Topic 15. The Shoot System

Introduction. This is the second of two lab topics that focus on the three plant organs (root, stem, leaf). In these labs we want you to recognize how tissues are organized in each of the three different plant organs; and to understand how this organization relates to the function of each organ.

In most plants, stems serve to a support the leaves which act as solar collectors to produce food. The the stem must conduct water up to and photosynthate down from the leaves. Stems and leaves are tightly integrated. Together they constitute **the shoot system**. Selective pressure in certain plant groups have resulted in modified stems and leaves that serve a number of different functions including food storage and defense. In some plants (cacti are examples), the stem is the primary photosynthetic organ and the leaves are greatly reduced.

I. *Coleus* Shoot Tip.

Take a prepared slide of a longitudinal section of a *Coleus* shoot tip, and survey the slide at 40x. Relate your preliminary observations to the living *Coleus* plant nearest you on your bench.

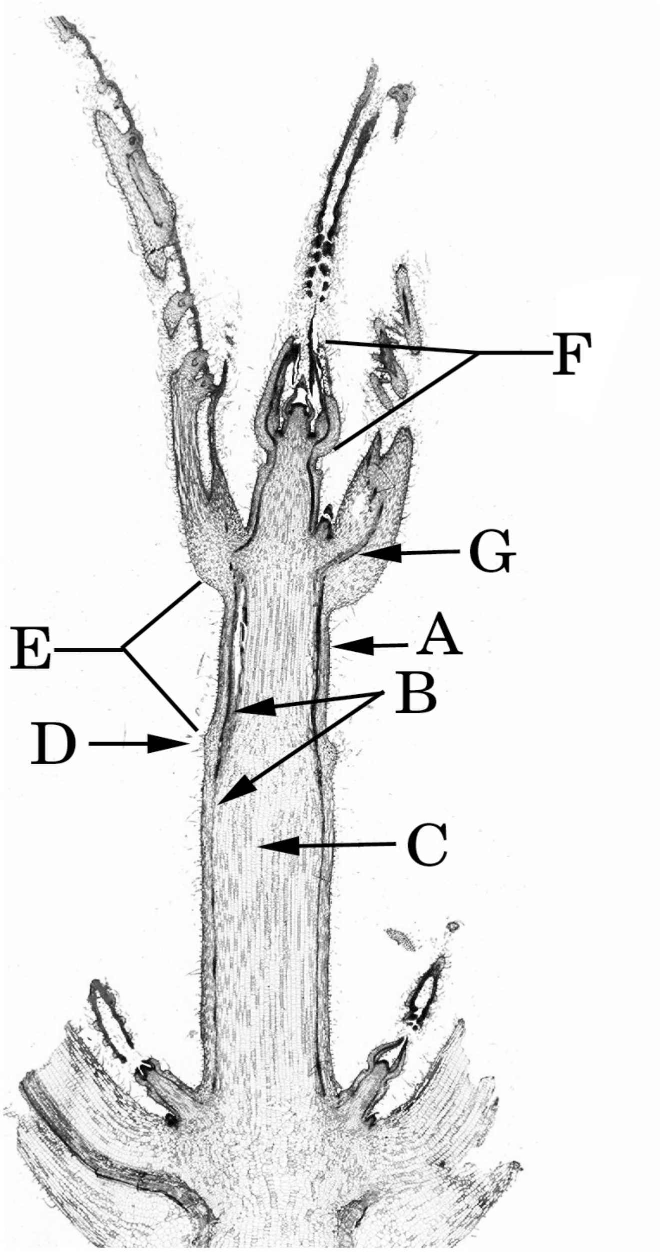
Are the leaves of the plant opposite or alternate?

How are the pairs of leaves at each node oriented relative to the leaves at the nodes above and below?

Again view the slide of *Coleus*. Based on what you learned from your observations of the living plant, can you determine how many nodes are represented on your slide?

Observe the tissues represented on your slide. Identify the three primary meristematic tissues, **protoderm, ground meristem,** and **procambium** below the apical meristem. Note the regions of the ground meristem that make up the **pith** and **cortex**. Because of the tight integration of leaf and stem, shoot anatomy is a bit more complex than that of the root. Strands of procambium tissue (**leaf traces**) diverge from the vascular bundles into the developing leaves (**the leaf primordia**). As they do so, they leave behind an area of ground meristem tissue called a **leaf gap**. To gain a clearer picture of the structure of these leaf gaps study the model of the *Coleus* shoot tip at the front.

