Biology 3B Laboratory
Land Plant Structure

Objectives

- Learn and recognize the basic tissues and structures of land plants
- Understand how these morphological features relate to plant structure and function
- Consider how these structures change through evolutionary time
- Be able to reconstruct the three-dimensional structure of the plant in your mind, based upon longitudinal and cross section examination.

Introduction

In the transition from small aquatic forms to large terrestrial forms plants solved a series of major evolutionary problems. In this lab we will look at s changes in plant body structure that evolved to meet the challenges of the terrestrial environment.

The first major adaptation was the **root-shoot system**, which solved the problem posed by gravity. Terrestrial plants anchor themselves in the soil with root systems, and develop upright stems that support leaves looking for sunlight. Roots also absorb and transport water and nutrients; aquatic plants exist in the water.

Evolving to large size always presents similar problems. In small organisms diffusion can meet the needs of interior cells. However, in larger organisms, internal cells are to far from the source; they cannot rely on simple diffusion to transport water, nutrients and gases. In the larger land plants a network of tubes called vascular tissue evolved to conduct water, nutrients, and food.

As you know, plant cells differ from animal cells. In particular, they posses cell walls that aid in structural support and chloroplasts that are involved in autotrophic reactions. Within plant we find several types of cells. In plants and animals, integrated groups of cells with common function and structure are called **tissues**. The basic functions of tissues in plant are growth, support and transport. Typical cell types that make up the basic plant tissues are shown in Table 1.

Table One. Cell Types Present in Plant Tissues

Tissue	Cell Types Present
Epidermis	Ground Cells, Guard Cells, Tricomes, Sclerenchyma Cells
Periderm	Cork Cells, Cork Cambium Cells, Parenchyma of Phelloderm, Sclerenchyma Cells
Xylem	Tracheid, Vessel Elements, Sclerenchyma Cells, Parenchyma Cells
Phloem	Sieve Cells, Companion Cells, Parenchyma Cells, Sclerenchyma Cells
Parenchyma	Parenchyma Cells
Sclerenchyma	Sclerenchyma Cells, fibers or sclereids
Collenchyma	Collenchyma Cells

A General Introduction to Plant Tissues

Growth in plants is carried out in a region called the **meristem**. Meristem cells are undifferentiated cells that divide quickly and build new tissues of various types (those shown in Table 1). Most flowering plants develop in similar ways. At the tips, or apices of the plant, both top and bottom, there is an area of active cell division. These actively dividing cells are sites of **primary growth** called the **apical meristem**. Primary growth extends shoots into the air and the roots down into the ground. Many herbaceous annual plants, like lilies and violets, have only primary growth, and their stems never increase much in thickness. However, in longer-lived plants the stems begin to thicken with age. In these plants, primary growth at the apical meristem is supplemented by **secondary growth** (lateral growth) or thickening. This lateral growth comes from the **lateral meristem**. The lateral meristem is a thin cylinder of tissue that rises through the plant.

Epidermis is the outermost layer of cells on leaves, flowers, fruits and seeds, and young (primary growth) stems and roots. Thus epidermis is highly variable. In addition to "ground cells" are guard cells, which regulate the opening of the **stomata** (singular = stoma). Tricomes are cells with specialized appendages, such as root hairs that increase water and nutrient uptake. The aerial face of epidermal cells is covered with a **cuticle**, composed of cutin and wax.

Periderm consists primarily of non-living cells called cork (**phellum**) derived from cork cambium. The cork cambium also produces a living tissue, **phelloderm**, composed of parenchyma cells. Periderm replaces the epidermis in plants that have secondary growth.

Xylem conducts water and dissolved nutrients throughout the plant. Xylem cells transport water in one direction only, from the roots to the leaves. Xylem cells are short-lived. There are two types of xylem cells commonly found in plants. The more primitive **tracheids** are characteristics of gymnosperms. The larger diameter **vessel elements** are characteristic of angiosperms.

Phloem conducts food throughout the plant. This transport is bidirectional depending on the concentration gradient within the plant. The **sieve cells** are the conducting elements. These living cells are aided by **companion cells**, which function to maintain the sieve cells.

Parenchyma cells are most common; they are found throughout the body of the plant. They make up the "ground tissue" or **pith**.

Sclerenchyma cells have a secondary cell wall, impregnated with lignin, and deposited inside the original cell wall. This makes them extra tough, and they are used wherever strong support is needed.

Collenchyma cells provide support in areas of primary growth. Their cell walls are thickened to provide support for the growing cells. The strings in celery are composed of collenchyma cells.

