Plant Cells, Tissues and Meristems

Figure 1. Plant stem cross-sections depicting various tissue and cell types.

A. Introduction to Plant Cells

Cells are the structural and functional units of living organisms. The plant cell has essentially everything that an animal cell does AND MORE.

Namely, plants are distinguished by their 1) cellulosic cell walls external to the living protoplast, 2) plastids (which can be chloroplasts, amyloplasts or leucoplasts, and chromoplasts), 3) large central vacuole, and 4) intercellular cytoplasmic connections called plasmodesmata.

The following is a more comprehensive list of the cellular structures (including organelles) that you will find in plant cells.

NUCLEUS – houses the chromosomes and is bound by a double membrane.
CHLOROPLAST – type of plastid, site of photosynthesis and is bound by a double membrane.
CHROMOPLAST – type of plastid containing carotenoid pigments, no chlorophyll.
AMYLOPLAST – type of plastid with no pigments, stores starch.
MITOCHONDRIA – double-membrane-bound organelle, site of respiration.
VACUOLE – large membrane-(tonoplast)-bound structure; stores water, chemicals, etc.
CELL WALL – relatively permeable, non-living barrier constraining the protoplast.
ENDOPLASMIC RETICULUM – complex membrane systems throughout protoplast.
GOLGI APPARATUS – site of protein processing; part of the endomembrane system.
PEROXISOME – small organelle with roles in photorespiration and lipid catabolism.
PLASMODESMATA – intercellular, cytoplasmic connections channels through cell walls that connect plant cell symplast.
Figure 2. Identify the indicated structures of the plant cell in the figure below. Try to name all of the structures based on what you observed in lab and the descriptions given before referring to the Photo Atlas, the text, or the various lab poster aids available.

B. Investigation of Plant Cells

1. Nucleus, cell wall and chloroplast: Elodea
Prepare a wet mount of an Elodea leaf by removing a single leaf from near the shoot tip and placing it in a drop of water on a slide. Cover it with a coverslip. Avoid the presence of a large air bubble on or next to the leaf by adding more water if needed. Draw a region with several cells and make the following observations (also include the mentioned organelles in your drawing):

*Using the fine focus, determine how many cell layers are present (Hint, as you move the objective up or down, the top, middle and bottom regions of the cell will come into focus).*

*Can you identify the nucleus and cell wall?*
Can you identify the **chloroplasts**? What is their general shape and color? How are they organized?

Can you detect any **cytoplasmic streaming**? Try to determine what “cytoplasmic streaming” means and what its function may be. Examine the entire leaf until you can detect the cytoplasmic streaming somewhere in the leaf. Does the streaming appear orderly or random?

**Identify the mitochondria.** They are about 10X smaller than the chloroplasts. They appear to be in constant motion. How does this motion compare to the streaming? This is called **Brownian Motion**.

2. **Chromoplasts: red pepper; carrot**
Prepare a paper thin wet mounts of **red pepper** and **carrot** for comparison (internal tissues, not an epidermis). Keep in mind that the thinner the tissue, the better success you will have in seeing the cells. Ask your instructor for assistance if needed. Draw several cells of each and make the following observations:

**Do you see any pigmentation in the cells?**

**Where do you see the pigmentation (i.e. is it contained in a particular structure within the cell or is it diffuse)?**

**How do the carrot and red pepper cells compare to each other?**

**How do they compare to the beet or red onion cells (below)?**

**Do the chromoplasts have a general shape?**

Above: Diagram of a wet mount in which the subject matter (e.g., a wedge of red pepper, carrot, potato or banana) may be too thick in parts. One can either try to obtain another, thinner free-hand section or simply make your observations in a portion of the tissue that is thinnest (i.e., the left side of the wedge of tissue in the diagram).
3. Amyloplasts: Potato
Prepare a paper thin wet mount from the potato avoiding the skin. Again avoid the tissue being too thick or the coverslip will not lay correct and you may damage the objective lens. Notice that the freshly cut potato extrudes a milky substance. We will look at that later. Prepare drawings of several cells from the potato illustrating the structure present. Make the following observations:

Identify a single cell by locating a cell wall outline and studying what happens when you move up and down with the fine focus knobs. You should see the cell wall come in and out of focus as the focal distance changes. Use this skill to observe the components of the cell.

Do you see any structures inside the cell?

What can you identify?

What shape do the internal organelles have?

Prepare a second potato section and stain it with IKI₂ OR stain the already existing section by drawing a drop of IKI₂ under the coverslip with a wicking action. In either scenario, you should be able to see a change in the amyloplasts.

What happened to the amyloplasts with the addition of the IKI₂? Why?

Take a look at the area near the tissue under the coverslip.
Do you see anything there? What are the stained structures? What you see represents that earlier milky substance that exuded from the potato upon cutting it. Why is it present?

4. Vacuole: Beet Vacuole: Beet or Red Onion
Prepare a wet mount of the beet root or red onion bulb. The red onion can be prepared as an epidermal peel (see below). Take a crisp fleshy leaf from the bulb and snap it back to peel of a small piece of the outer (red) epidermis.