Label the Figure:. A - C refer to the **three primary meristems**. Other labels indicate the following. **leaf primordium, node, leaf trace,** and **internode.**



A. ____________________

B. ____________________

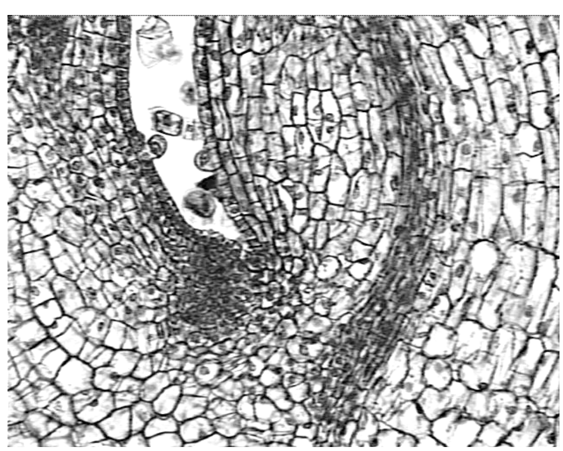
C. ____________________

D. ____________________

E. ____________________

F. ____________________

G. ____________________



Detail of a leaf Gap

II. Growth Response in Shoots - Negative Gravitropism

<u>The Effect of Seedling Age on Positive Gravitropism</u>

(one group to do this per section)

As in roots, shoots respond to environmental stimuli through growth. To survive, a plant's shoot must grow upwards towards the light. This response is due to differential elongation of the cells in the region of elongation. In a horizontal stem, the cells on the bottom will tend to elongate more than those on the upper side, resulting in the tip of the shoot tip bending upwards. How gravity is "felt" by the plant, and how this signal is translated, isn't completely understood, but the response is mediated by auxin.

<u>Procedure</u>. Take two seedling tomatoes of different ages, and measure their length. Lay them both on their sides in one large saucer. Next class meeting, measure exactly where on each plant the stem began to curve upwards, and record your observations

Plant	Older	Younger
Distance from the soil to the point where bending starts		
Proportion of the total* stem above the point where bending starts		

*Length bending starts to the tip ÷ Total length of the plant

III. Growth Response in Shoots to Dark Conditions

(three groups to do this per section)

Plant three bean seeds in each of two paper cups. Label each cup with your section and table numbers. Place one cup on the window sill in each room. Place the other in an enclosed box on the side bench. When you observe the first foliage leaves of your light-grown seedlings emerging, remove your dark-grown seedlings from their enclosure. Compare the growth form of the beans subject to each treatment.

What is the average length of the dark grown seedlings?

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What is the average length of the light grown seedlings?

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Describe other differences between the dark and light grown seedlings.

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How is the growth form of the dark-grown plant adaptive?

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Place the dark-grown plants on the window sill. Next lab, again observe the two plants. What has happened to the dark-grown plants during the time they were exposed to light?

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IV. Growth Response in Shoots: Apical Dominance.

Introduction. Plants exhibit varying degrees of apical dominance. In trees, we see examples with a pyramidal habit with one central leader such as pines .There are also examples such as elm and maple with no central leader, where the habit of the tree is rounded. The degree of apical dominance found in different plants may be related to differences in the amount of IAA produced by their meristems, or may be due to differences in the response of their buds and lateral shoots to IAA, or may be both. In this activity we will explore these ideas.

Each table of students will do a separate experiment. One group will use sunflowers. Commercial sunflowers (*Helianthus annuus*) manifest a high degree of apical dominance.Their lateral buds remain totally dormant and their apical meristem eventually produces a terminal inflorescence marking the end of growth of the plant. The hypothesis we will consider here is....

> **Apical dominance is absolute, the lateral buds cannot grow under any range of auxin concentrations.**

Another group will use tomatoes, *Lycopersicon esculentum*. *Lycopersicon* displays apical dominance but not to the degree of sunflower. The hypothesis we will consider here is....

> **Apical dominance is caused by the production of auxins by the apical bud.**

A third group will use *Coleus*. In *Coleus,* there is little or no apical dominance as the buds begin to grow immediately behind the apex of the plant. There are two alternative hypotheses we can consider here ....

