# PLANTS II: VASCULAR PLANT STRUCTURE & FUNCTION

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The first plant lab presented you with the main groups of plants: nonvascular plants, vascular non-seed plants, and the two groups of vascular seed plants (gymnosperms and angiosperms). Today's lab is designed to demonstrate some of the detailed structures of vascular seed plants and to show how some of these structures work.

📖 **Reading:** Campbell, Ch. 35.

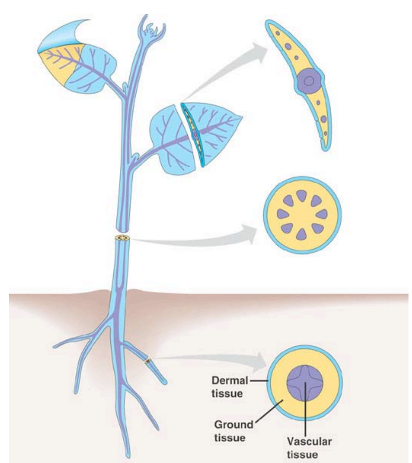
## BASIC FEATURES OF VASCULAR PLANTS

Each cell of a vascular plant is no more complex than an algal (protist) cell, and yet plant bodies are much more complex than protists. This complexity is at the level of tissues and organs. Vascular plants are more complex in their body organization than non-vascular plants, and are much more complex than photosynthetic protists such as seaweeds.

### Tissues

A tissue is a group of cells with similar appearance and function. Plants have three tissue systems:

- **Dermal tissues** cover the entire outside of the plant – roots, stems, and leaves. Dermal tissues include the epidermis of leaves and green stems and the outer layer of bark in woody plants.
- **Vascular tissues** transport water and other molecules throughout the plant body. Vascular tissues include xylem and phloem, which you'll study in detail later.
- **Ground tissues** make up the rest of the plant, including the cells responsible for photosynthesis inside the leaves.




### Organs

An organ is a structure that carries out a particular function and contains several kinds of tissues. For example, a leaf is an organ; leaves have several kinds of tissues. Vascular plants have three basic kinds of vegetative (non-reproductive) organs: **leaves**, **stems**, and **roots**. In this lab, you'll look at some of the wide variety that exists within each of these categories in terms of structure and function.

### How plants grow

You may remember from the last lab that the large, long-lived part of a vascular plant life cycle is the diploid sporophyte. A sporophyte begins as a zygote (a fertilized egg). The development of the adult plant body from the zygote requires two processes: **cell proliferation** to make new cells and **differentiation** to give those cells their proper identity. (Later, you'll see that both these processes also occur in animal development, but in a very different way.)

Plant growth is generally confined to **meristems**, which are regions of the plant body specialized for growth. There are meristems in the roots and in the shoot (the part above ground). **Apical**

**meristems** at the tips of roots and stems make the plant grow longer and produce leaves. This is called primary growth; it produces all the tissue types in a plant.

Woody plants get thicker by adding rings of **secondary growth** at **lateral meristems**. You'll see how this works later in this lab.

Plants have **indeterminate growth**. This means that they can continue growing throughout their lives, can change their growth pattern in response to their environment, and can replace parts that get damaged. Animal growth is normally determinate; growth only occurs up to a specific size. Individual plant organs such as leaves also show determinate growth.

## LEAVES

Leaves are what plants are all about; they are the sites of photosynthesis and gas exchange. The leaves of seed plants contain several different specialized types of cells, which interact to make a functioning leaf. You should become familiar with each type of cell and what it does.

