Vascular Plant Anatomy

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Recommended Citation
http://scholarexchange.furman.edu/bio-publications/8
INTRODUCTION:

Plants are eukaryotes. Eukaryotes have cells that contain membrane bound organelles and nuclei. Plant cells can be distinguished from animal cells in that many of the leaf and stem cells contain chloroplasts where chlorophyll uses solar energy to convert water and carbon dioxide into sugars and carbohydrates. The following exercises will help you review the structures found in plant cells.

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"#3" is found in eukaryotic cells. It contains the chromosomes which contain the plant’s genetic material. "#3's" two primary functions are: (1) control of (2) store genetic information. "#3" was first discovered by Scottish Botanist Robert Brown in 1831 while microscopically studying orchids. Brown named the opaque area in epidermal cells the areola now labeled "D"

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"n" is a double membrane. The outer membrane is continuous with the rough endoplasmic reticulum (ER) with its attached ribosomes. The space between the outer and inner membranes is also continuous with rough endoplasmic reticulum space. This space can fill with newly synthesized proteins similarly to the rough endoplasmic reticulum.

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"m" are the sites where the inner and outer membranes of "n" are joined. They allow passage of materials into and out of "#3"

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"o" is a "sub-organelle" of "#3". "o's" function is the production and assembly of ribosomes. No membrane separates "o" from the nucleoplasm.

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"p" are composed of RNA and proteins and function to translate messenger RNA (mRNA) into polypeptides (proteins). "p" can float freely in the cytoplasm (internal fluid of the cell) or bind to "l". "p" are not bound by a membrane and therefore are not considered organelles.

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"l" is part of the endomembrane system. "l" modifies proteins, makes macromolecules, and aids transfer of substances throughout the cell. The structure and composition of "l" is similar to the plasma membrane, although it is actually an extension of "n". "l" is the site of translation, folding, and transport of proteins.

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"q" has functions in several metabolic processes, including synthesis of lipids, metabolism of carbohydrates, and detoxification of drugs and poisons.

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The primary function of "s" is to process and package macromolecules, such as proteins and lipids, after their synthesis and before they make their way to their destination. "s" is particularly important in the processing of proteins for secretion. This apparatus forms a part of the endomembrane system.

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"h" is the location of cellular respiration, in particularity the Citric Acid Cycle and Electron Transport Chain by which ATP is formed. They are composed of a double membrane system. The inner membrane is folded into cristae. The space between the inner and outer membranes is the location of the proton gradient used to make ATP.

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"t" help maintain cellular structure. This is a dynamic structure that maintains cell shape, enables some cell motion (using structures such as flagella and cilia), and plays important roles in both intra-cellular transport (the movement of vesicles and organelles, for example) and cellular division.

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“#1” is an organelle found in plant cells and eukaryotic algae that conduct photosynthesis.

“#1” captures light energy from the sun to produce the free energy stored in ATP and NADPH through a process called photosynthesis.

e” are “grains” produced during the process of photosynthesis. They can be made visible by potassium iodide.

“b” is a selectively permeable membrane comprising the outer layer of the cell. It consists of phospholipid and protein molecules that separate the cell interior from its surroundings. “b” controls movement into and out of cell through the use of receptors and cell adhesion proteins. These receptors and proteins play a role in cell behavior and organization of cells in tissues.

c” surrounds the cell in bacteria, archaea, fungi, plants, and algae. “c” can be removed using degrading enzymes. When “c” is removed the term protoplast is used to describe the cell and its surrounding plasma membrane. “c”’s main purpose is to protect the cell.

“#2” are membrane-bounded compartments within some eukaryotic cells that can serve a variety of secretory, excretory, and storage functions. Their contents are distinct from the cytoplasm. “#2” are especially conspicuous in most plant cells that have a single central one which often takes up more than 80% of the cell interior. It is surrounded by a membrane called the tonoplast.

PLANT CELL TYPES
Vascular plant contain four basic cell types: parenchyma, collenchyma, sclerenchyma, and vascular.

Parenchyma. Parenchyma constitute ~80% of all plant cells. (Hint: if you must identify a cell type under the microscope, choose parenchymal). Parenchyma can be found throughout the plant body (e.g., in stems, middle of leaves, roots, flesh of a fruit) where they will have different functions. Parenchyma cells have thin (primary) cell walls, are capable of dividing, and play a major role in storage, photosynthesis, secretion, and wound healing.

Cell walls are located outside the plasma membrane. They are formed from materials delivered to the outside of the cell through the process of exocytosis. During cytokinesis the middle lamella is laid down first after which the primary cell wall is then formed. Some cells will form thicker secondary walls. Communication can occur through the plasmodesmata that link the cytoplasm of adjacent cells through openings (pits) in the cell walls.