> **Apical dominance is not manifested because the apical bud fails to produce sufficient auxin.**

and

> **Apical dominance is not manifested because the lateral buds do dot respond to auxin.**

<u>Procedure</u>.

For <u>sunflower</u> and <u>tomato</u>, take a pot with three plants. Remove the apical bud with any tightly clustered nodes at the apex from two of these plants. Add IAA in lanolin to one of these two by simply placing the capsule with the lanolin mixture over the cut stump.

For <u>*Coleus*</u>, take a pot with three plants. Add IAA in lanolin to one by simply applying the lanolin mixture liberally over the intact apex. Remove the apical bud of the second, and conduct no further treatment on the third.

Report. After two weeks an oral report will be due from your group on the results of your experiment.

V. Growth Response in Shoots. Effect of Gibberellic Acid on the Development of Genetically Dwarf Peas.

Gibberellic acid is a plant hormone associated with cell elongation. Dwarf peas either have lost the capability to synthesize GA, or else, the ability to respond to GA.

Procedure. One group will treat a pot of genetically dwarf plants with GA. There are many plants in each pot. Vary the dose applied to each plant using one, two or three drops. Each drop contains roughly 2.5 x 10^{-4} grams of GA. Tie differently colored string to each plant according to its dose. To treat a plant simply apply drops of GA anywhere on the shoot. Allow the plants to dry; label the pot with your section number, and place your pot on the window sill in your room. Over the next two weeks note the difference in the growth of the treated plants with the various doses and the untreated control.

Report. After two weeks an oral report will be due from your group on the results of your experiment. Do your observations support the idea that the dwarf plants have lost the ability to produce GA, or have the plants lost the ability to respond to GA.

VI. Stem Anatomy of Herbaceous Eudicots in Cross Section

Survey a slide of a cross section of a *Medicago* stem at 40x with your microscope. Note the arrangement of the **vascular bundles** dividing the **ground tissue** into **pith**, and **cortex**. This is a typical arrangement found in many eudicots. These same plants commonly have roots with tissues arranged like that of *Ranunculus* studied earlier with the vascular tissue in the center.

Structurally, how might this arrangement of the vascular bundles be adaptive to the plant?

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Switch to 100x and carefully study the xylem in one vascular bundle. Note that it consists of both red stained vessel elements and parenchyma cells. Also notice that the vessels become smaller towards the pith. Carefully survey the vessel elements to see which have incomplete secondary walls. These are protoxylem vessel elements.

In the stem, does the procambium fated to differentiate into xylem differentiate from the outside in, as you saw in the root, or from the inside out?

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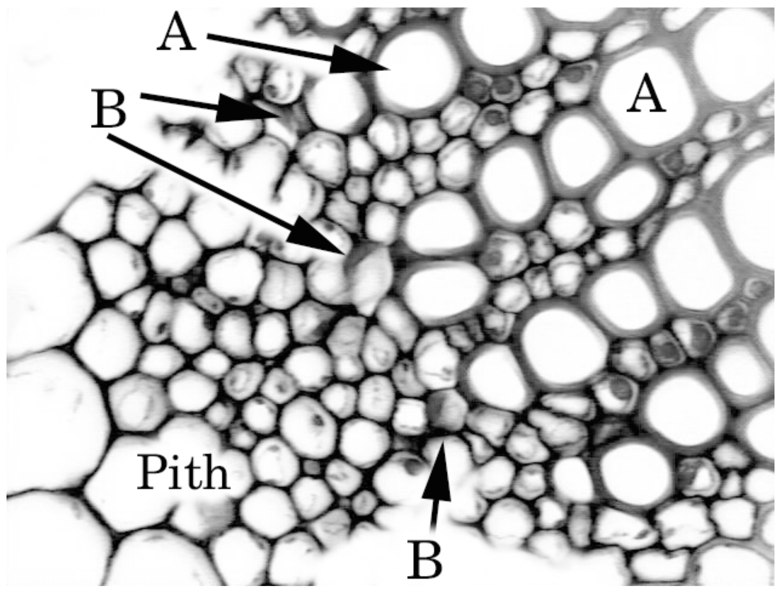
Switch your view to the phloem and carefully study the tissue at 400x. Identify sieve-tube elements and companion cells. The area of the phloem towards the cortex is filled with **fibers**. Along with sieve tube members, companion cells and parenchyma cells, phloem often includes fibers as seen here.