Structure of Stems

The stem is the aboveground growth structure of the plant. At the very top of the stem, is an **apical meristem**. The meristematic tissue is protected by a **terminal bud**. Buds are shortened stems. The scales of the bud are small modified leaves. These bud scales fall off as new growth starts in the spring. The bud scales leave behind a characteristic scar, the **bud scale scar**. New lateral branches emerge from smaller buds called **axillary buds** just above the joint of the leaf and the stem. There are certain points where all such growth occurs, called **nodes**. The length of stem between these growing points, or nodes, is the **internode**. So leaves and branches emerge at the nodes. After the leaves fall off the stem, you can still see the crescent shaped **leaf scar** on the stem where the base of the leaf was attached. Vascular bundles extend out from the stem into each leaf on the plant. If you look carefully at the leaf scars, you can see a series of tiny holes. These are the scars of the vascular bundles, or **bundle scars**.

Table Two. Plant Cell Characteristics, Location and Function

Cell Type	Characteristics	Location	Function
Parenchyma	Shape: polyhedral, or variable Cell Wall: primary or secondary, may be suberized, lignified cutinized Alive at maturity	Throughout plant, in cortex, pith and pith rays, in xylem and phloem	Respiration, digestion, photosynthesis, storage and conduction, healing and regeneration
Collenchyma	Shape: elongate Cell Wall: primary only (non-lignified) Living at maturity	Beneath epidermis in elongating stems, often present in patches or cylinders of tissue, in ribs along veins in some leaves	Support in primary plant body
Fibers	Shape: very long Cell Wall: primary, secondary (lignified) Often dead at maturity	Usually in xylem and phloem, also in monocot leaves	Support and storage
Sclereids	Shape: variable, shorter than fibers Cell Wall: primary, secondary (lignified) May be living or dead at maturity	Throughout plant	Protection, mechanical support
Tracheids	Shape: elongate, tapered Cell Wall: primary and secondary (lignified), pits but no perforations Dead at maturity	Xylem	Primary water conducting elements in gymnosperms, also found in angiosperms
Vessel elements	Shape: elongate, shorter than tracheids. Assembled in end to end groups to create a vessel Dead at maturity	Xylem	Primary water conducting elements in angiosperms
Sieve Cells	Shape: elongate, tapered Cell Wall: mostly primary, callose associated with wall and pores Living at maturity	Phloem	Food-conducting element in gymnosperms
Sieve-tube members	Shape: elongate Cell Wall: primary with sieve areas, sieve areas on end wall with larger pores than side walls Living at maturity	Phloem	Food conducting element in angiosperms
Companion Cells	Shape: variable, elongate Cell Wall: primary Living at maturity	Phloem	Movement of food into and out of sieve tube members

Observe and sketch some of the stem materials present in the lab. Observe the leaf scars under a dissecting scope and look for the vascular bundle scars. (See CR 730)

Observe and sketch an apical meristem shown on the *Coleus* stem tip. All of the cells in the meristem are relatively small, with small vacuoles and large nuclei. Identify the primordial leaves. Beneath the apical meristem are three meristematic tissues. **Protoderm**, the outermost layer, develops from into the epidermis. **Ground meristem**, most of the tissue at the shoot tip, gives rise to pith and cortex in dicots. **Procambium** give rise to the xylem and phloem as the stem matures. (See CR 732)

Observe and sketch the apical meristem in the sectioned cabbage head. At the leaf axils look for undeveloped lateral buds.

Inside the stem, the **lateral meristem** forms the vascular cambium, which develops into new xylem and phloem cells, rising in a cylinder through the stem. Outside the cylinder of the vascular cambium is the **cortex** or bark. Inside the cylinder is the **pith**. As the vascular cambium divides and develops into new vascular tissues, it always develops phloem toward the outside of the stem and xylem towards the inside of the stem. Xylem cells are always larger, and stain a dark red. They are always toward the inside of the vascular bundle. Phloem cells are smaller, and stain a light green. Phloem is always found toward the outside of the vascular bundle. In dicot stems the vascular bundles are neatly as small ovals around the ring of vascular cambium that creates them. In monocots, this vascular cambium is scattered in small strands throughout the pith. The vascular bundles of monocots are scattered throughout the stem, not organized into a ring as they are in dicots.

Observe, sketch and label cross sections of monocot and dicot stems (slides labeled "*Zea mays* Mature stem c.s." and "*Helianthus* stem xs, separate bundles"). Look for the **vascular bundles**, and identify the **xylem** and **phloem**. Can you see the difference between monocot and dicot vascular tissues?

