

Vascular Plant Morphology Laboratory 1

Internal Anatomy and Organization of the Plant body

Plant sporophytes are constructed of **cells** that are organized in to units of a common function (not necessarily common structure) that are termed **tissues**, and tissues are arranged into **organs**; the principal units of the sporophyte body. Some tissues are interconnected throughout the sporophyte to make up **tissue systems**. The three basic types of mature cells are **parenchyma**, **collenchyma** and **sclerenchyma**. Immature cells and tissues are referred to as **meristematic**, and they are found in regions of growth that are termed **meristems**. The three basic types of mature tissues are **dermal** (i.e., epidermis), **vascular** (i.e., xylem and phloem), and **ground** (i.e., everything else, including cortex of stems and roots, pith of stems, and mesophyll of leaves).

The basic organs of most vascular plant sporophytes are **stems**, **leaves**, **roots**, and **sporangia**. However, as was explained in class, the simplest and most ancient vascular plants do not have their vegetative organs differentiated into stems, leaves and roots. Such plants have only **axes** above and below ground, and these axes bear sporangia in positions that are distinct for each group.

Refer to your lecture notes and to a basic botany text book if you are not comfortable with these basic concepts of plant anatomy. We recommend that you bring a copy of a basic botany text book along with Gifford and Foster to each laboratory to help you become acquainted with the features of each group of plants. The following exercises are designed to refresh your memory about the basic features of plant anatomy, and to allow you to be confident that you are "up to speed" on the features that we will be using to compare and contrast major groups of plants throughout this quarter. Look over what follows, and use the following material as needed to be prepared.

CELLS AND TISSUES

Plant cells may assume numerous morphological and physiological forms. In addition, they may occur in organized masses called tissues. **Simple tissues** (parenchyma, collenchyma, and sclerenchyma) are composed of a single cell type, whereas **complex tissues** (epidermis, xylem, and phloem) **are made of more than one cell type**. Refer to the illustrations and photographs within your text while observing each of the cell and tissue types in this lab.

Cells and Simple Tissues - (parenchyma, collenchyma, and sclerenchyma)

1. Parenchyma are morphologically simple (usually isodiametric), physiologically complex, cells that are **living** at maturity. The functions of parenchyma are varied, and include: storage, metabolism, and support (via turgor pressure). Parenchyma are unique among mature cell types in their capacity to de-differentiate and redifferentiate into other cell types. Parenchyma cells may occur within complex tissues (see below), or in masses, in which case it is also a simple tissue. Most of the cells/tissue in a herbaceous plant are parenchyma. Observe a prepared slide of a *Cucurbita* stem. Identify the epidermis ("skin"), vascular bundles, cortex, and pith. Identify parenchyma (thin walled cells with large vacuoles (membrane

bound organelles used for storage and osmo-regulation) in the cortex and pith. Be sure you can identify parenchyma in both longitudinal and transverse (cross-sectional) views. Diagram a parenchymal cell including primary cell wall (sclerenchymal cells possess a secondary cell wall in addition to the primary cell wall), plasmalemma, nucleus, and vacuole. What is turgor pressure?

2. Collenchyma cells are also living at maturity, and always occur in the outer layers of the cortex, immediately below the epidermis. Collenchyma are elongated cells (parallel to the axis of the stem), and can be identified by their unevenly thickened primary cell walls. Collenchyma always occurs as a simple tissue, never as part of a complex tissue. The function of collenchyma is primarily to provide support to non-woody parts of a stem, particularly young stems that are still elongating (this will become more clear when we study primary and secondary growth). Make cross-sections of celery stalks, stain them with saffranin and make wet mounts. Identify the cell walls and lumens (the area contained within a cell wall) of individual collenchyma cells with the strands of collenchyma. Now, identify collenchyma in transverse and longitudinal view in a prepared slide of a *Cucurbita* stem. Diagram longitudinal and transverse views of collenchyma.

3. Sclerenchyma cells are dead at maturity, possess lignified secondary cell walls, and assume many different forms and functions.