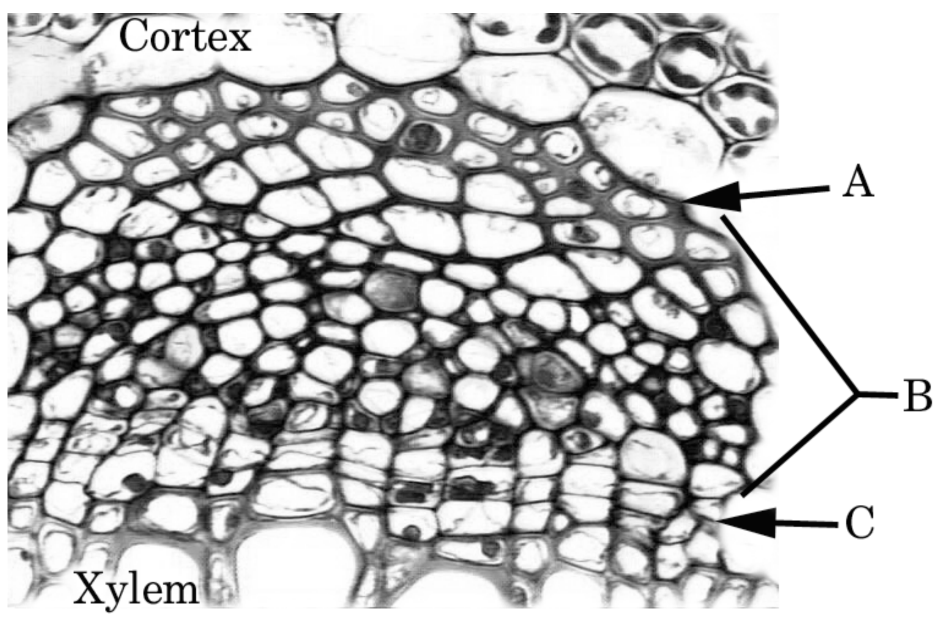
Label the Figures

Details of the *Medicago* Stem



A = ________

B = ________



A = ________

B = ________

C= ________

Observe the tissue between the primary xylem and phloem. This is the region of the **fascicular cambium**. The cells here were derived from procambium and maintain their ability to undergo cell division. A layer of dividing cells called **interfascicular cambia** also forms between the vascular bundles. Together these form one continuous cylinder of **vascular cambium** which will grow and increase the girdth of the stem. This growth is termed **secondary growth** and the tissues produced **secondary tissues**. Label the figure.

Detail of *Medicago* Stem Cross Section with Cambium.

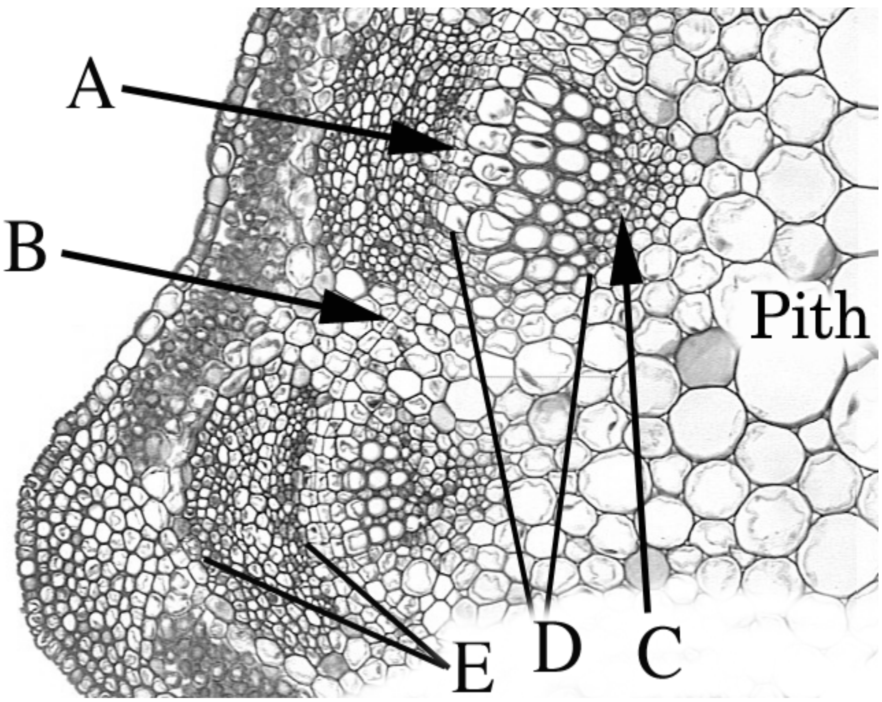
A = ___________

B = ___________

C = ___________

D = ___________

E = ___________



Draw the following cell types from the cross section of Medicago.

