BIOL 221 – Concepts of Botany Fall 2007

Topic 08: **Primary Plant Body: The Shoot System**

A. Introduction

The shoot consists of stems and leaves. It is quite modular in its construction. A shoot is made up of repeated units known as PHYTOMERES (see Figure below). Inspect the figure and note the basic rules of plant architecture.

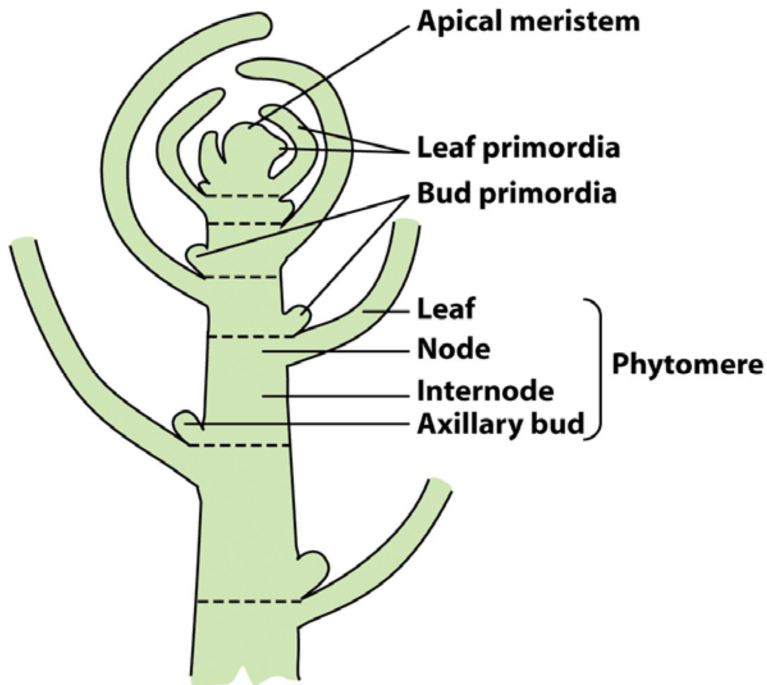


Figure 25-3
Biology of Plants, Seventh Edition

Leaves are always attached to what?

Where are AXILLARY BUDS positioned?

What develop from AXILLARY BUDS?

From what do stems and leaves ultimately develop?

The point of leaf attachment to the stem is termed what?

Why are more distal internodes shorter than those less distal?

Leaves function in what?

Stems function in what?

B. Comparative Morphology of the Shoot (living material)

Each student group of 4 has a plant of *Setcreasea* (purple heart) and *Rhoeo* (oyster-plant) on their bench. They are very very closely related (both are in the Spiderwort & Wandering-Jew family) yet look rather different in the arrangement of leaves.

Does Setcreasea have internodes?

Does Rhoeo have nodes? Internodes?

What is responsible for the difference in the apparent arrangement of the leaves between Setcreasea and Rhoeo?

Rhoeo is said to have a ROSETTE habit. What does this mean?

C. Dissection of shot apex (living material)

Find the shoot apex and, in particular, the dome above the shoot apical meristem of sunflower (*Helianthus*) seedlings. To do this, pair-up with another student and a seedling on your bench, and dissect away the larger leaves (cut them gently at their petioles) surrounding the shoot apex.

What do you see with the naked-eye? With the dissecting scope? With the compound scope (with razor thin longitudinal median section mounted on a slide)? *Draw what you see.*

D. Investigation of *Coleus* shoot and shoot apical meristem structure (prepared slide)

Read through the section below and become familiar with the terminology. Use the illustration included to orient yourself regarding the position of the structures. Then obtain a prepared slide of a **Coleus stem tip (longitudinal section , abbreviated "l.s.")** *and* ***prepare a detailed drawing of the entire shoot tip region***. ***Clearly label on your drawing all of the structures and regions described in the narrative below. Use the blank page following this section for your drawing.***

Compare your prepared slide of the shoot with the drawing in the Figure on the next page. They may not be exactly the same, but the following important points should apply: (1) from top to bottom the stem gets wider, (2) from top to bottom the leaves get larger, (3) from top to bottom the leaves get further apart.