1. **Sclereids:** Sclereids are blunt sclerenchyma cells. Their function is usually to provide protection (e.g. the integument of a seed coat is composed of sclereids). Cut a sliver of flesh from a *Pyrus* fruit, finely chop the flesh and gently crush it with a cover slip (to disrupt the clusters of sclereids), remove the cover slip (momentarily) to stain it with phloroglucinol, and make a wet mount. Observe the brachysclereids. Brachysclereids possess pit canals that are formed within the secondary cell wall. Identify the primary cell wall, secondary cell wall, pit canals, and lumen of a brachysclereid. Diagram a brachysclereid including each feature.

- A) Is a secondary cell wall to the outside or inside of a primary cell wall?
- B) What does lignified mean?

2. **Fibers:** Fibers are elongated sclerenchyma cells. Their function is to provide support to parts that are no longer elongating. Identify sclereids in macerated *Quercus* wood, then identify the fibers that cap the vascular bundles in the prepared slide of *Ranunculus* stem. Diagram a fiber.

3. Other Cells that are often classified as sclerenchyma include tracheids and vessel tube elements, because they are dead at maturity and possess lignified secondary walls. These cell types will be covered under the complex tissue Xylem, where they normally occur.

Complex Tissues -

1. Xylem: The function of xylem is the conduction of water and minerals (absorbed by the roots) throughout the plant body. Xylem is composed of both sclerenchyma (i.e. fibers) and parenchyma, as well as cells unique to xylem, tracheids and vessel tube elements. Because both tracheids and vessel tube elements are dead at maturity and possess secondary cell walls, they are considered by many botanists to be highly specialized types of sclerenchyma. These are:

A. **Tracheids** are usually elongated cells, and are characterized by their possession of bordered pits. Refer to your text for a detailed illustration of a bordered pit and an explanation of its function. Bordered pits are areas where secondary cell wall is interrupted and the primary cell wall is thinned, facilitating the passage of water. The union of bordered pits from two adjacent tracheids is called a pit pair. Observe a prepared slide of macerated *Pinus* wood and identify tracheids and their bordered pits. Now observe a prepared slide of a transverse view of *Pinus* wood on demonstration. Identify two adjacent tracheids and their pit pair. Diagram a tracheid and include bordered pits. Is a bordered pit a hole completely through both cell walls?

B. **Vessel Elements** (VE) are invariably the largest cells in a plant. VE's form tubes that run throughout the plant. VE's are characterized by their generally short length and open end wall, called a perforation plate, where the next VE will occur. Identify a VE (from an entire vessel) and its perforation plates in a prepared slide of a longitudinal view of a *Cucurbita* stem. Identify a VE in transverse section (you will not see the perforation plates in this view). Diagram a VE, including the simple pits on the side walls and the perforation plates. Is a perforation plate a hole completely through both cell walls?

2. Phloem: The function of phloem is the conduction of photosynthates and metabolites throughout the plant body. Phloem is composed of parenchyma, sclerenchyma (i.e. fibers), and specialized cells called sieve tube elements and companion cells (both of which are living at maturity). Use your text for reference while looking at phloem.

A. **Sieve Tube Elements** (SE) are specialized for the conduction of photosynthates and metabolites. They are characteristically narrow, elongate cells with flat, perforated, end walls (called sieve plates). When SE's are injured, a proteinaceous plug is formed around the sieve plate (called a sieve plug or slime plug) which impedes movement of pathogens (bacteria or virus). Identify SE's in transverse and longitudinal sections of *Cucurbita* stem.

B. **Companion Cells:** Companion cells are very narrow cells that control protein synthesis for SE's (which lack nuclei). Each SE has a single companion cell. Identify a companion cell adjacent to a SE in both transverse and longitudinal sections of a *Cucurbita* stem. Diagram a SE and its companion cell in transverse and longitudinal views.

3. Identify the fibers that cap the phloem in both transverse and longitudinal sections of a *Cucurbita* stem.

PRIMARY ROOTS

Primary growth is defined as the development of mature tissues from an apical meristem. In this lab you will be looking at the development and organization of mature root tissues from the root apical meristem. Meristematic tissues are undifferentiated, mitotically active cells that produce "daughter" cells. Daughter cells differentiate into mature cells and tissues. Refer to the discussions and illustrations within your text for each topic.