Figure 3. Illustration of peeling off a piece of epidermis from a leaf of an onion bulb.
To prepare the beet, use a razor blade to cut a very thin section. You should be able to see light through it. The section should be as close to paper thin as possible. To large and the coverslip will not lay right. Make your observations near the edge of the tissue slice where you are more likely to encounter a 1-2 cell thick layer. Make the following observations, and draw your observations:

*Are the cells clear or colored? The water-soluble pigment is in the cells’ large central vacuole.*

*Notice the size of the vacuole relative to the whole cell as demarcated by the cell wall. How much of the cell does the vacuole occupy?*

*What organelles can you identify in this tissue?*

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**C. The 3 Plant Tissue Systems**

Plants have three tissue systems: **dermal, ground, and vascular tissue systems**. In the primary plant body, the dermal system consists of the epidermis; the vascular system consists of vascular tissues arranged in bundles (i.e., vascular bundles); and the ground tissue system (the “cortex” and “pith” in Fig. 4) consists of all other tissues between the vascular and dermal tissues.

![Diagram of plant tissue systems](image)

*Fig. 4. Typical dicot arrangement of the 3 tissue systems (i.e., dermal, ground, & vascular).*

**C1. Dermal Tissue System Basics**

The external cell layer of the plant has a function similar to our skin in that it provides a physical separation from the environment. Only a single tissue makes up the dermal tissue: the **EPIDERMIS**. This tissue is generally **COMPLEX** in that various cell types can be present, such as guard cells of stomatal complexes, the cells of trichomes (plant hairs), etc.

1. Prepare a wet mount of an **onion bulb** epidermis (often referred to as an onion peel) as describe earlier. Observe the nature of the tissue as a whole instead of the individual cells.

*Make a sketch of what you see:*
How many different types of cells can you distinguish?

2. Observe a prepared slide of *Sedum epidermis* (w.m.) and compare it to what you saw with you onion peel. This section is similar to the onion peel in that it represents a surface view of the Sedum epidermis. Aside from the color, how are they different (hint: do you see any stomata?)?

3. Look for stomata in a prepared slide of a cross section of a typical *monocot leaf*. This section shows the different cells and tissues that make up a leaf. Focus on the EPIDERMAL layer, make observations and an up-close drawing of a stoma in cross-section. Label the stoma and the guard cells.

Does the epidermis appear to be continuous or are there occasional gaps present? What might be the reason for the presence of the gaps?

Can you identify more than one type of cell? If so, which kinds?

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C2. Ground Tissue System Basics
The bulk of the plant body is filled with ground tissue, of which the most common and generalized type is parenchyma. Although parenchyma, collenchyma, and sclerenchyma can be found in the vascular tissues as well, they are very typically found in the ground tissue system, depending on the species.

**PARENCHYMA.** Living at functional maturity. Thin-walled, apparently nonspecialized cells functioning in photosynthesis, storage, or secretion (Fig. 5).

**COLLENCHYMA.** Living at functional maturity. Consists of elongate cells with unevenly thickened, flexible primary cell walls, typically occurring in strands beneath the epidermis. Collenchyma functions in flexible support and usually is found in petioles or beneath leaf ribs and stem angles (Fig. 5).
SCLERENCHYMA. Dead at functional maturity. Cells have very thick, inflexible secondarily thickened, usually lignified, cell walls. Their cell walls function in support and protection. Sclerenchyma can be elongate and fibrous (FIBERS), occurring in networks or strands, or the cells can be of irregular shapes forming isolated or nests of stone cells (SCLERIDS) (Fig. 5).

1. Observe a prepared slide depicting a cross section of Ranunculus roots. Draw the root and identify the three primary tissue regions. Note: in this root, as in most and unlike the stem, the vascular tissue lies in the very center of the root such that there is no pith or ground tissue. What type of ground tissue is present in the cortex of this root? How do you know?

2. Review the prepared cross section of a typical monocot leaf. Draw and identify the three primary tissues regions in the leaf. Examine the leaf along its entire length. Which of the ground tissues can you identify as being present?

3. Obtain a celery petiole and break it in half (feel free to eat part of it). Notice the presence of strands that can be peeled from the celery. These strands are strands of collenchyma tissue. Make a cross section wet mount of the celery petiole to observe the collenchyma. Draw several cells of the collenchyma. Take a look at the strand under the microscope also.

4. Sclerenchyma cells can sometimes be seen associated with vascular tissue of some species or strengthening the stem of other species. In some plants like pear, the fruit contains sclerenchyma cells known as stone cells. These cells give the fruit a gritty texture. Make a wet mount of pear fruit tissue and identify, draw the stone cells.
5. Observe a prepared cross section of a *Helianthus* (Sunflower) stem. The center of the stem is the pith.

Which type of ground tissue (parenchyma, sclerenchyma, or collenchymas) is the pith made of?

Draw a typical cell from the pith. Do you see any intercellular spaces?

Can you recognize all three tissue systems in this slide?

