, while eudicot leaves have a branched network of major veins.
- Plant taxonomists use floral morphology, leaf morphology, the branching pattern of veins, and the spatial arrangement of leaves to help identify and classify plants.
 - For example, simple leaves have a single, undivided blade, while compound leaves have several leaflets attached to the petiole.
 - Many large leaves are compound, which allows them to withstand strong winds without tearing.
 - The structural adaptation of compound leaves also confines pathogens that invade the leaf to one leaflet.
- Most leaves are specialized for photosynthesis.
- Some plants have leaves that have become adapted for other functions, including tendrils that cling to supports, spines of cacti for defense, leaves modified for water storage, and brightly colored leaves that attract pollinators.

Plant organs are composed of three tissue systems: dermal, vascular, and ground.

- Each organ of a plant has three **tissue systems**: dermal, vascular, and ground tissues.
- Each system is continuous throughout the plant body.
- The **dermal tissue system** is the plant's outer protective covering.
- In nonwoody plants, the dermal tissue system is a single layer of tightly packed cells, or **epidermis**.
- The epidermis of leaves and most stems secretes a waxy coating, the **cuticle**, which helps the aerial parts of the plant retain water.
- In woody plants, protective tissues called **periderm** replace the epidermis in older regions of stems and roots.
- The epidermis has other specialized characteristics consistent with the function of the organ it covers.
 - For example, the root hairs are extensions of epidermal cells near the tips of the roots.
 - *Trichomes*, outgrowths of shoot epidermis, reduce water loss and reflect light. They protect against insects with sticky secretions of insecticidal biochemicals.
- The **vascular tissue system** is involved in the transport of materials between roots and shoots.
 - **Xylem** conveys water and dissolved minerals upward from roots into the shoots.

- **Phloem** transports sugars, the products of photosynthesis, to the roots and sites of growth, such as developing leaves and fruits.
- The vascular tissue of a root or stem is called the **stele**.
- In angiosperms, the root stele forms a solid central *vascular cylinder*, while the stele of stems and leaves consists of *vascular bundles*, separate strands of xylem and phloem.
- Both xylem and phloem are complex tissues with a variety of cell types.
- The **ground tissue system** is tissue that is neither dermal nor vascular.
- Ground tissue is divided into **pith**, internal to vascular tissue, and **cortex**, external to the vascular tissue.
- The functions of specialized cells within ground tissue include photosynthesis, storage, and support.

Plant tissues are composed of three basic cell types: parenchyma, collenchyma, and sclerenchyma.

- Plant cells are differentiated, with each type of plant cell possessing structural adaptations that make specific functions possible.
 - Cell differentiation may be evident within the protoplast, the cell contents exclusive of the cell wall.
 - Modifications of cell walls also play a role in plant cell differentiation.
- The major types of differentiated plant cells are parenchyma, collenchyma, sclerenchyma, water-conducting cells of the xylem, and sugar-conducting cells of the phloem.
- Mature **parenchyma** cells have primary walls that are relatively thin and flexible; most lack secondary walls.
- The protoplast of a parenchyma cell usually has a large central vacuole.
- Parenchyma cells are often depicted as “typical” plant cells because they generally are the least specialized, but there are exceptions.
 - For example, the highly specialized sieve-tube elements of the phloem are parenchyma cells.
- Parenchyma cells perform most of the metabolic functions of the plant, synthesizing and storing various organic products.
 - For example, photosynthesis occurs within the chloroplasts of parenchyma cells in the leaf.
 - Some parenchyma cells in the stems and roots have colorless plastids that store starch.
 - The fleshy tissue of most fruit is composed of parenchyma cells.
- Most parenchyma cells retain the ability to divide and differentiate into other cell types under special conditions, such as the repair and replacement of organs after injury to the plant.
- In the laboratory, it is possible to regenerate an entire plant from a single parenchyma cell.
- **Collenchyma cells** have thicker primary walls than parenchyma cells, although the walls are unevenly thick.
- Grouped into strands or cylinders, collenchyma cells help support young parts of the plant shoot.
- Young stems and petioles often have strands of collenchyma just below the epidermis, providing support without restraining growth.
- Mature collenchyma cells are living and flexible and elongate with the stems and leaves they support.
- **Sclerenchyma cells** have thick secondary walls usually strengthened by lignin; they function as supporting elements of the plant.

- Sclerenchyma cells are much more rigid than collenchyma cells.
- Unlike parenchyma cells, sclerenchyma cells cannot elongate.
- Sclerenchyma cells occur in plant regions that have stopped lengthening.
- Many sclerenchyma cells are dead at functional maturity, but they produce rigid secondary cell walls before the protoplast dies.
 - In parts of the plant that are still elongating, secondary walls are deposited in a spiral or ring pattern, enabling the cell wall to stretch like a spring as the cell grows.
- Two types of sclerenchyma cells, **fibers** and **sclereids**, are specialized entirely for support.
 - Fibers are long, slender, and tapered, and usually occur in groups.
 - Fibers from hemp are used for making rope, and fibers from flax are woven into linen.
 - Sclereids are irregular in shape and shorter than fibers. They have very thick, lignified secondary walls.
 - Sclereids impart hardness to nutshells and seed coats and the gritty texture to pear fruits.
- The water-conducting elements of xylem, the **tracheids** and **vessel elements**, are elongated cells that are dead at functional maturity.
 - The thickened cell walls remain as a nonliving conduit through which water can flow.
- Both tracheids and vessels have secondary walls interrupted by **pits**, thinner regions where only primary walls are present.
- Water moves from cell to cell mainly through pits.
- Tracheids are long, thin cells with tapered ends.
- Because their secondary walls are hardened with lignin, tracheids function in support as well as transport.
- Vessel elements are generally wider, shorter, thinner-walled, and less tapered than tracheids.
- Vessel elements are aligned end to end, forming long micropipes or xylem vessels.
- The ends are perforated, enabling water to flow freely.
- In the phloem, sucrose, other organic compounds, and some mineral ions move through tubes formed by chains of cells called **sieve-tube elements**.
- Sieve-tube elements are alive at functional maturity, although a sieve-tube element lacks a nucleus, ribosomes, and a distinct vacuole.
- The end walls, the sieve plates, have pores that facilitate the flow of fluid between cells.
- Each sieve-tube element has a nonconducting nucleated companion cell, which is connected to the sieve-tube element by numerous plasmodesmata.
- The nucleus and ribosomes of the companion cell serve both that cell and the adjacent sieve-tube element.
- In some plants, companion cells in leaves help load sugar into the sieve-tube elements, which transport the sugars to other parts of the plant.