Exercise 1: Use a razor blade to make a very thin section of a potato stem (tuber) and place it on a clean microscope slide. Add a drop of water to the thin section and cover it with a cover slip. Examine the thin section under the microscope beginning with low power. The cells you see are parenchyma. Notice grayish blobs within each cell that look something like water droplets. Add a drop of iodine to one side of the cover slip and at the same time use a paper towel to absorb the excess water at the other side of the cover slip. Note the rather sudden color change that occurs to these grayish blobs.

Study Questions #1:
What characterizes parenchyma cells? (Hint: describe the cell walls).

What are the objects that were stained with the iodine? (Hint: why do we eat potatoes?)

Are these particular parenchyma cells involved in photosynthesis, storage or secretion?
**Collenchyma.** Have you ever experienced the stringy material in a stalk of celery? Those elastic strings are composed of collenchyma cells. Collenchyma cells allow plants to bend but not break while giving the plant strength. The name “colla” in Greek means “glue”. The elastic nature of these cells is due to their unevenly-thickened (primary) cell walls.

**Exercise 2:** Examine a prepared slide of the poisonous plant, *Ricinus* (Castor Bean) beginning with low power. Look just below the epidermis until you see the collenchyma cells. The collenchyma cells will have irregularly-thickened cell walls that will often form a diamond like pattern.

**Study Questions 2:** From the plant’s standpoint, do you believe that collenchyma cells contain chloroplasts for photosynthesis in addition to their elastic role? Why or why not? Think about the stems in many herbaceous (non-woody plants).

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**Sclerenchyma.** “Skleros” in Greek means “hard”. Sclerenchyma cells (or sclerids for short) are VERY hard, relative to their size. Plants use sclerids in specific places where strength is critical. The sclerids strength comes from the thickened secondary walls that are more rigid than primary walls. Plant fibers are a type of sclerid that are usually found in stems and are extremely long and thin. Other sclerids are blunt resembling miniature diamonds.

**Sclerids – Exercise 3:** Use a razor blade to make a thin section of the flesh of a pear. Mount the thin section on a microscope slide with a drop of water followed by a cover slip. Using the low power, find a section of the tissue that has a cluster of sclerenchyma cells. This may look like a cluster of diamond or irregularly shaped cells. Use the diaphragm on the microscope to reduce the light which will result in more contrast making the sclerids easier to see. Sclerids consist mostly of secondary walls and very little cytoplasm. You might be able to see tiny holes or pits in the walls. Sclerids account for the grit that you encounter when you eat pears.

**Study Question 3:** What might be the purpose of these thick walled cells within the tissue of the pear?
**Fibers – Exercise 4:** Obtain a prepared slide of wood. Under low power, look for the long, thin, thick walled cells. These are a second form of sclerenchyma called fibers. Like the sclerids the fibers have thick secondary cell walls.

**Study Question 4:**

In what type of plant might you find fibers?

What would be the purpose of these fiber cells?

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**Vascular Tissues: Xylem and Phloem**

**Xylem:** The term xylem is Greek for “wood”. Indeed wood building material is the xylem from trees. There are two forms of xylem tissue: Tracheids and Vessels.

<table>
<thead>
<tr>
<th>Tracheids</th>
<th>Vessels</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="Tracheid" /></td>
<td><img src="image2.png" alt="Vessel" /></td>
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<table>
<thead>
<tr>
<th>Feature</th>
<th>Tracheids</th>
<th>Vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main conducting cell of pteridophytes (ferns) and gymnosperms</td>
<td>Main conducting cells of angiosperms</td>
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<tr>
<td>Tracheids are single long cells that overlap at their ends.</td>
<td>Individual vessel elements are joined into long continuous tubes that originate from longitudinal files of cells.</td>
<td></td>
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<tr>
<td>Narrow diameter</td>
<td>Wide diameter</td>
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<tr>
<td>Large pits which are less in number</td>
<td>Small pits that are greater in number.</td>
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<tr>
<td>End walls are not perforated</td>
<td>Perforated end walls</td>
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<tr>
<td>Less efficient in water conduction due to absence of perforated end walls.</td>
<td>More efficient in water conduction due to open end walls.</td>
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<tr>
<td>Cell walls are more thickened with a narrow lumen</td>
<td>Wall are less thickened with a large lumen</td>
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Xylem transports water, inorganic ions, and organic substances from the plant roots up through the plant. This transport does not require the input of energy by the xylem cells which are dead at maturity. Xylem transport occurs through by the Transpiration-Cohesion-Tension Theory.