Parenchyma cell

Vessel Element with Associated Parenchyma Cells

Sieve-tube Element with a Companion Cell

VII. The Monocot Stem.

Place a slide of the *Zea* (corn) stem on your microscope and survey the cross section of the stem at 40x. (Not the longitudinal section!)

How are the tissue systems organized differently than in *Medicago*?

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Switch to 400x and closely examine a vascular bundle. First locate the xylem marked by the prominent vessels. Identify the protoxylem vessels based on their incomplete secondary walls. Now examine the phloem. Identify both sieve tube members and companion cells - this is an easy task in this tissue. Note the sclerenchyma surrounding the bundle. Note that monocots do not form cambia which produce secondary tissues.

Draw the phloem tissue. Label sieve-tube elements and companion cells.

Figure of Vascular Bundle of Zea Stem. Identify all labels.

A = ____________

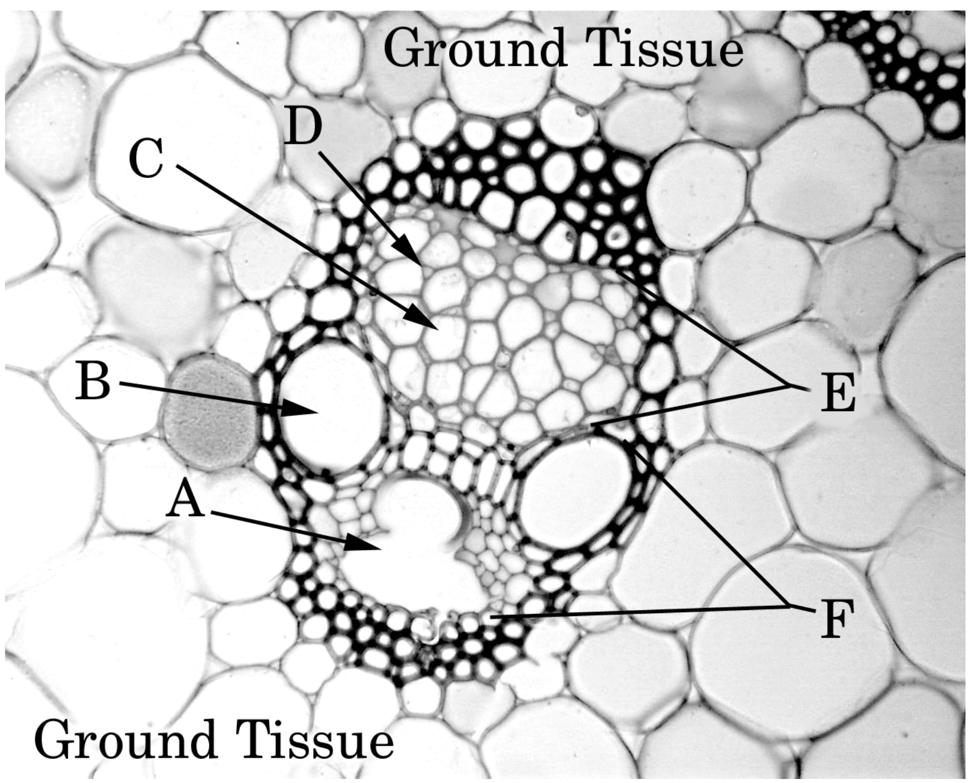
B = ____________

C = ____________

D = ____________

E = ____________

F = ____________



VIII. Leaves.

Typically, leaves have determinate growth. They grow to maturity and then all growth stops - forever. As we saw with the *Coleus* shoot tip, new leaves are produced from the apical meristem of the shoot. As covered in our first lab, leaves are associated with **axillary bud** which forms branches in the shoot