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.

Leaves form at the sides of the **shoot apex** (**A**). The leaves, growing out of the stem as appendages, get larger as they get older. They are fast-growing compared to the apex, and a **leaf primordium** (**B**) soon overarches the shoot apex. Cells quickly become different from each other inside a young leaf. Some cells deep within the primordium elongate and are more darkly stained. These comprise the meristematic vascular tissue, the **procambium** (**C1**). Segments of the vascular tissue can be seen in the stem, also (**C2**). But at any distance from the shoot apex, and in all but the youngest leaves, some of the procambium would have matured as conducting elements of xylem and phloem. The procambium forms upward in the axis and out into each leaf. In a section, the strands appear discontinuous because they go in and out of the plane of sectioning. **Identify and label the shoot apex, leaf primordia, and procambium in your slide and drawing.**

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.**

Because the distance between leaves increases from top to bottom in the shoot, we know that the internodes are forming. How long is each internode? This is a rather tricky question to explore. By looking at the whole plant you see that the leaves alternate in their positions on the stem with each successive pair. **Thus, only half the leaves can show in the longitudinal section**. One **internode** (**D**) is labeled in the photo. We know this is an internode because the bump below it is the top of a **leaf base** (**E**) of a leaf that is out of the plane of sectioning. Notice that the next **older internode** (**F**) is probably longer than the first internode we labeled. Internodes close to the shoot apex are too tiny to measure. Note how the outline of the **leaf primordium** (**B**) runs right into the bump below it. **Identify the internodes in your slide and drawing.**

In the drawing, **axillary buds** (**G2**) are present at the juncture of a leaf with the stem at the base of the older internode we labelled (**F**). These have their own **procambium** (**C3**) and their own leaf primordia. Compare these axillary shoots to the top of the main axis. Axillary buds grow to become axillary shoots that attain all the organizational features of the main shoot, as they age. Younger **axillary buds** (**G1**) are also visible, but these do not have leaf primordia or procambium. **Identify the axillary buds of different ages on your slide and drawing.**

Increased length of the axis and increased width depends on (1) increase in cell number by cell division, and (2) cell enlargement. Increase in axis length is greater than increase in width in *Coleus*. You should be able to **verify this feature on your slide**. However, be cautious when judging the individual cells. In the younger parts of a shoot, cell division can offset increases in cell size as the axis grows. The final size of the cells is not attained in the part of the shoot that was sectioned. You need older parts to see final cell size.

This stem tip is probably too young to find fully matured vascular bundles with the full complement of xylem and phloem. Most of the incipient vascular bundles exist still as procambial strands.

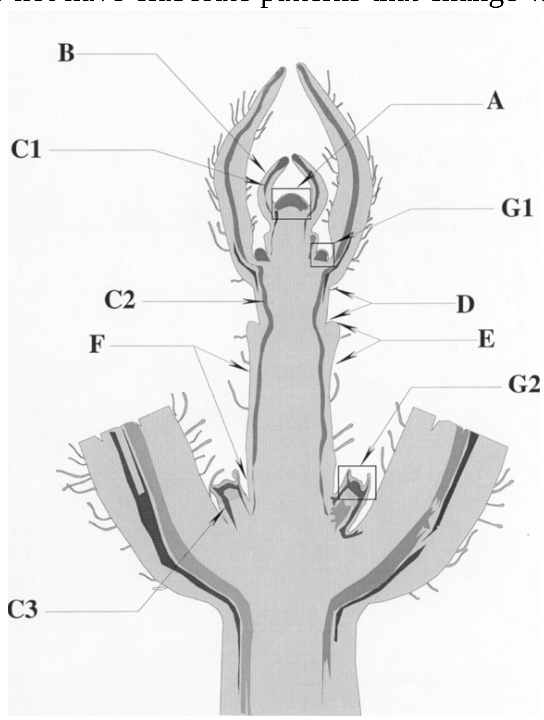
If anything, you will be able to see the first xylem elements maturing. The conducting elements of the xylem closest to the pith are the first to mature. These matured while the axis was elongating, and their wall patterns (rings and helices) can be stretched out. These early-matured cells are in the **protoxylem**. Xylem elements maturing after elongation stops can have more complex wall patterns, and are called the **metaxylem** elements. Likewise, phloem can be divided into protophloem and metaphloem, but the walls do not have elaborate patterns that change with the age of the axis.

