Chapter 6

Biology of Flowering Plants

Anatomy – Seedlings, Meristems, Stems, and Roots

Objectives

Seedling germination and anatomy. Understand meristem structure and function and how meristems are protected during germination. Understand germination. Know the function of the structures of a typical dicot and a typical monocot seedling.

Primary growth and tissues. Know the difference between primary growth and secondary growth. Know the structure and function of the major types of primary tissues and the cells that constitute these tissues.

Seed germination and seedling structure

When a seed is deposited in an environment suitable for germination, several external (*e.g.* temperature, light, and water) and internal factors (*e.g.* gibberellins) break dormancy and cause resumption of embryo growth. The seed coat, which protects the embryo, and seed dormancy, which ensures adequate conditions for growth before breaking from the protective seed coat, are adaptations to a terrestrial environment. During germination, the nutritive tissue is used for the growth of the embryo.

The first structure to emerge from most seeds is the primary root, which enables the developing seedling to become anchored in the soil and to absorb water for metabolism. There are two major types of structural root systems[1], the taproot system (found in all seed plants except monocots) and the fibrous root system (found in monocots). In the taproot system, the primary root persists, gives rise to lateral roots, and is termed the taproot. In the fibrous root system, the primary root does not persist and the main root system develops from roots that arise from the stem. Taproot systems generally penetrate deeper into the soil. The record depth for penetration of roots is ~53 meters (~175 feet) by the desert shrub mesquite (*Prosopis juliflora*).

Roots extend through soil by cell division that takes place at the root apical meristem. Meristems[2] (from Greek *merismos* meaning division) are embryonic cells that retain the potential to divide long after embryogenesis. The root cap, made of parenchyma cells, protects the root apical meristem from abrasion by soil. After the primary root emerges, lateral roots[3] emerge from within the primary root. In addition, most roots form root hairs, extensions of the epidermis, that increase the surface area of the root, thus allowing for increased water and solute absorption.

Emergence of the shoot during germination varies in different plant groups[4]. In some dicot plants, the hypocotyl elongates and bends to form a hook. The shoot apical meristem and cotyledons are at the end of the hypocotyl hook and are therefore protected from abrasion by soil. In addition, the seed coat often remains around the meristem and cotyledons, further protecting

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[1] Fig. 24-2
[2] p. 510, Fig. 23-1
[3] pp. 540-541
[4] pp. 506-507, Fig. 22-10, Fig. 22-11

them from abrasion. Once the hook emerges from the soil and light is sensed, the hook straightens thus positioning the shoot apical meristem at the top of the shoot and the cotyledons emerge from the seed coat and become photosynthetic until true leaves develop and the cotyledons wither or become photosynthetic. This type of germination in which the cotyledons are pulled above soil by the hypocotyl hook is called epigeous. In contrast to a hypocotyl hook, in some dicot plants, an epicotyl hook forms. Because, in this case, the hook grows from above the cotyledons, the cotyledons are not carried above ground with the shoot apical meristem and thus, remain underground. This type of germination is called hypogeous.

In the majority of monocot seeds[5], the endosperm is the stored food. In some monocots, the single cotyledon forms a hook that carries the seed coat and enclosed endosperm to the soil surface, and, in some cases, the cotyledon becomes photosynthetic. In other monocots, such as maize, after the primary root emerges, a sheath-like coleoptile emerges. When the coleoptile reaches the soil surface, the first leaves emerge.

Specimen 1: Dicot seedling[6]

1. Carefully remove a bean seedling from the soil. Be sure to include the entire seedling including the roots.

2. Draw and label the parts of the seedling. Identify the primary root and root hairs (if possible), seed coat, cotyledons, first true leaf, hypocotyl, and epicotyl of the seedling.

3. Answer the following question under your drawing: Does this seed type undergo hypogeous or epigeous germination and, how do you know?

Specimen 2: Monocot seedling[7]

1. Carefully remove an entire young maize seedling from the soil. (Remember that the maize kernel is a fruit, the majority of which is seed, and the external layer that is usually yellow or other colors is derived from the ovary.)

2. Draw and label the parts of the seedling. Identify the primary root and root hairs (if possible), the coleoptile, and the first true leaf.

Primary and Secondary Growth

Meristems. During embryogenesis, the apical-basal axis and radial patterning of the plant are established. Plant development occurs by meristematic activity. Apical meristems are found at the tips of roots and of stems. The apical meristems[8] give rise to the primary meristematic tissues, protoderm, procambium, and ground meristem, eventually consisting of differentiated specific cell types in primary tissues[9]. This growth is termed primary growth, whereas secondary growth, which does not occur in monocot shoots, is derived from secondary or lateral meristems (*e.g.* vascular cambium).