The Lilac (Syringa) Leaf

Cross Section. Survey the prepared slide of a cross section of *Syringa* leaf at 40x. Note how the three tissue systems are organized. Switch to 400x and carefully study an area of the blade away from the midvein. Observe the **upper** and **lower epidermi**s and carefully note any differences between these tissue layers. The **ground tissue** of the leaf is called the mesophyll, and is divided into an upper layer of vertically arranged cells (the **palisade parenchyma**) and a lower layer of horizontally arranged cells (the **spongy parenchyma**). **Veins** make up the vascular tissue. Each vein is encased in a layer of parenchyma cells called a **bundle sheath**. Every cell of the mesophyll is in close proximity to a minor vein. This is critical because the veins move water into and photosynthate out of the leaf. To gain an appreciation of how pervading this network of veins is, observe the demonstration slide of a cleared leaf available at the side bench.

Things to consider while viewing the cross section of the blade.

1. How might it be adaptive to have the palisade parenchyma arranged vertically?

2. Would you expect to find more stomata on the upper or on the lower epidermis?

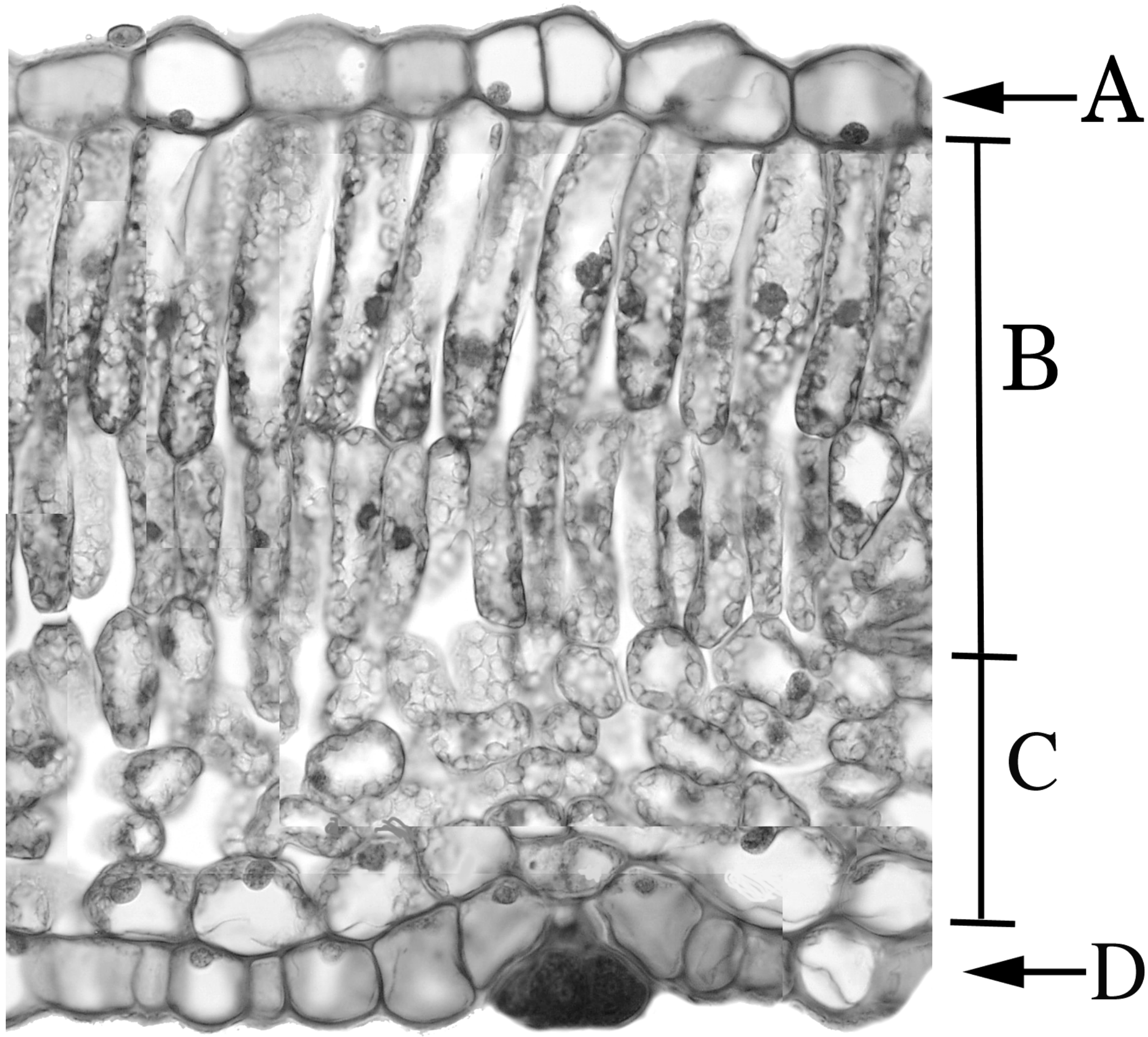
3. How do materials move to and from the minor veins to the cells of the ground tissue (palisade parenchyma + spongy parenchyma)?