How is this meristematic tissue similar or different to the root meristem?

Can you follow a cell from the middle of the shoot back to a single meristem cell?

Do you see any other region in the shoot similar to the apical meristem?

What are they?



Drawing of a longitudinal section of a shoot of *Coleus* (copyright Karl Niklas).

Coleus shoot tip observations and structures:

E. Comparative Anatomy of Stems

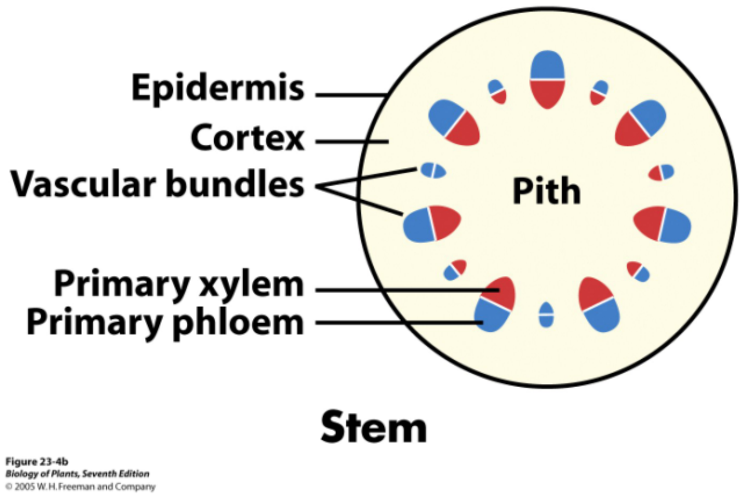


Fig. Typical dicot arrangement of the 3 tissue systems (i.e., dermal, ground, & vascular).

The organization of the stem has a lot of similarities with the root. The dermal, ground and vascular tissue systems are readily recognizable and are made of the same types of cells. In the following exercises, you will become familiar with the differences between dicot and monocot stem organization as well as be able to relate this new information back to the root anatomy for comparison.

E1. Typical Dicot: *Helianthus* stem cross-section (cross-section abbreviated as "c.s.")

Things to see & do: **-dicot organization of 3 tissue systems (as per Figure above).**
-types tissues (i.e., parenchyma and collencyma) in the ground tissue.
-diversity of cell types in the xylem and phloem. Note the fibers capping the phloem-sides of the vascular bundles.

Helianthus (sunflower) exhibits the typical dicot arrangement of the 3 tissue systems (i.e., dermal, ground, & vascular tissue systems). Observe the prepared slides and locate each of the labeled features in the Figure above.

Notice that each vascular strand is separated from its neighbor by ground tissue (where pith and cortex come into contact).

Now focus on a vascular bundle. Locate the xylem (water, mineral) and phloem (sugar solution) conducting tissues in each bundle. Note their appearance (e.g., cell types and forms). Note that xylem is a complex tissue.

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.

Draw your dicot cross section and label the different vascular tissue cell types. Include labels for the ground tissue (parenchyma, collenchyma, sclerenchyma) the cortex, pith and epidermis.

How does the stem organization compare to the root organization of a dicot?

How does dicot stem organization compare to monocot root organization?

What is the layer of cells surrounding the vascular bundle?

Helianthus demonstrates the VASCULAR CAMBIUM. Locate and label it. This region is between the xylem and phloem cells.

Locate and label the fibers capping the phloem region.