1. Observe a prepared slide of a longitudinal view of a young *Salix* root. Identify the root apical meristem and root cap.

- A) What is the function of an apical meristem?
- B) What is/are the function(s) of a root cap?

2. Primary meristems consist of meristematic cells that are predestined to differentiate into specific tissues. Protoderm develops into epidermis, procambium develops into vascular tissues (xylem and phloem), and ground meristem develops into the tissue that compose the cortex and pith. Next, identify the three primary meristems: 1) protoderm, 2) procambium, and 3) ground meristem in the same slide as above. Note the enlarged, darkly stained nuclei, an indicator of mitotic activity.

3. Three basic zones of development occur in a developing root (and shoot): 1) the zone of cellular division includes the apical meristem and the early stages of primary meristems, 2) the zone of elongation includes most of the primary meristematic tissues, and 3) the zone of maturation includes the latter stages of primary meristematic tissues and mature tissues themselves. Note that plant growth is the combined result of cell division and enlargement. Identify each of these zones in your slide, as well as root hairs. Note that root hairs arise in the zone of elongation and reach their full size in the zone of maturation. Their function is to increase the surface area of the epidermis which facilitates water and mineral absorption.

4. Obtain slides of transverse sections of mature *Salix* (willow). Look at the *Salix* root first. Identify the epidermis, cortex, and vascular cylinder. The innermost layer of the cortex is a highly modified ring of cells called the endodermis. Each endodermal cell has a ring of water resistant material (suberin) called the casperian strip. Identify the endodermis, which is characterized by thickened, lignified cell walls, in the *Salix* root. Locate the casperian strip of an endodermal cell, which will appear as red dots on both anticlinal (perpendicular to the epidermis) cell walls.

- A) What is the function of the endodermis?
- B) What primary meristem gave rise to the endodermis?
- C) To what phase of the life cycle does the endodermis belong?

5. Identify xylem on the same slide. Note that the xylem is star shaped in transverse section, and that the smallest cells are at the tips of the "star". These smaller cells are called protoxylem, indicating they were the first xylary cells to mature. The cells in the center are called metaxylem, indicating that they were the last to mature.

- A) What primary meristem gave rise to xylem?
- B) Why would you expect protoxylem to be smaller than metaxylem?

6. Identify the phloem, which occurs in outer the "pockets" of the xylem. SE's, companion cells, protophloem, and metaphloem are very difficult to identify in young roots. Note that there is less phloem than xylem. Locate the band of cells that separate the xylem from the phloem. This band is called the residual procambium. The residual procambium will be eventual source of wood as we will see in a later lab. Only dicot roots possess residual procambium. Be aware that some introductory texts loosely refer to residual procambium as vascular cambium. What is the ploidy of phloem? Why?

7. Repeat 4-8 using a prepared slide of a *Zea* (corn) root. Note that *Zea* is a monocot. Monocot roots can be distinguished from dicot roots by their possession of a pith and lack of a residual procambium..

8. Observe the prepared slides of non-branching and branching *Salix* roots on demonstration. In a non-branching root, identify the pericycle, a layer of cells immediately outside of the phloem and inside of the endodermis. The pericycle produces branch roots. Observe the branching *Salix* root, and note its internal origin. Eventually a branch root will emerge through the epidermis. Monocot roots branch in the same fashion.

PRIMARY SHOOTS

Primary Growth and Development -

1. Examine the shoot system of a mature plant. Identify the shoot tip, nodes, internodes, leaves, and axillary buds. Note that axillary buds always occur above a leaf. Axillary buds give rise to branch shoots. Thus, branching in a shoot system is exogenous (of external origin). How does this compare to branching in a root system?

2. Examine a longitudinal section through a *Coleus* stem tip. Identify the apical meristem, leaf primordia (developing leaf), bud primordia (developing axillary buds), nodes, and internodes. Beginning with the apical meristem, follow the development of shoot tissues. Identify protoderm, procambium, and ground meristem, pith, and cortex.