4. What structure controls the movement of materials to and from the veins?

Carefully observe the midvein. Note that the xylem is on the top and the phloem is on the bottom. Try to identify sieve tube members in the phloem.

Based on how the xylem and phloem are arranged in the midrib, how are these tissues arranged in the lilac stem?

Label the Figure



Cross Section of Syringa Leaf Blade 1,000x

A = ________________ **B =** ________________

C = ________________ **D =**

Lilac Leaf Paradermal Section.

Place a prepared slide of a *Syringa* leaf in paradermal section onto your stage. First identify the upper epidermis by its concentration of stomata. Progressively identify and study the palisade parenchyma bordering the upper epidermis, the spongy parenchyma bordering the palisade parenchyma, and the lower epidermis.

- **Note** the amount of intercellular space in both regions of mesophyll.

- **Note** the tight arrangement of the basal epidermal cells.

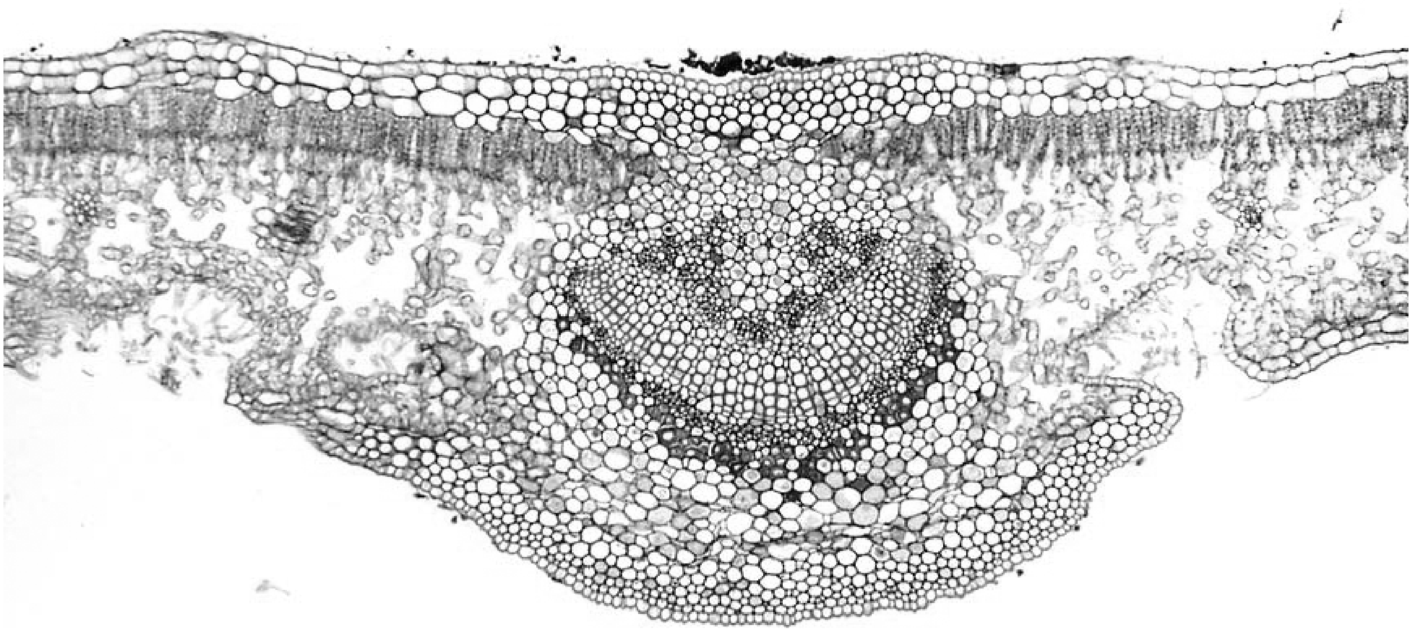
Draw a minor vein. Label vessel elements and the bundle sheath.