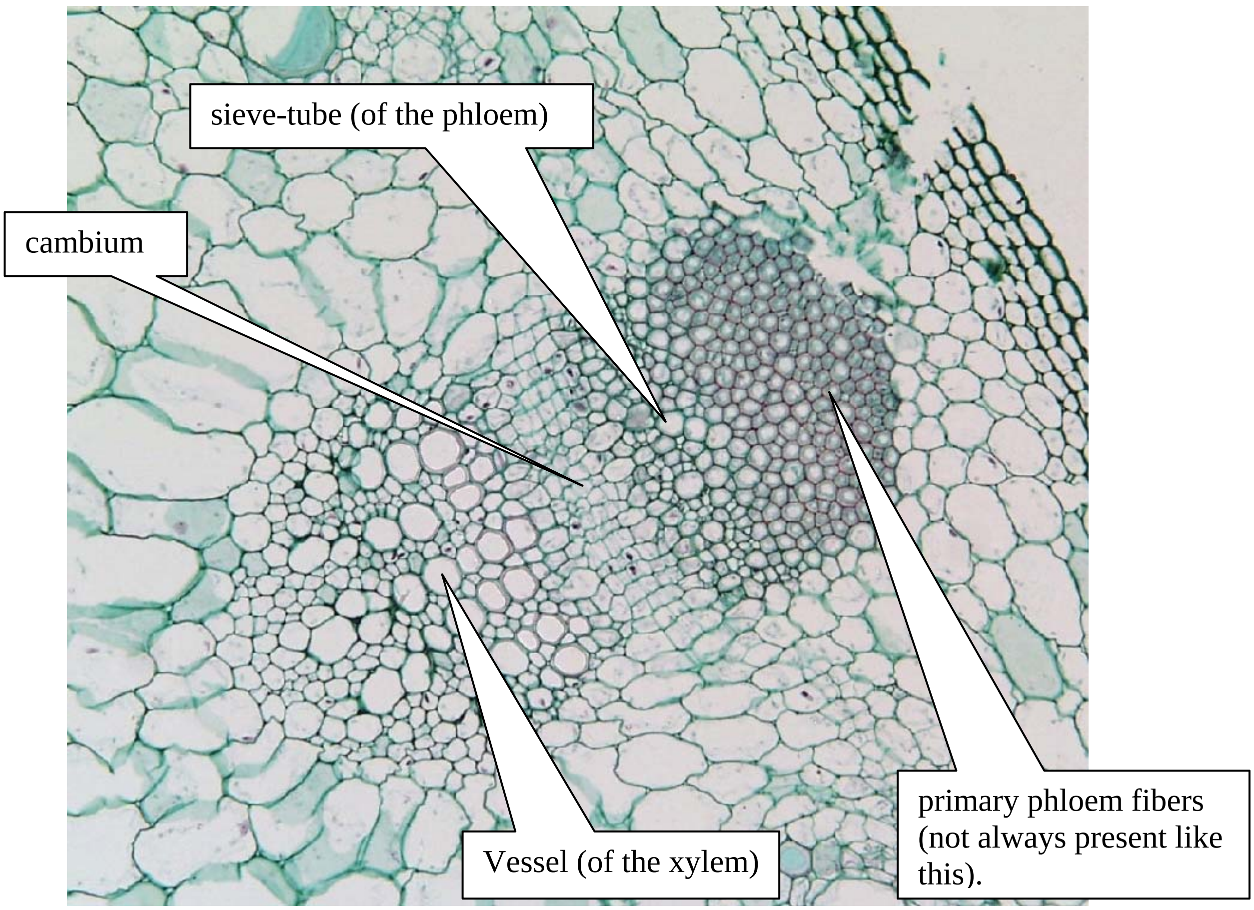


Fig. *Helianthus* (sunflower) vascular bundle, close-up. The blue stain is picking up the cellulose of the primary cell wall. The red stain is picking up the lignin of the tracheary elements and fibers.

E2. Typical Monocot: ***Zea* (maize)** stem cross-section (cross-section abbreviated as "c.s.")

Things to see & do: **-monocot organization of 3 tissue systems.**
-types tissues (i.e., parenchyma and collencyma) in the ground tissue.
-all structures labeled in Figure of *Zea* vascular bundle below.

Zea (corn, maize) exhibits the typical MONOCOT arrangement of the 3 tissue systems. Observe the prepared slides.

How is this organization different from that of the typical dicot?