A) You will not be able to identify any mature cells or tissues in this slide (keep in mind the size of the shoot tip). What are the mature tissues that each of these primary meristems become?

B) Can you find a node (where procambium diverges in to the leaf primordium)? These areas are also commonly called "leaf gaps". However, because seed plants have eusteles instead of siphonosteles they are not the same as leaf gaps in ferns. Do you understand the differences? If not, ask.

3. Examine mature plants on demonstration. Marks were made at regular intervals along the length of the stem. Based on the present distances between marks, which part of the stem elongated?

4. Examine a transverse section through a monocot (*Zea*) stem. Identify the epidermis and vascular bundles. Note that the vascular bundles do not form a single, discrete ring. Identify the bundle sheaths, composed of fibers, that surround each vascular bundle. Now identify the sieve tube members and companion cells of the primary phloem, and the vessel members of the proto- and metaxylem (primary xylem).

5. Examine a transverse section through a dicot (*Medicago*) stem. Identify the epidermis, cortex, pith, and vascular bundles. Within a vascular bundle, identify the phloem, phloem fibers, primary xylem, and procambium. Note that the procambium forms a complete ring throughout the stem. Procambium within a vascular bundle separates the primary xylem and phloem, and is therefore called intrafascicular ("within a fascicle) procambium, whereas procambium between bundles is called interfascicular ("between fascicles") procambium. The regions between the vascular bundles, composed of parenchyma and interfascicular procambium are called pith rays. Did the *Zea* (monocot) stem possess residual procambium?

SECONDARY GROWTH:

In general, secondary growth (lateral growth) is accomplished by the activity of two meristmatic tissues, the **vascular cambium** and the **cork cambium**. Vascular cambium produces **secondary xylem** (inwardly) and **secondary phloem** (outwardly). Secondary xylem is also called wood. The additional production of secondary xylem and phloem is needed to supply the ever growing portions of the shoot or root. Vascular cambium is produced by residual procambium in shoots, and by residual procambium and pericycle in roots.

Cork cambium (or **phellogen**) produces cork (**phellem**) and cork skin (**phelloderm**). Together, all three layers are called the **periderm**. Cork protects the shoot and root as the epidermis is destroyed by secondary growth. Cork is occasionally interrupted by spongy areas known as **lenticels** which aid in gaseous exchange. The development of cork cambium is more complicated. In shoots, cork cambium is initially produced by the cortex and later by secondary phloem (this will become apparent later). In roots, cork cambium is initially produced by the pericycle and later by secondary phloem.

Most monocots do not possess secondary growth. However, some, like palms, produced new vascular bundles and ground tissue, but not wood. The distinguishing feature of secondary growth in dicots is the lateral production of cells in discrete rows.

1. Obtain a prepared slide of transverse section of a woody dicot stem. Identify the pith. Working outwardly, identify the primary xylem, secondary xylem, vascular cambium, secondary phloem, primary phloem, cortex, phellogen, and phellem and lenticel(s) (The phelloderm is very difficult to identify. It is a non-discript layer of cells immediately below the phellogen).

- A) Why is the secondary xylem and phloem always to either side of the vascular cambium?
- B) Is the primary xylem pushed inwardly by the secondary tissues?

2. On the same slide, identify the growth rings within the secondary xylem. They are the result of differential growth rates usually associated with seasons. **Early season (spring) wood** is composed of larger vessel members, whereas **late season wood (summer) wood** is composed of smaller vessel members, and terminate as a dark ring. To determine the age of the stem on your slide, count the number of rings. Identify the **xylary** and **phloem rays**. These are sheets of cells (parenchyma and sometimes tracheids) that are oriented laterally, and are a system for the lateral conduction of water, minerals, and metabolites. Observe transverse, tangential, and radial sections of a *Pinus* stem on demonstration. Identify the xylary rays in each section. Why is lateral conduction necessary?

3. Observe the sectioned palm trunk on demonstration. Note that secondary growth in this monocot does not produce wood. Identify the vascular bundles and ground tissue.