**Xylem - Exercise 5:** Examine the diagram above. Describe in your own words how water is able to move through a plant. Some concepts to keep in mind: (1) water moves from a High Water Potential (low negative MegaPascals MPa) to a Low Water Potential (high negative MegaPascals MPa) down a concentration gradient, (2) water has both high cohesion and adhesion properties, (3) transpiration is the evaporation of water from the leaves of a plant.

How does the anatomy of xylem cells aid in their function of carrying water through the plant?
Phloem is a word derived from Greek that means “bark”, which is an indication to where it is located in a tree. Unlike xylem (which is composed of dead cells at maturity), the phloem is alive at maturity and carries organic nutrients, particularly sucrose, to all parts of the plant. Phloem tissue consists of sieve-tube elements and companion cells. The sieve-tube elements lack nuclei, have very few vacuoles, but contain other organelles such as ribosomes. Sieve-tube members are joined end to end to form a tube that conducts food materials throughout the plant. The end walls of these cells have many small pores and are called sieve plates and have enlarged plasmodesmata. Sieve-tube elements depend on the companion cells which are connected to the sieve-tube elements by plasmodesmata and carry out all of the cellular functions for the sieve-tube element.

The Pressure Flow Hypothesis was proposed by Ernst Munch in 1930 to explain the mechanism of phloem translocation. While movement of water and minerals through the xylem is driven by negative pressures (tension), movement through the phloem is driven by positive hydrostatic pressures. This positive hydrostatic pressure flow (also called bulk flow) is the process of translocation. Pressure flow is accomplished by phloem loading and unloading of sugars. Cells at a sugar source (like a leaf) "load" the sieve-tube elements by actively transporting solute molecules into the cell. This causes water to move from the xylem into the sieve-tube element by osmosis, creating pressure that pushes the sap down the phloem tissue. In sugar sinks, cells actively transport solutes out of the sieve-tube elements, producing the opposite effect.

Organic molecules such as sugars, amino acids, certain hormones, and even messenger RNAs are transported in the phloem through sieve tube elements. A sugar source is any part of the plant that is producing or releasing sugar. During the spring, storage organs such as the roots are sugar sources, and the plant's many growing areas are sugar sinks. During times of active photosynthesis the leaves are the sugar sources and the roots or developing flowers and fruits are the sinks. This means that the flow of phloem sap
can change directions during the year. This does not occur in xylem cells which display unidirectional (upward) flow.

**Phloem - Exercise 6:** Locate the position of phloem on the cross section of the tree trunk.

**Study Question 6:**
Why must phloem cells be alive at maturity?

Why do Beavers just eat the outside bark of a tree?

**PLANT ORGANS**

Plants can grow two ways: up (shoots) and down (roots) that occurs from the **primary growth** of meristems, or out due to the increase in girth that occurs from **secondary growth** of cambiums. During a plant’s early life, growth is generally up and down and is accomplished by **meristems**. Some plants like dicots or woody/herbaceous flowering plants but not monocots or non-woody plants, have the ability to grow in diameter with the help of two additional meristems (**cork cambium** and **vascular cambium**).

**Study Question 7:** Why would it be important for plants to be able to grow both up and down and in girth?

**Shoot Development**

**Exercise 7:** Examine a prepared slide of a **Coleus** stem in longitudinal section (a cut made from top to bottom). It should look something like Batman with big pointed ears.

**Study Question 7:** Label the drawing below from the **Coleus** structures you observe under the microscope. Label the (1) apical bud, (2) lateral buds, (3) vascular tissue, (4) leaf primordia

![Coleus Stem Tip](commons.wikimedia.org/wiki/File:Coleus_stemtip.jpg)

Which type of growth tissue is illustrated here? Meristem or Cambium?

In which direction will this tissue cause the plant to grow?
Stems

There are two main types of plants: monocotyledons and dicotyledons (see the last section of this laboratory exercise). These two types of plants have different stems.

**Herbaceous Dicot Stem of a Sunflower (Helianthus)**

*Exercise 8:* Examine a prepared slide of a *Helianthus* stem in cross section under lower power. Look for the rounded structures that seem to circle the outer edge of the stem. Using medium power on the microscope zoom in on one of these rounded structures. Make two drawings of the *Helianthus* stem, one under the low power and one under the higher power. The corn stem can increase in girth because of the vascular cambium that lies between the xylem and phloem cells within the stem.