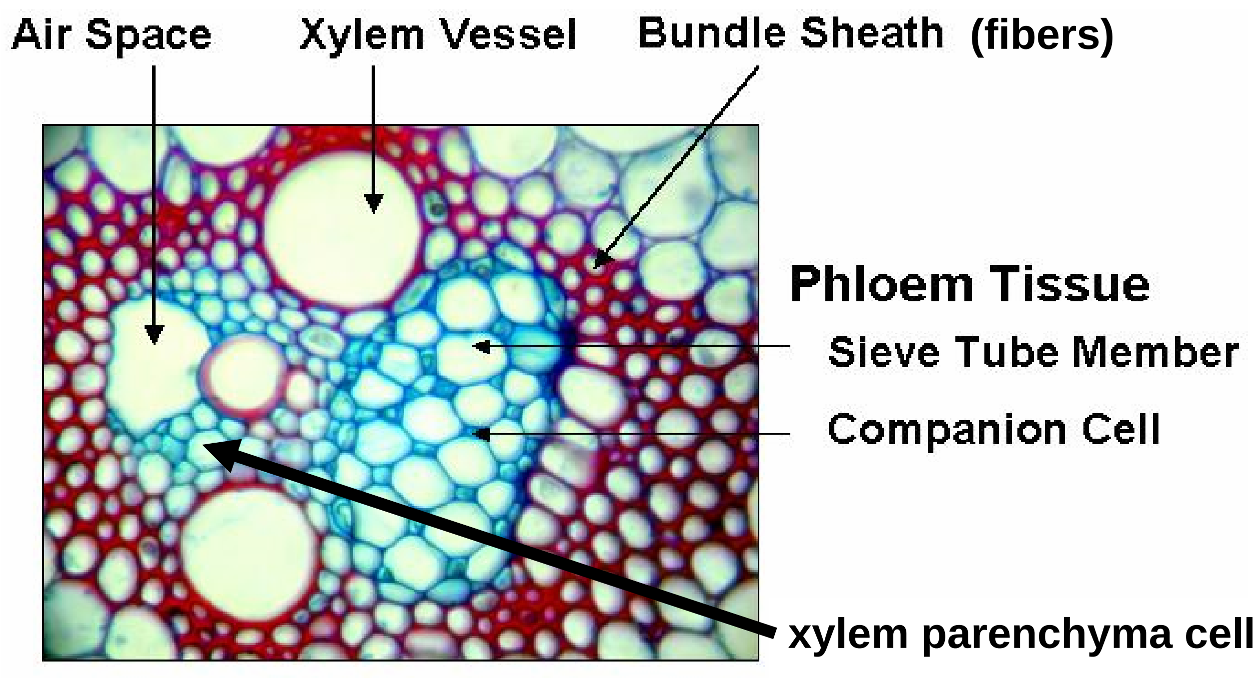


Fig. *Zea* (maize) vascular bundle, close-up. The blue stain is picking up the cellulose of the primary cell wall. The red stain is picking up the lignified secondary cell walls of the xylem vessels and fibers.

E3. *Zea* (maize) stem longitudinal-section (long-section abbreviated as "l.s.")

Things to see & do: **-organization of 3 tissue systems.**
-types tissues (i.e., parenchyma and collencyma) in the ground tissue.

Can you discern the 3 tissue systems in the long section?