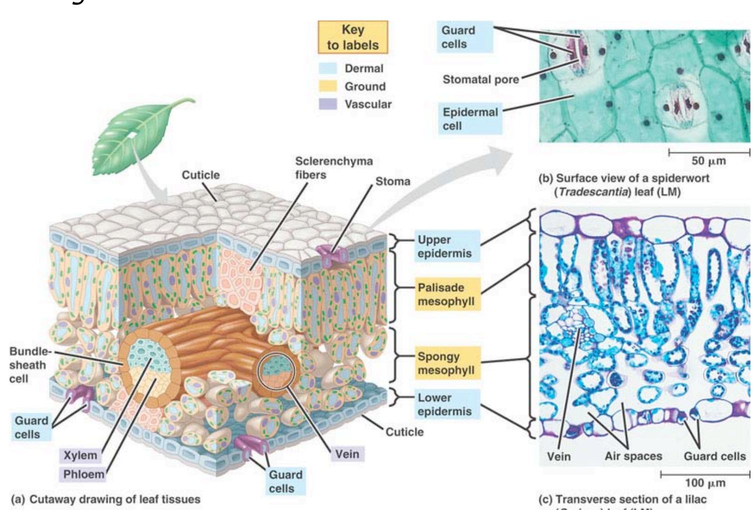
**Observe the whole leaves of various land plants.** While these leaves show a variety of shapes, they all do more or less the same job. Some of the differences in shape can be understood in terms of the conflicting requirements that leaves face: absorbing light, exchanging gases, avoiding dehydration, avoiding predation.

Break off a small piece of a leaf and look at it under the microscope; you should be able to identify dermal, ground, and vascular tissue.

Which leaves are **simple**, and which are **compound**?

Within the flowering plants (angiosperms), there are two large groups with different styles of leaves. **Dicots** (roses, for example) have leaves with a netlike, branching system of veins. **Monocots** (grasses, for example) have parallel veins. Later in this lab you'll see more differences between dicots and monocots. See Campbell, p. 603 for a summary of monocots and dicots.

**Observe the prepared slides of *Syringa* (Lilac) leaf cross section.** *Study fig. 35.17 in Campbell along with this slide.*



(a) Cutaway drawing of leaf tissues
(b) Surface view of a spiderwort (*Tradescantia*) leaf (LM)
(c) Transverse section of a lilac (*Syringa*) leaf (LM)

You should be able to recognize and describe the function of these parts of a leaf cross-section:

- **epidermis** (dermal tissue)

- **cuticle** (this is a layer outside the cells; it's not a tissue)
- **stoma** (plural: stomata)
- **guard cells** (dermal tissue)
- **mesophyll** (ground tissue)
- **vascular bundles**, containing:
- **xylem** (vascular tissue)
- **phloem** (vascular tissue)

Note that all these cells share some features that mark them as typical plant cells: they are very large compared to animal cells, they are contained in a boxlike cell wall, and most of the volume of the cell is filled with a membrane-bound storage organelle, the central vacuole.

The **vascular bundles** contain two types of **vascular tissue**. **Phloem** transports photosynthetic products from the leaves to the rest of the plant, and **xylem** carries water and inorganic nutrients up from the roots to the rest of the plant.

- **Observe the prepared slides of *Zea* (corn) leaf cross-section and longitudinal section.** Corn is a monocot, and a member of the grass family. It contains all the features listed above for *Syringa* leaves, but with two notable differences. First, corn leaves have parallel veins. This means that in a leaf cross-section, you'll see all the veins cut straight across. (In a leaf with reticulate venation, some of the veins will be cut straight across, and some will be cut at an angle.) The parallel venation of *Zea* leaves should also be obvious in longitudinal sections. The other notable way that *Zea* leaves differ from those of *Syringa* is that the vascular bundles in *Zea* are surrounded by **bundle sheath cells**. These cells aid in corn's specialized mode of photosynthesis, called C4 photosynthesis. (Most plants perform C3 photosynthesis. The differences between these two photosynthetic pathways are covered in Bio 6B.)
- **Observe the prepared slides of *Pinus* leaves (needles).** We have microscope slides of two different kinds of pine needles. Five-needle pines have needles that grow in bunches of five, and single-needle pines grow with one per bunch. Inside these needles, you'll see all the features listed above for *Syringa* leaves.
- **Observe the live specimens of *Elodea* and other aquatic plants.** Can you see the cuticle? The stomata? The mesophyll? Why do these leaves look different from the leaves of land plants? What do they have in common with algae or nonvascular plants?
- **Observe the live specimen of an onion.** Can you find leaves, stem, and roots?