Find the **epidermis, cortex, sclerenchyma** and **pith** in the dicot stem. (See CR 733)

In gymnosperms and dicots that live more than a year (woody plants versus herbaceous plants), last year's phloem is crushed against the bark by the new phloem. Xylem cells grow in a new ring surrounding last year's xylem cells. Old xylem cells are very stiff, and form what we call the "wood" of the plant. In addition, various compounds produced by the plant can be abandoned in this old xylem. These annual patterns form the growth rings seen in the cross section of a cut tree. The broad lighter colored ring is the rapid growth of spring, while the narrow darker colored ring is the slower growth of summer. This type of **secondary growth** results in increased girth. Two lateral meristems are involved in the secondary growth. **Vascular cambium** produces secondary phloem and secondary xylem or the "wood" described above. Cork cambium produces a tough, thickened covering for stems and roots, ultimately called **periderm**. **Bark** is a term that includes secondary phloem, cork cambium, and cork. (See CR 736)

Observe the slide of “*Pelargonium* stem x.s.” and identify the cork and cork cambium layers. Sketch and label the “bark” layers.

Observe the slide of “*Tilia* stems, one two and three yrs and older” and sketch and label the central pith area, primary xylem, secondary xylem (see rings in older stem sections); the vascular cambium between the secondary xylem and phloem; the bark layers; and the radiating xylem and phloem rays.

Hardwood comes from angiosperms, softwood comes from gymnosperms. The difference in the wood of these two groups is associated with the structure of the xylem. In gymnosperms the xylem is composed of tracheids, which are smaller than vessel members found in angiosperms. In addition, tracheids conduct water only through pits in their side walls. In angiosperms, water is conducted through perforated end walls and sides (pits) of the vessel elements (as well as tracheids).

Observe the slides of macerated wood (“ Tilia: macerated wood, w.m.” and “Pinus australis, mac.”) What you are seeing are mostly xylem cells. In gymnosperms you will see exclusively tracheids, in angiosperms you should see both tracheids and vessel elements. Vessel elements are shorter and have thinner walls. (See CR 725)

Observe the section from a whole tree trunk (stem). Sketch the rings and xylem rays. Can you see the heartwood and sapwood. Heart wood is the inner xylem layer; it is nonfunctional. The sapwood is the outer xylem layer.

Stems can be modified in several ways. The **rhizome** is a horizontal stem that spreads the plant. **Stolons**, or runners, are another type of modified stem that are seen in plants such as the strawberry. **Bulbs**, like the onion, are actually a very compressed underground stem. The layers of the onion that we peel back are highly modified leaves. Another type of stem specially modified for food storage is the **tuber**, the best example of this is the potato. **Vines** are another form of modified stem. Vines climb up existing stems, therefore they do not invest heavily in support structures like a rigid stem.

Observe any examples of modified stems found on display in the lab.

Structure of Roots

Roots serve not only to hold the plant in the soil, and take up water and dissolved nutrients, but also as a site to store food for the plant. The main body of the root is called the **primary root**. The **lateral or secondary roots** develop as lateral extensions from the primary root. Along the outer surface of the root are small finger-like extensions called **root hairs**, where water uptake takes place. The epidermis of the root has no waxy cuticle. The outer layer of the root is a thick cortex, used for food storage.

The cylinder of vascular tissue, or **stele**, runs up through the center of the root. It forms a broad “X”. The larger cells of the “X” are the xylem, and the smaller cells between these arms are the phloem. The outer cells of the ring that encloses the vascular bundles are a special tissue called the **endodermis**. The endodermis (inner skin) controls the flow of water into the center of the root where you find the xylem. These cells are bordered on every side but one by a thin waxy strip called the **Casparian strip**. Water and dissolved materials can’t get between or around the endodermal cells. Water must actually pass through them, giving the root a living interface to regulate the influx of water into the plant.

Examine the slide of a buttercup root (“Ranunculus acris, young and mature roots”). Identify and sketch the **stele** and the **vascular bundles**. The large "arms" are made of xylem cells, and the smaller cells nestled between them are phloem cells.

At the tip of the root, we find the other **apical meristem**. This meristem is covered by a tough layer of cells called the **root cap**. Just behind the apical meristem is a zone in which cells are growing longer and larger, the **zone of elongation**. Above this zone is the area of the root where the new cells are starting to differentiate into specialized cells like xylem and phloem. This is the **zone of differentiation**.

Observe a longitudinal section of either Zea or Ranunculus. Sketch one of these. Identify and label the **root cap**, **apical meristem**, **zone of elongation**, and **zone of maturation**. Know the functions of these tissues.

There are several different kinds of roots. Most roots are either tap roots or fibrous roots. **Tap roots**, like those of carrots or dandelions, are huge primary roots with lots of stored food. Plants like grasses and other monocots, on the other hand, have **fibrous roots**, in which no one root dominates the rest. Many plants, like English Ivy and cat’s claw vines, have roots that emerge directly from the stem. Such roots are called **adventitious roots**. A few plants, like corn and mangroves, have **prop roots** (also called buttress roots)that emerge above ground, near the base of the shoot, and help prop up the plant.