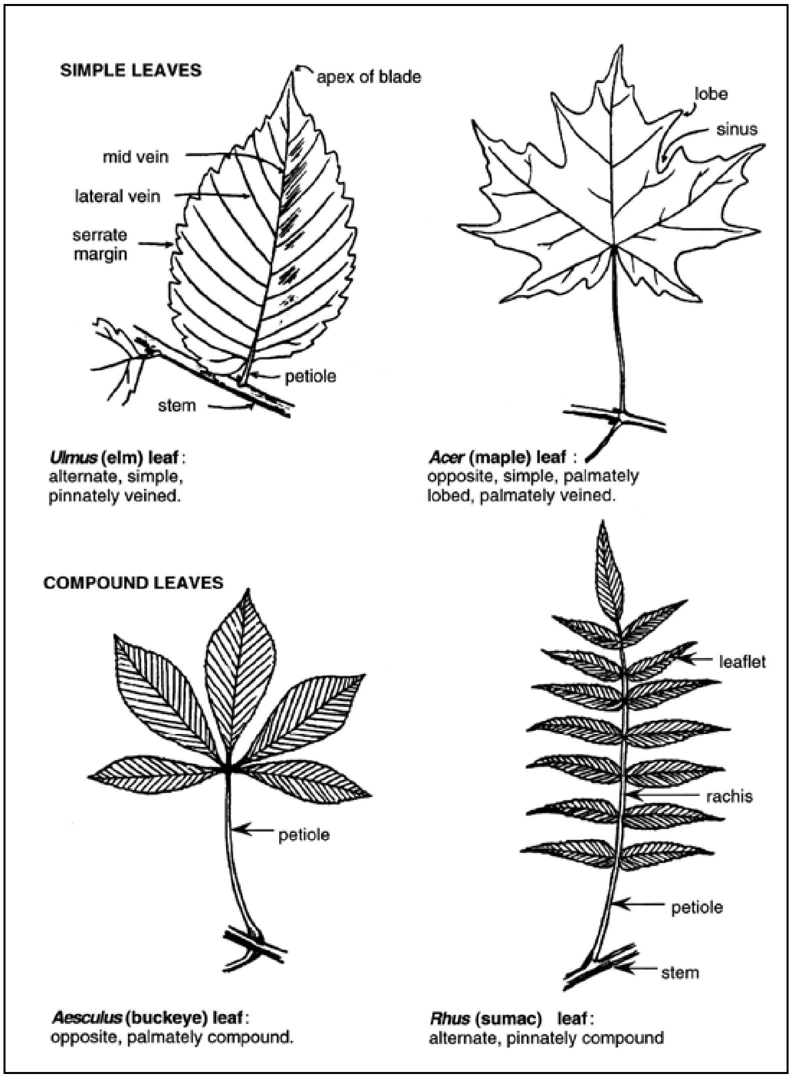
Relate organization perceived in long-section with that seen in cross-section.

Now, look for the xylem and phloem in the vascular bundles. Xylem is closer to the center of the stem than phloem.

F. Basic Leaf Morphology

Basic leaf structure includes the **PETIOLE** that attaches the leaf to the stem (leaves are referred to as "sessile" when there is no petiole), the **BLADE** which is the flattened portion of the leaf attached to the petiole, the **MIDRIB** or midvein which is the thickened longitudinal rib of many leaves, and will serves as the vascular link to the stem, smaller **VEINS**, and the **MARGIN** or outer edge of the leaf. Be aware of these terms when examining the plants in today's lab.

Leaves will vary from species to species in their **VENATION** (vein pattern), **MARGIN** (outer edge), **COMPLEXITY** (shape and dissection of the blade), and **ARRANGEMENT** (positioning on the stem). Refer to the **Photo Atlas Fig 9.61** to review what these terms mean.



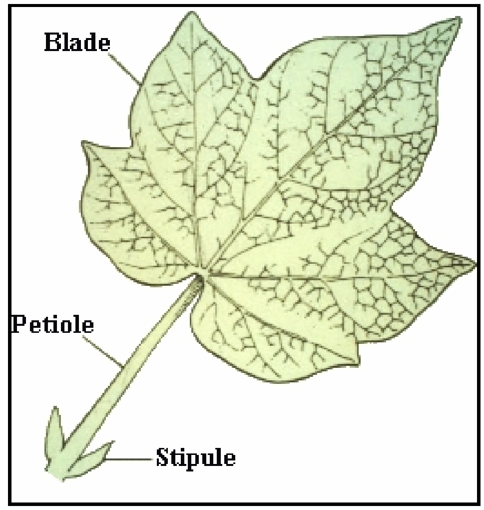


Fig., above. Basic leaf structure.

Fig., left. Some terms used to describe leaves.