## STEMS

Stems hold the plant up and they transport materials between the leaves and the roots. In large plants, most of the mass may be in the stems (tree trunks, for example).

### Vascular tissue in stems

Stems contain xylem and phloem. Remember that xylem is responsible for the transport of water and inorganic minerals, while phloem is responsible for the transport of photosynthetic products from the leaves. Water transport often requires large pressure gradients, so xylem walls are particularly thick. Xylem cells are dead when they are mature – the empty cell walls of numerous cells are joined together to make long pipes. Mature phloem cells still have intact plasma membranes when they are mature, but they lack a nucleus and a large central vacuole.

The arrangement of vascular bundles differs between monocots and dicots.

⚐ **Observe the prepared slides of *Helianthus* stem** (cross section). This is a dicot stem; like other dicots, it has vascular bundles arranged in a ring. Each bundle contains phloem and xylem. The xylem is composed of red-stained, thick-walled cells; xylem cells occur on the inside of each vascular bundle, closer to the center of the stem. The phloem is composed of blue-stained, thinner-walled cells, and occupies the outer part of each vascular bundle. The inner part of the stem is filled with pith, a ground tissue. The outer layer is epidermis.

⚐ **Observe the prepared slides of *Zea* stem** (cross-section). *Zea* (corn) is a monocot – a member of the grass family. Like other monocots, *Zea* stems have vascular bundles scattered throughout the stem, rather than arranged in a ring, like dicots. You may also see leaves that grow wrapped around the stem. Older corn stems can become hollow inside.

## Primary and secondary growth

As a tree or bush grows over a period of years, its stems get both longer and thicker. The added length comes from new cells added at the **apical meristem** at the tip (apex) of each branch. This is called **primary growth**.

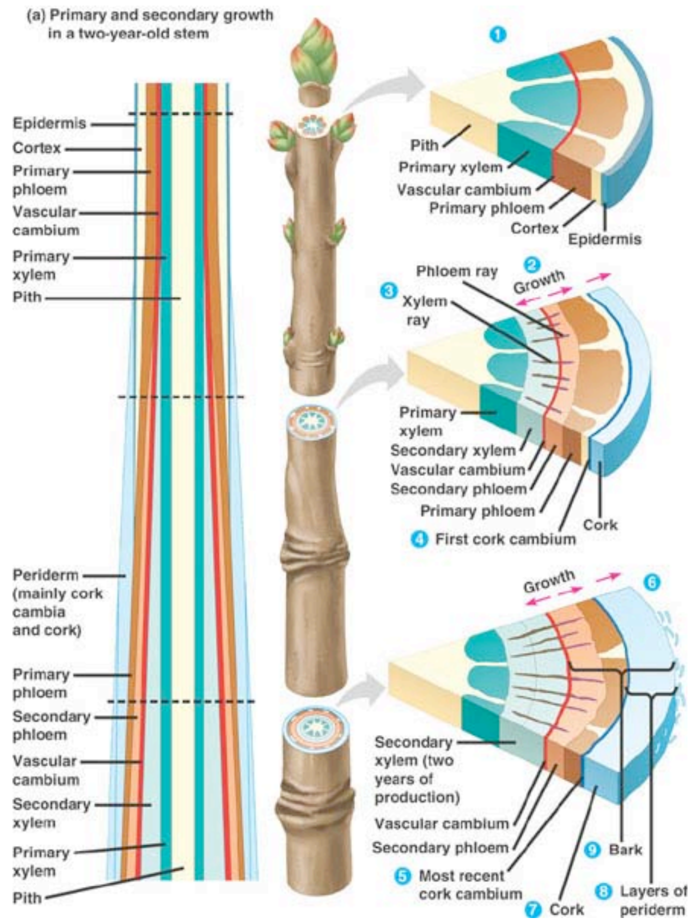
⚐ **Observe the prepared slides of *Coleus* stem** (longitudinal section). This is the growing tip of a dicot stem; note the zone of rapid cell proliferation (small cells) in the apical meristem. After new cells are produced in this area, they will elongate considerably; this elongation contributes most of the increase in length of the stem.