![Diagram of a typical dicot stem](image)

Fig. 5. Idealized three-dimensional diagram of sections through a typical dicot stem (with no secondary growth), illustrating the locations and general morphologies of various cell and tissue types. (Adapted from Niklas, *Plant Biomechanics*, p. 267, University of Chicago Press, 1992).
C3. Vascular Tissue System Basics (see Figs. 4, and 5)
The vascular tissue has the role of long distance transport of nutrients and water throughout the plant. This tissue system is critical for the survival of the plant. There are two different complex types of vascular tissue, XYLEM and PHLOEM.

**XYLEM.**
**TRACHEIDS** – The primary conducting elements in gymnosperms (e.g., pine). Cell with pitted walls and dead at maturity. They also function in support.

**VESSEL ELEMENTS** – The primary conducting elements of angiosperms. Broad empty, tube-like cells connected end-to-end to form **VESSELS**.

**Xylem FIBERS**—Very long cells with very thick walls. Vessels function in transport and fibers provide support; both are dead and empty cells at maturity.

**Xylem PARENCHYMA**—relatively unspecialized, thin-walled cells rather more abundant in the ground tissue.

**PHLOEM**
The conducting cells of phloem are **SIEVE CELLS** in gymnosperms. **SIEVE-TUBE MEMBER** in angiosperms.

The above two are essentially the counterparts of tracheids and vessel elements, but they are living at maturity.

**COMPANION CELLS**—parenchyma cells associated with and facilitating the function of sieve-tube members.

**PHLOEM FIBERS** (e.g., *Helianthus*!!; next section).

1. Using the *Helianthus* slide, locate the vascular tissue and draw a single bundle. Locate the xylem (water, mineral) and phloem (sugar solution, signaling molecules) conducting tissues in each bundle. Note their appearance (e.g., cell types and forms). See Fig. 6 as a reference. Note that xylem is not homogeneous in cell size or type.

2. Obtain a *Zea* (corn) cross-section. Locate several vascular bundles and note that they are arranged differently than in Helianthus. Find the xylem and, in particular, see if you can identify 1 or more relatively wide-diameter vessel elements! Also note that the Zea vascular bundles are surrounded by red-staining (lignified) fibers for added support. Draw this.
Note: Cross-sections do not show you the wall thickening patterns of xylem cells. But they do show you how xylem cells differ in girth (diameter). Metaxylem cells have larger diameters than protoxylem cells and they are further away from the pith than are protoxylem cells.

Fig. 6. *Helianthus* (sunflower) vascular bundle, close-up. The blue stain is picking up the cellulose of the primary cell wall. The red stain is picking up the lignified.

3. *Cucurbita* (pumpkin) longitudinal section, prepared slide. This shows PHLOEM in long section in exquisite detail. Locate sieve tubes and their respective sieve tube elements. Also note where these elements meet at SIEVE PLATES. Note also the
presence of callose or P-protein collected around these sieve plates. This callose and/or P-protein accumulation is an artifact of the histological procedure to make this slide. Explain this...

D. Meristem Basics
D1. Introduction. The meristematic tissues contain cells that have the ability to divide thus contributing to the overall growth of the plant. APICAL MERISTEMS are found at the terminus of both the root (ROOT APICAL MERISTEM) and the shoot (SHOOT APICAL MERISTEM) and are the source of all root and shoot tissue respectively. Further from the apical meristem, there is differentiation of still-meristematic tissue into three types of PRIMARY MERISTEMS: the PROTODERM, the PROCAMBIUM, and the GROUND MERISTEM. The primary meristems give rise to the PRIMARY TISSUES, each of which has a specific function and predictable location within the plant body.

The DERMAL TISSUE (EPIDERMIS) is the primary tissue generated from the protoderm and serves as a protective covering for the plant. The GROUND TISSUE is generated from the ground meristem and makes up most of the internal structures in the plant. The procambium in turn gives rise to the VASCULAR TISSUE that facilitates long-distance transport.

Fig. 7. Flow chart illustrating the primary tissues derived from the apical meristem.
D2. Exercise

1. Obtain a prepared slide of an onion (*Allium*) root tip. This slide is a longitudinal section (labeled as l.s.). The ROOT APICAL MERISTEM is at the tip behind the root cap, the natural terminal end (rounded), and consists of small cells with densely staining cytoplasm and a high frequency of mitotic figures, indicating active cell division.

*Can you detect mitotic activity in any of the cells?*

*Where do you see the most amount of mitotic activity?*

*How does the meristem contribute to the growth of the plant?*

2. Obtain a prepared slide of a Coleus stem tip (longitudinal section, abbreviated “l.s.”). At the shoot apex, cells are very small, nearly isodiametric, and look much alike. From the outer layer of the shoot apex (tunica) comes the dermal layer, which we call **protoderm** in the meristematic region, and **epidermis** in the mature parts of the plant.

The shoot apex can be organized into the TUNICA and CORPUS. The tunica consists of the outermost two layers of cells of the shoot apical meristem. The corpus consists of the internal cell layers and tissue. **Identify and label these regions on your drawing.**