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[5] Fig. 22-12
[6] Fig. 22-11
[7] Fig. 22-12
[8] Fig. 23-1
[9] Fig. 23-2

Specimen 3: Prepared slide of longitudinal section of root apical meristem

1. Observe at 10x.
2. Observe the faint region at the lower tip of the root. This is the root cap[10], which protects the meristem from abrasion by soil.
3. Observe the region with small cells just above the root cap. This is the apical meristem, the region of cell division.
4. Observe the region where cells are more elongated than at the meristem. This is the region of cell elongation.
5. Observe the region above the region of elongation, where the cells in the rows appear different from on another. This is the region of cell maturation and differentiation. In this region, you may find root hairs.
6. Draw the longitudinal section of the root tip at 10x and label the root cap, apical meristem (region of cell division), region of elongation, and region of maturation. Include details of cell structure across a small portion of each region.

Specimen 4: Prepared slide of longitudinal section of shoot apical meristem

1. Observe at 10x.
2. Observe the domed tip of the stem. This is the apical meristem, the region of cell division. Notice that the cells are small and dense.
3. Observe the leaf primordia, which develop into leaves, arising from the perimeter of the apical meristem.
4. Observe the knob-like bud primordial at the base of the leaves. The bud primordia can develop into branches.
5. Draw the longitudinal section of the shoot tip at 10x and label the apical meristem, leaf primordia, and bud primordia.

Tissue systems. There are three tissue systems[11] that arise from the primary meristematic tissues. The dermal tissue system originates from the protoderm, the ground tissue system originates from the ground meristem, and the vascular tissue system originates from the procambium. Some tissues are composed of only one cell type and called simple tissues, whereas others, such as the epidermis, are composed of more than one cell type and are called complex tissue. Each of the major plant parts (roots, stems, and leaves (recall the floral organs are modified leaves)) is made up of these three basic tissue types. In each plant part, these tissues have specialized cells and thus perform specialized functions.

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[10] p. 530, Fig. 24-4, Fig. 24-5
[11] Summary table pp. 526-527

Dermal tissue. The dermal tissue[12], epidermis, is the outermost tissue layer (unless significant secondary growth occurs). Most of the epidermal cells are compactly arranged, providing mechanical protection and the walls of the epidermal cells of the aerial parts of the plant are covered with a cuticle, composed mainly of cutin and wax, to minimize water loss. Interspersed among the epidermal cells are pairs of specialized cells called guard cells[13]. Each pair of guard cells creates a pore, stoma (pl. stomata), between them. Through stomata, CO_2 for photosynthesis is taken up and water vapor evaporates. The guard cells regulate the aperture of the pore. Trichomes[14] are another specialized type of dermal cell. Trichomes of roots, root hairs, facilitate the absorption of water and minerals from the soil. Trichomes of leaves reflect solar radiation to decrease leaf temperature and water loss, secrete defensive chemicals, deter insects from eating leaves, and, for carnivorous plants, trap insects.

Ground tissue. Ground tissue[15] usually forms the bulk of the tissues of a plant and is primarily involved in photosynthesis and storage. The cell types that comprise the ground tissue are parenchyma, sclerenchyma, and collenchyma. Parenchyma cells are living at maturity and usually have only a primary cell wall. Parenchyma cells are capable of cell division and therefore are important in regeneration and wound healing. Sclerenchyma cells, at maturity, lack protoplasts. Sclerenchyma (from Greek *skleros* meaning hard) cells have thick secondary cell walls and provide mechanical support. There are two primary types of sclerenchyma cells, fibers (*e.g.* of hemp, jute, and flax) that are long and slender and sclerids that are variable in shape. Sclerids are found in many seed coats, nutshells, and the stones of fruits like peaches. Collenchyma cells are living at maturity and are commonly found in strands beneath the epidermis in stems and petioles. Their unevenly thickened, nonlignified primary walls are soft, pliable, and supportive, especially for young tissues.

Vascular tissue. Vascular tissue[16] is specialized for transport and forms a continuous system throughout the body of the plant. The vascular system consists of two major tissue types, the xylem and the phloem, that are derived from the procambium region of the meristem.

Xylem is specialized for water and mineral transport and provides support. The water and mineral transporting cells of the xylem are the tracheary elements, which have secondary walls and maybe tertiary walls and lack protoplasts at maturity. There are two types of tracheary elements, tracheids and vessel elements. Tracheids, which lack perforations, are less specialized than vessel elements. Vessel elements are perforated and stacked end-to-end and are therefore efficient water-conducting cells. The xylem tissue may also contain fibers for support and parenchyma for storage.