Stems get thicker through **secondary growth**, which occurs at lateral meristems. **Lateral meristems** form rings around the stems of woody plants. Much of the tissue added in secondary growth is vascular tissue; wood is composed primarily of multiple layers of xylem.

⚐ **Observe the prepared slides of *Tilia* 1-, 2-, and 3-year stem** (cross section). *Study fig. 35.18 in Campbell along with this slide.* This slide shows three different cross sections of stems: 1 year old, 2 years old, and 3 years old.

**One-year stem:** No secondary growth is present. This stem looks similar to the *Helianthus* stem listed above. Pith (a **ground tissue**) fills the middle of the stem. **Xylem** (red and thick, as usual) forms the next layer. Unlike the *Helianthus* stem, the *Tilia* stem may have a complete ring of xylem instead of separate bundles. **Phloem** makes the next obvious layer outside the xylem; it often appears as bundles separated by ground tissue ("pith rays"). Between the xylem and the phloem there is a thin layer called the vascular cambium; this layer is easier to find on the older stems. Outside the phloem there is a layer of **ground tissue** called cortex, then a thin layer of **epidermis**.

**2-year stem:** one year's worth of secondary growth has been added to the first year's primary growth. This secondary growth is added at two **lateral meristems**. Secondary vascular tissue is added at the **vascular cambium**, a thin layer between the xylem and the phloem. You should be able to identify two bands of xylem: the inner ring is the **primary xylem** from the first year's growth, and the outer is **secondary xylem** from the second year. The variable size of the cells is due to the fact that growth occurs rapidly in the summer, producing larger cells, but slows down in the winter. The vascular cambium continually adds new xylem to the outside of the existing xylem layers.




The addition of secondary xylem inside the vascular cambium pushes the other layers out. The phloem layer gets stretched out as the xylem grows. **Secondary phloem** is added on the outside of the vascular cambium, filling in the phloem layer.

Outside the phloem there is another lateral meristem, called the **cork cambium**. This meristem produces secondary growth of the outer layers of the bark, including the epidermis. Bark includes everything outside the vascular cambium.

**3-year stem:** One more year's worth of secondary growth has been added. The stem fills with secondary xylem; this is what makes wood. The ring of phloem must increase in diameter as the stem grows, but it does not become thicker and thicker.

**Observe the dicot tree trunk cross-section.** Note the many growth rings. What part is primary growth and what part is secondary growth? Where would you find a lateral meristem? Is there an apical meristem? Xylem & phloem? Note that this tree is mostly made of secondary xylem. The growth rings of secondary xylem may be divided into heartwood and sapwood. **Heartwood** fills the inside of the trunk, and it often darker. Heartwood is xylem that has stopped functioning. Sapwood is the outer set of secondary xylem rings; it is often lighter in color. **Sapwood** actively functions as vascular tissue; it contains sap.

**Observe the palm tree trunk cross-section.** Palm trees are monocots, and they lack the lateral meristem that is responsible for the secondary growth that adds woody rings in dicot trees. Much of the volume of a palm tree trunk is ground tissue rather than vascular tissue. Palm trees don't form growth rings; they can become thicker through the expansion of the ground tissue or through the addition of thickened leaf bases that form around the trunk.

## ROOTS

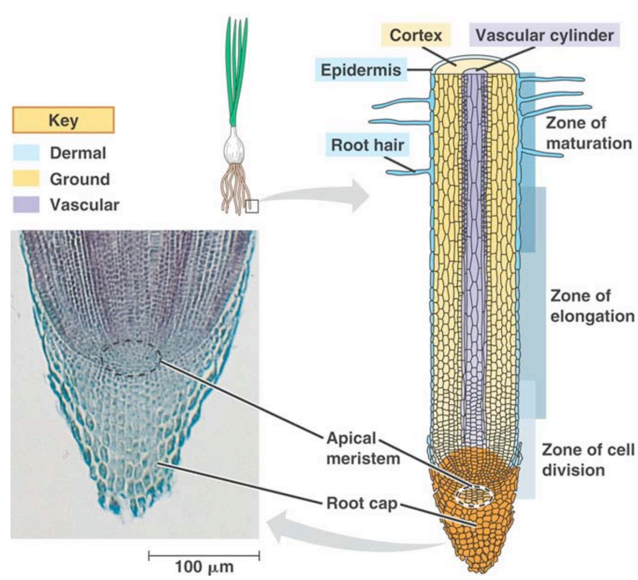
Roots absorb water and inorganic nutrients from the ground. In some respects, they are like gas exchange structures: they have a large surface area and a thin outer covering (the epidermis). Unlike gas exchange structures, though, roots must often grow deep to find more water and to hold up large plants.