*Study Question 8:* Label drawing of the *Helianthus* stem with the following terms Xylem, Phloem, Vascular Cambium, Pith, and Epidermis. Also label the group of fibers that are protecting the top of the vascular bundle. Draw a circle around the vascular bundle.

![Image of Helianthus stem](image)

**Herbaceous Monocot Stem of Corn (Zea)**

*Exercise 9:* Examine a prepared slide of a corn stem in cross section at low power. Do you see the vascular bundles that look like monkey faces? Monocots typically do not add tissue to their girth, because they do not have a vascular cambium between the xylem and phloem.

*Study Question 9:* Label the drawing of the *Zea* stem cross section below with the following terms, Xylem, Phloem, Epidermis, and Bundle Cap (the fibers that protect the vascular bundle). Circle the Vascular Bundle.

![Image of Zea stem](image)

What differences do you see between the monocot and the dicot stems? What tissue is present in the dicot that is not in the monocot stem? How does this affect the increase in girth of the plant?
LEAVES

Leaves are solar receptors flattened to absorb as much sunlight as possible. Unfortunately this configuration (high surface area to small volume), also causes plants to lose large amounts of water through transpiration. Because of this dilemma, leaves have adaptations to maximize photosynthesis and reduce water loss.

Leaves may have a cuticle, a thin waxy layer particularly on the upper surface of leaves that reduces water loss. Stomata are small pores usually found on the underneath side of the leaf that allow plants to do gas exchange, giving up oxygen from photosynthesis while taking in carbon dioxide for cellular respiration. Stomata aid in the reduction of water loss by regulating the size of the pore opening (the stoma). Stoma opening is controlled by special epidermal cells called guard cells and their associated subsidiary cells.

Leaves may also have trichomes that help protect the plant from water loss by acting as baffles to reduce evaporation. Trichomes sometimes also inhibit insect herbivory by producing special antiherbivory chemical. For example, marijuana plant trichomes are the source of THC, the chemical responsible for its pharmacological effect. THC droplets form on trichomes and stick to harmful insects causing their death.

Exercise 10: Obtain a leaf from the Spider Plant (Tradescantia). Carefully peel the outer skin from the bottom side of the leaf using your fingernails. Place the epidermis on a microscope slide with a drop of water, add a cover slip. Examine the epidermis first under low power and then under medium power. Find the stomatal apparatus and identify the guard cell and its neighbor, the subsidiary cell.

Study Question 10: Label the diagram below with the following terms. Guard cell, subsidiary cell, epidermal cell, and stoma (the pore). Circle the stomatal apparatus. Notice the trichomes (hairs) on the leaf surface.

Tradescantia lower epidermis showing stomata. (A) low power, (B) high power

Which cells contain the chloroplasts? ________________________________

When photosynthesis occurs the guard cells have the energy to actively pump potassium from the subsidiary cells into the guard cells. Water follows the potassium causing the stoma to open. This is because each sausage-shaped cell bends away from one another with the increasing water (turgor) pressure due to an uneven layer of cell wall around the stoma.

What happens when stomata close?
Exercise 11: Examine the prepared slides of *Ligustrum* (a dicot) and *Zea* (a monocot). Notice that one of the typical characteristics of a monocot are the parallel veins in the leaves.

*Study Question 11:* Examine a prepared slide *Ligustrum* (dicot) leaf under lower power. Label the drawing above with the Epidermis, Vascular Bundle with Xylem & Phloem, Palisade Parenchyma, Spongy Parenchyma, and Stomatal Apparatus with the Guard Cells and Stoma.

*Study Question 12:* Examine a prepared slide of a *Zea* leaf (moncot) under lower power. Label the drawing Upper and Lower Epidermis, Vascular Bundle with Xylem & Phloem, Bundle Sheath, and Stomatal Apparatus with the Guard Cells and Stoma.

Why are the mesophylls (middle of the leaves) different between monocots and dicots?
ROOTS
Roots serve two primary purposes: to absorb water and nutrients from soil, and to store food (starch) from photosynthesis.

*Study Question 13:* Obtain a prepared slide of a *Ranunculus* root in cross section. Look for the following structures, then label the drawing below. The root is surrounded by the epidermis. The stele in a dicot contains the vascular system in and is found in the center of the root. The xylem will be the large cells in the center that form a cross shape while the phloem is found between the arms of the xylem. The cortex is the outer storage portion of the root. The inner most layer of cells of the cortex is the endodermis. Just inside (toward the stele) is a layer of cells called the pericycle.

Use the web to find out what the pericycle is and why it is important.

Use the web to find out what important cellular structure is contained on the lateral and transverse walls of the endodermis. What does this structure help the root do?