Sketch the root system of a monocot and a dicot as displayed in the lab.

Draw a lateral root forming on *Salix* (Willow).

Observe any specialized root systems on display in the lab. In particular, observe the slide of “bean root nodule section”. Rhizobium, a bacterium, present in these nodules, fixes atmospheric nitrogen and makes it available to the plant.

Structure of Leaves

Leaves are structured to make the process of photosynthesis as efficient as possible. Leaves have an upper and lower **epidermis**, covered by a **waxy cuticle**. Both surfaces are have numerous **stomata**, formed by bean-shaped guard cells that regulate the passage of gases and water vapor to and from the leaf. Most of the stomata are found on the underside of the leaf.

Between the upper and lower epidermis is a layer of parenchyma cells that possess chloroplasts. It is in this “mesophyll” or middle leaf layer that most photosynthesis occurs. Below the upper epidermis is a fairly solid layer of rectangular cells called **palisade parenchyma**. Below this is a much more open layer of palisade cells, called **spongy parenchyma**; this layer has air spaces for diffusion of oxygen and carbon dioxide.
All leaves consist of a simple flat **blade** on a stalk. The stalk, or **petiole**, has a swollen, curved base, where it attaches to the stem. This curved base is called the **stipule**. There are several leaf modifications. For example, celery is a modified leaf in which the petiole and stipule are very long and fleshy, with a short leaf on the top. In most leaves, a large **midrib** passes through the center of the leaf, carrying the vascular bundle from the stem out into the tissue of the leaf, sending out numerous side branches, or veins, to reach all parts of the leaf.
Simple leaves consist of a single blade on a single petiole. However, many flowering plants have **compound leaves**, with many leaflets sharing a single petiole. If these leaves are arranged like the fingers on the palm of your hand, we call them **palmately compound**. If they are arranged like the barbs on a feather, or “pinna”, we call them **pinnately compound**. Leaves can also be arranged on the stem in one of three ways: in pairs, **opposite** one another, **alternate** on either side of the stem, or in small tufts called **whorls**. Leaf shape is also regularly described. Oval leaves are called **ovate**. A long thin leaf is **linear**; spear shaped is **lanceolate**. The margins of a leaf may be entire (smooth), serrated, or lobed. The “hand-shaped” maple or sycamore leaf is called palmately lobed.
The veination pattern in leaves is also described by similar terms. The veins may be palmate, branching out from main veins to smaller and smaller veins. Maple leaves are an example. Pinnate veination refers to leaves with small veins emanating from the main vein, or midrib. Oak leaves are pinnately veined. In Gingko leaves, there are no main veins, only small dichotomously branching veins. In Monocots, the veins are all parallel.

Observe, sketch and desribe leaf arrangement, leaf shape, margin, and veination in several the living and fossil leaves on display in the lab.

Sketch a cross section of a monocot and dicot leaf ("Corm Leaf, c.s." and "*Phaseolus vulgaris* leaf c.s."). (See CR 734). Identify, draw and label guard cells, collenchyma, veins, xylem, phloem, cuticle, and epidermal cells. Identify these layers: Upper epidermis, palisade parenchyma, spongy parenchyma, lower epidermis.

Observe modified leaves present in the lab. **Spines** are modified leaves. **Thorns** are modified stems produced in the axil. **Prickles**, seen, on roses, raspberries, and blackberries, are actually modifications of the epidermis and not leaves. **Tendrils** are modified leaves or a leaf and stem that aid in supporting vines. Bulbs, such as onions, are fleshy undergrounds leaves.

Insectivorous plants have leaves modified for trapping insects. These plants are evolutionarily diverse. Pitcher plants trap insects in a modified vase shape-leaf, which is filled with water. Insects fall into the water filled pitcher and drown. Digestive enzymes break down the insect and make its nutrients available to the plant. In Southeast Asia, plants in the genus *Nepenthes* have evolved a large boot shaped pitcher on tendril that extends from the leaf tip. This pitcher is also water filled with digestive enzymes. The *Nepenthes rajah* has a pitcher over 15 cm long and is reputed to capture small rodents! The Venus fly trap, *Dionea muscilupa*, has an active insect trapping mechanism. The two halves of the capture leaf are hinged. If trigger hairs are touched, these two halves close, trapping the insect.

Observe the live *Nepenthes* in lab. Observe the digestive glands present in the cross section of a Venus fly trap leaf ("Dionea muscilupa: x.s. leaf")

Something to remember:
Monocots - one cotyledon (seed leaf), vascular bundles scattered in the pith, flower parts in threes, leaves with parallel venation
Dicots - two cotyledons, vascular bundles in a ring, flower parts in 4's, 5's, or multiples, leaves with net venation