F1.Work in groups of 3-4. Move around the room and examine the leaves of the 12 PLANT SPECIMENS provided and determine the venation, margin, complexity, and arrangement of each. In addition, be sure to notice the parts of the leaf and make how the shoot is organized (i.e. the phytomere). Record your observations of the leaf morphology below:

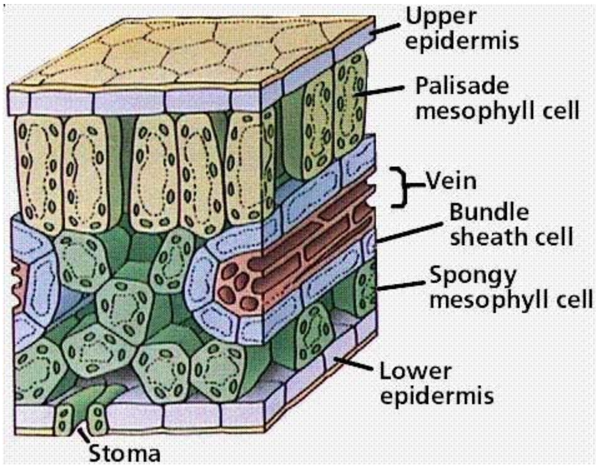
Leaf Morphology Observations:

Plant	Venation	Margin	Complexity	Arrangement
1.				
2.				
3.				
4.				
5.				
6.				

Plant	Venation	Margin	Complexity	Arrangement
7.				
8.				
9.				
10.				
11.				
12.				

G. Basic Leaf Anatomy

G1. **PREPARED SLIDE:** Typical dicot (lilac) leaf cross-section (c.s.)
Observe the anatomy of a typical DICOT leaf using the typical dicot leaf cross-section (c.s.). Please note that the following figure is a schematic illustration of an idealized leaf. Use this to orient yourself on the leaf cross-section slide.



Place your labeled leaf drawing here.

Fig. General schematic of a leaf in section.

In the space provided, DRAW your observations.

Label all of the tissues and cells indicated in the figure.

Identify and label the Xylem and Phloem in the vascular bundle.

Indicate the presence of any AIR SPACES.
Why would air spaces be important in a leaf?

H. Basic Leaf Anatomy

H1. **Living Tissue:** Place a drop of water on a clean slide. Make a 0.5 cm^2 upper epidermal peel from a leaf of ***Rhoeo*** (spiderwort family). Place the peel face up on the drop, then place another drop over it and cover with a cover-slip. Repeat with the lower epidermis. Observe the tissue using the compound light microscope at 20X or higher for good comparison.

Do you see stomata with the compound scope?

*Draw a region of the **UPPER** leaf epidermis that contains both guard cells and normal epidermal cells.*

*Draw a comparable region of the **LOWER** leaf epidermis.*

Note the frequency of the guard cells on the upper surface and compare it to the lower.

Are stomata more frequent on one surface than the other?

H2. **<u>PREPARED SLIDE:</u>** Return to the <u>Typical dicot leaf in x-section</u>.

Look for stomata in x-section.
Draw and label the stomata plus some of the adjacent epidermal cells.

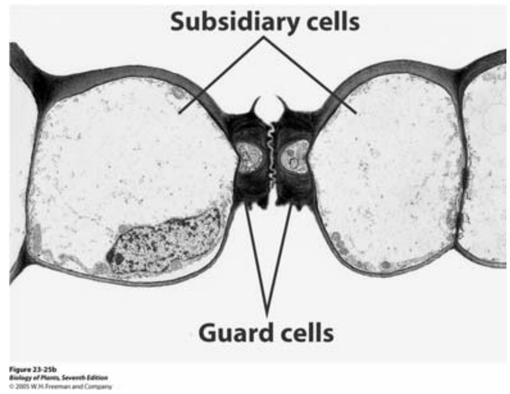


Fig. 7. Cross section example of guard cells surrounding a stomatal pore with subsidiary cells on each side

Locate the ground tissue (that tissue other than the epidermis and vascular bundles, in the middle of the leaf). This ground tissue in the leaf is called “MESOPHYLL” and it may be differentiated into “SPONGY MESOPHYLL” and “PALISADE MESOPHYLL” in most horizontal leaves (i.e., those with upper and lower surfaces). The palisade mesophyll consists of columnar and more densely spaced cells packed with chloroplasts. The spongy mesophyll also has chloroplasts and its most conspicuously not as densely packed as the palisade mesophyll (i.e., there are more intercellular air spaces in the spongy mesophyll).