4. Observe transverse slides of primary and secondary dicot roots on demonstration. From what tissues does the vascular cambium and cork cambium arise? How can you tell primary and secondary roots and shoots apart? Make a diagram (quick sketch) of each to help.

THE LEAF

1. Identify the **petiole** and **lamina** (blade) of **simple**, **palmately compound**, and **pinnately compound** leaves on demonstration. Now identify leaves with **netted** versus **parallel** venations. Identify the midvein of leaves with non-parallel venation (it is very difficult to determine the precise pattern of non-parallel venation from a slide).

2. Examine a prepared slide of a *Syringia* leaf, adapted to moist habitats. Identify the xylem and phloem of the midvein and lateral veins. Now identify upper and lower epidermis, **cuticle** and **stomata**.

- A) What is the function of stomata?
- B) What is the cuticle composed of, and what is its function?
- C) On which side of the leaf do stomata occur? Why?

Now identify the **palisade** and **spongy mesophyll**, and the **stomatal chambers**. What are the primary functions of each type of mesophyll?

3. Make an epidermal peel of a number of leaves. Identify the epidermis, **trichomes**, and **stomatal complex** (i.e. **guard cells**, **stoma**, and **subsidiary cells**). Note the unevenly thickened cell walls of the guard cells.

4. Now repeat #2 with a prepared slide of a *Nerium* leaf; a leaf adapted to dry habitats. *Nerium* possesses a thickened upper epidermis and cuticle, and stomata sunken in "**stomatal crypts**" (depressions in which stomata occur). What do you think is the purpose of sunken stomata?

5. Now repeat #2 with a prepared slide of a *Nymphaea* leaf; a leaf adapted to aqueous habitats. Note the thin epidermis and cuticle, branched sclereids, and large air spaces in the spongy mesophyll. Why do you think the air spaces are so large?

6. Now repeat #2 with a prepared slide of a *Zea* leaf. Note the numerous vascular bundles, surrounded by a bundle sheath, and the stomata on both upper and lower sides of the epidermis. What type of leaf venation does *Zea* possess?

7. Now repeat # 2 with a prepared slide of a *Pinus* leaf. Note the sunken stomata, **resin ducts**, and endodermis. **Transfusion tissue** (a tissue composed of laterally oriented parenchyma and tracheids) occurs between the vascular bundles and the endodermis. To what type of environment do you think *Pinus* leaves are adapted?

8. Observe the prepared slide of an abscising leaf on demonstration. Identify the **separation layer**, where the leaf will break off, and the **abscission zone**, where a protective wall of tissue has been built in the stem. What are the functions of these two features?

9. Observe the modified leaves on demonstration. Identify **bud scales** (leaves modified for the protection of over-wintering buds), **spines** (leaves reduced to sharp, pointed, structures. Usually, stipules are the part of the leaf that have been modified into spines), **tendrils** (leaves modified into clasping structures), and **insectivorous leaves**.

MODIFIED ORGANS

1. Observe the modified stems on demonstration. Identify node and leaf in each of the following:
 - A) **Rhizomes**: Horizontal stems that grow below or on the surface of the soil.
 - B) **Stolons** (runners): Horizontal stems that grow on the soil surface that produce new plants at nodes.
 - C) **Tubers**: Enlarged rhizomes specialized in food storage.
 - D) **Bulbs**: Short, erect stems with fleshy leaves specialized for food storage.
 - E) **Corms**: Short, erect stems with papery leaves.
 - F) **Tendrils**: Aerial stems specialized for "grasping" and climbing.
 - G) **Thorns**: Short, sharp, determinate, branches.
 - H) **Cladophylls**: Stems that are flattened and resemble leaves.

6. Examine the woody twigs on demonstration. Identify the **terminal bud** ensheathed in **terminal bud scales** (protective leaves that are produced every fall). Moving down the stem, identify nodes, lenticels, axillary buds, **leaf scars** and their **bundle scars**, and **terminal bud scale scars**. Counting back from the terminal bud, find the 1998 and 1997 terminal bud scale scars.