Phloem transports many substances throughout the plant including sugars (produced from photosynthesis and transported to parts of the plant that are not photosynthetic), amino acids, plant growth regulators, proteins, and RNA. The transporting cells of the phloem are the sieve elements, which do not have secondary walls. There are two types of sieve elements, sieve cells (found in gymnosperms) and sieve-tube elements (found in angiosperms). Sieve-tube elements are stacked and are connected by sieve plates, which are large pores in the cell walls; thus, forming a tube. Associated with each sieve-tube element is one (or sometimes two) companion

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[12] pp. 523-525
[13] Fig. 23-24
[14] Fig. 23-27
[15] pp. 513-515
[16] pp. 516-522

cell that maintains the enucleate sieve-tube element and loads and unloads substances to and from the sieve-tube element/companion cell complex.

Organization of tissue and cell types throughout the plant body. We will now study the arrangement and functional specialization of these tissue types in different plant parts. Note that we will study only primary tissues in this lab.

Specimen 5: Prepared slide of cross section through a dicot root (*Ranunculus*)

1. Observe at 4x. Observe the outer-most layer of cells, the epidermis, and the inner core, the vascular cylinder. The rest of the tissue is ground tissue.

2. Observe the ring of cells that separates the ground tissue from the vascular tissue. Zoom in on one of the cells of this ring of cells with the 10x and then the 40x objectives. This ring of cells is the endodermis and each cell is an endodermal cell. Notice that the side-walls and the outer walls are thicker. The walls of these cells perform a specialized function during water uptake by the root as will be discussed in more detail later.

3. Observe at 10x the layer of cells immediately interior to the endodermis. This layer is the pericycle. Cell division in the pericycle results in formation of lateral roots; thus, the pericycle is considered a meristem.

4. Observe at 10x the vascular cylinder. The xylem forms and x-shaped core and the phloem is between the "arms" of the xylem core in dicot roots.

5. Draw the root cross section at 10x and label the epidermis, ground tissue, vascular cylinder, endodermis, pericycle, xylem, and phloem.

Endodermis. Endodermal cells are specialized to accomplish the critical function of requiring the solutes that enters the root to cross a plasma membrane prior to transport by the xylem throughout the plant. The cell wall of each endodermal cell is banded by a Casparian strip. This strip is made of a fatty substance (suberin), which is impermeable to water. Water flows from the soil into the root through the cell walls of the epidermal cells and the cells of the ground tissue. The cell wall is non-selective, and all dissolved substances enter the root. But the water cannot cross the Casparian strip, and is therefore forced to enter the endodermal cell through the plasma membrane. The selective plasma membrane of the endodermal cell acts as a filter.

Specimen 6: Prepared slide of a cross section through a dicot stem (*Ranunculus*)

1. Observe at 4x. As in the root, the epidermal cells are on the perimeter of the cross section.

2. Observe the vascular bundles that form a ring within the cross section. The ring of vascular bundles is characteristic of dicots; whereas, vascular bundles of monocots are scattered throughout the stem. The ring arrangement of vascular bundles is important for the secondary growth that occurs in dicots, but does not occur in monocots. The region between the epidermis and the vascular bundles is composed of parenchyma cells and is called the cortex, part of the ground tissue. The region enclosed by the ring of vascular bundles is the central pith, also part of the ground tissue.

3. Observe one of the vascular bundles at 10x. Observe the large vessels of the xylem tissue closer to the pith and the phloem closer to the cortex. The cells between the xylem and phloem are the cambium, which is the progenitor of secondary growth.

4. Observe the cells that surround each bundle, they are the bundle sheath cells.

5. Draw the dicot stem cross section at 10x and label the epidermis, cortex, vascular bundles, pith, xylem, phloem, and cambium.

Specimen 7: Prepared slide of a cross section through a monocot stem (*Zea mays*)

1. Observe at 4x. Observe the arrangement of vascular bundles in the monocot.

2. Draw at 10x and label the epidermis, ground tissue, vascular bundles, phloem, and xylem.

3. In your notebook, write a comparison of the arrangement of vascular bundles of dicot and monocot stems.

Review questions

1. What are the primary functions of roots and what aspects of root structure facilitate each function?

2. During germination, from where does a seedling get nutrients to grow? After germination and throughout the life of the plant, from where does a seedling get nutrients to grow?

3. Draw a sketch, at the tissue level, of what a dicot stem would look like after significant secondary growth and label the regions of phloem, cambium, and xylem. How is the arrangement of vascular bundles conducive to secondary growth in dicots, but not in monocots?