**Observe the display of a fibrous root system and a tap root system.** The fibrous root system is typical of monocots, and the taproot is typical of dicots.

**Observe the various jars of preserved roots.** These show different styles or features of roots. The sweet potato root is modified for storage of starch. Adventitious roots form above the ground; in corn plants, these are called prop roots because they prop up the plant. Some plants have root nodules that provide a home for bacteria that fix nitrogen; you can see these on the "bean root nodules" and the "nitrogen-fixing soybean."

**Observe the prepared slide of *Ranunculus* (buttercup) mature root.** This is a typical dicot root. Note that the anatomy is quite different from that of a stem. The vascular tissue forms a single bundle in the middle of the root. There is no pith in the center, but much of the outer part of the root is composed of a similar **ground tissue**, called cortex. The vascular bundle is surrounded by a layer of **endodermis**, which helps control the movement of materials into and out of the phloem and xylem. The endodermis forms the casparian strip (not visible in the slide), which plays a key role in controlling transport. The casparian strip will be discussed in lecture.

**Observe the prepared slide of *Smilax* root.** This is a typical monocot root. In this root, there is an area of pith (ground tissue) in the center, with xylem and phloem bundles arranged around the center. Like the dicot root, this one has a well-defined **endodermis**, with cortex (ground tissue) filling the space between the endodermis and the **epidermis**.




**Observe the prepared slide of *Allium* (onion) root tip.** *Study fig. 35.12 in Campbell along with this slide.* This is a monocot. In this slide you can see how new cells are added at the apical meristem; this process is similar for monocots and dicots. You should also be able to see the varying appearance of cell nuclei and chromosomes in cells that are in different stages of mitosis.

## QUESTIONS FOR PLANT LAB 2

### Know the structures

You should be able to recognize all the terms that are in bold in this handout. For the lab exam, you may see any of the specimens from this lab with a pointer indicating a particular structure. The question would be "What is this?," and the possible answers could be:

- Apical meristem
- Cork cambium
- Cuticle
- Dermal tissue
- Dicot (recognize leaves, stems, roots)
- Endodermis
- Epidermis
- Fibrous roots
- Ground tissue
- Guard cell
- Heartwood
- Lateral meristem
- Leaf
- Mesophyll
- Monocot (recognize leaves, stems, roots)
- Phloem
- Primary or secondary phloem
- Primary or secondary xylem
- Root
- Sapwood
- Stem
- Stoma
- Tap roots
- Vascular cambium
- Vascular tissue
- Xylem

### Other important concepts

- Secondary growth
- Primary growth
- Cell proliferation
- Differentiation
- Determinate vs. indeterminate growth
- Haploid vs. diploid
- Meristematic growth
- Vascular plants vs. nonvascular

### Concept questions

1. Identify dermal, ground, and vascular tissues in leaves, stems, and roots. What is the function of each of these tissue systems in each type of organ?
2. Can you find primary and secondary growth in leaves, stems, and roots?
3. Where would you find meristematic tissue in a typical stem?
4. What kind of tissues are generated by apical meristems?
5. Do you think humans have anything equivalent to meristems?
6. How is xylem different from phloem?
7. Why do roots have xylem and phloem?
8. Why do leaves have xylem and phloem?
9. Of the features discussed in this lab, which ones would be present in mosses? Which ones would be present in ferns?