H3. Rhoeo, free hand cross-sections.
Using two pieces of styrofoam cups to gently but securely "sandwhich" a section of leaf (ask instructor for technique details), use sharp razor blade to make razor-thin cross-(transverse)-sections of the leaf. Make several and float them into a small petri-dish of water to keep them moist until you are ready to mount them. Then take the thinnest section(s) and mount them onto a slide.

Is the mesophyll differentiated into palisade and spongy mesophylls in this species? If so, relate this to the upper vs. lower sides of the leaf. Explain any pattern in terms of functional anatomy and ecology.

I. Leaf Adaptations: Mesomorphic Leaves (typical leaf anatomy)

Review your observations of the typical dicot leaf. Make a note of how the PALISADE PARENCHYMA and the SPONGY PARENCHYMA are arranged.

How many layers do you typically see for this type of leaf?

Also note the appearance of the epidermis and the ground tissues.

Use your observations to compare this type of leaf to the leaves in Sections E – I.

J. Leaf Adaptations: Xeromorphic (arid leaf anatomy)

J1. Observe and DRAW the xeromorphic leaf examples: *Nerium oleander* & *Ammophila* ("beach grass") in cross-section. These types of leaves are specially adapted to growth in harsh, arid environments. *Nerium* has fine examples of trichomes and *Ammophila* demonstrates stomata.

How do these leaves differ from Lilac?

Label your drawing with the typical tissues, cells.

Label the STOMATAL CRYPTS and CUTICLE.

What purpose do these structures have?

Identify and label the trichomes and stomata.
Where are they found?

How is the cuticle different from Lilac?

How does the Epidermis differ?

Is there any change in the basic organization of the ground or vascular tissues?

K. Leaf Adaptations: Hydromorphic Leaves (water leaf anatomy)

K1. Observe and DRAW the hydromorphic leaf example: *Nymphaea odorata*, "water-lily" in cross-section. This type of leaf is adapted for aquatic habitats and often is submerged in water.

Draw the cross-section of the water lily.

Label all of the typical tissues and cells.

Label the intercellular spaces.

How does this type leaf differ from the previous two?

How would the organization of the ground tissue help this type of plant survive?

Do you see any SCLERIDS in the mesophyll?

What might their purpose be?

How does the mesophyll tissue differ from xerophytes?

Are there any differences in the organization of the Ground and vascular tissues compared to mesophytes?

L. Unknown Leaf Identification Study: Determine if Meso-. Xero-, or Hydrophyte

L1. Use the prepared slide labeled "Leaf-types cross-section" for this part. This slide has examples of all three types of leaves looked in the previous sections. If professor asks, on a blank page DRAW and LABEL each cross-section as the type of leaf it represents (there is space on back page). Label the typical structures including: epidermis, ground, vascular tissues, mesophyll, palisade parenchyma, spongy parenchyma, bundle sheath cells, xylem and phloem. In addition, LABEL the structures and differences that are associated with that type of leaf.

M. Variations of leaves: MONOCOTS with Grass-like (vertical) leaves

The leaves of monocots, like grasses, have a slightly different organization but still contain all of the primary tissues one would expect. Consider the differences in comparison to the Lilac leaf.

M1. Observe the cross-section of a **typical monocot (in this case grass) leaf**. Draw and label the cross-section with the typical leaf tissues and cells. Include the specialized features.

How is the ground tissue organized differently from the dicot leaf?

What is missing?

Suggest a reason for the missing layer.

Distinctive to many grasses are BULLIFORM CELLS? Find these and suggested an adaptive function.

<u>Optional Assignment (as per instructor's fancy): Comparative Analysis of Leaf Types</u>
Use the prepared slide labeled "Leaf-types cross-section" for this part. This slide has examples of all three types of leaves looked in the previous sections. On the last page of this handout, use the space provided to DRAW and LABEL each cross-section as the type of leaf it represents. <u>Label the typical structures including: epidermis, ground, vascular tissues, mesophyll, palisade parenchyma, spongy parenchyma, bundle sheath cells, xylem and phloem. In addition, LABEL the structures and differences that are associated with that type of leaf.</u>

<u>MESOPHYTE:</u>

<u>XEROPHYTE:</u>

<u>HYDROPHYTE:</u>