Draw a region of the lower epidermis. Label guard cells, basal cells of the epidermis, and the cuticle.

Anatomy of Leaves Adapted for Dry or Wet Environments

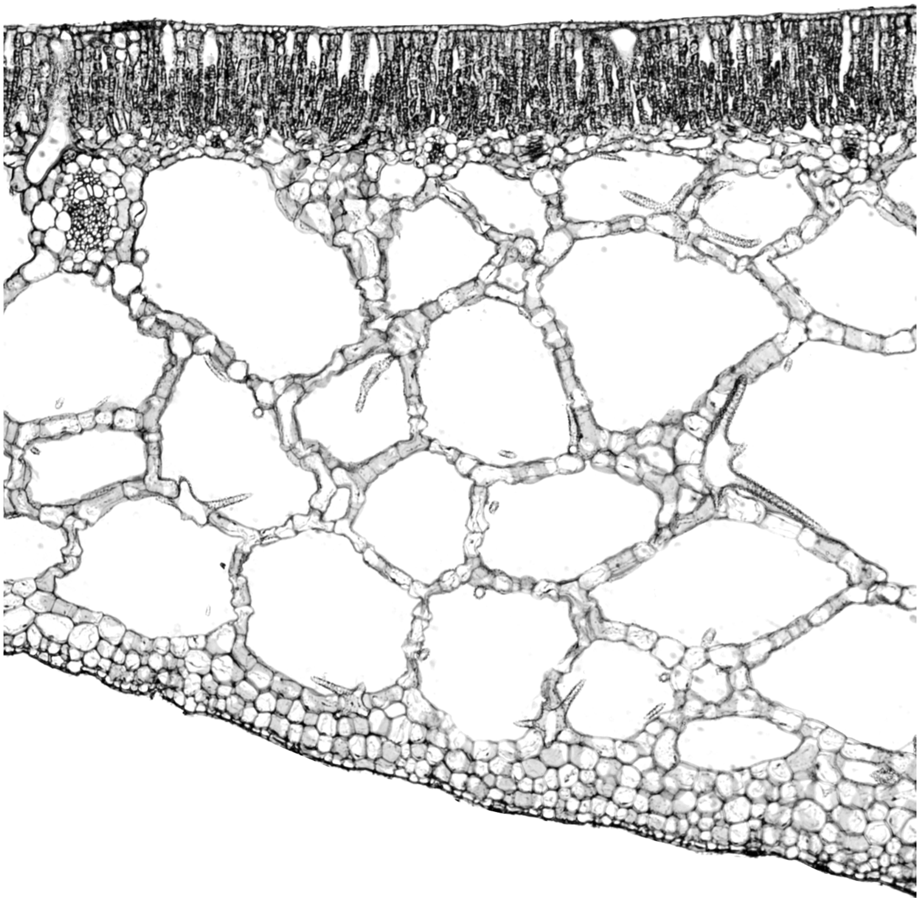
Syringa is a plant adapted to moist conditions. In your slide box are examples of two different other leaves adapted to different moisture levels. Both of these leaves have the same basic anatomy as *Syringa*. Each, however, has major differences.

Observe the leaves of *Nerium* and *Nymphaea*. Write down at least two ways they are different from *Syringa,* reflecting how they are modified to their specific environment. Exchange ideas with your classmates and with your TA.



Cross Section of Leaf of *Nerium oleander*

Notes for *Nerium oleander*. A plant that lives in a dry environment.



Cross section of *Nymphaea oderata*

Notes & Sketches for *Nymphaea*

oderata, a plant that lives in the water.

Zea Leaf Cross Section

Corn is an example of a typical grass leaf. Take a prepared slide of a cross section of *Zea* leaf and survey it at 40x. Now observe the corn plant on your bench. Note the parallel veins of the leaf. This is typical of the venation of monocots. Again study your slide and note the regular spacing of the veins. Also note that the ground tissue is uniform and is not differentiated into palisade and spongy layers.

How might this arrangement of the ground tissue be related to the natural orientation of grass leaves? ____

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Observe one of the veins at 400x and identify the xylem vessel elements. In the phloem, identify sieve tube members and companion cells. Note the bundle sheath.

Label the figure.

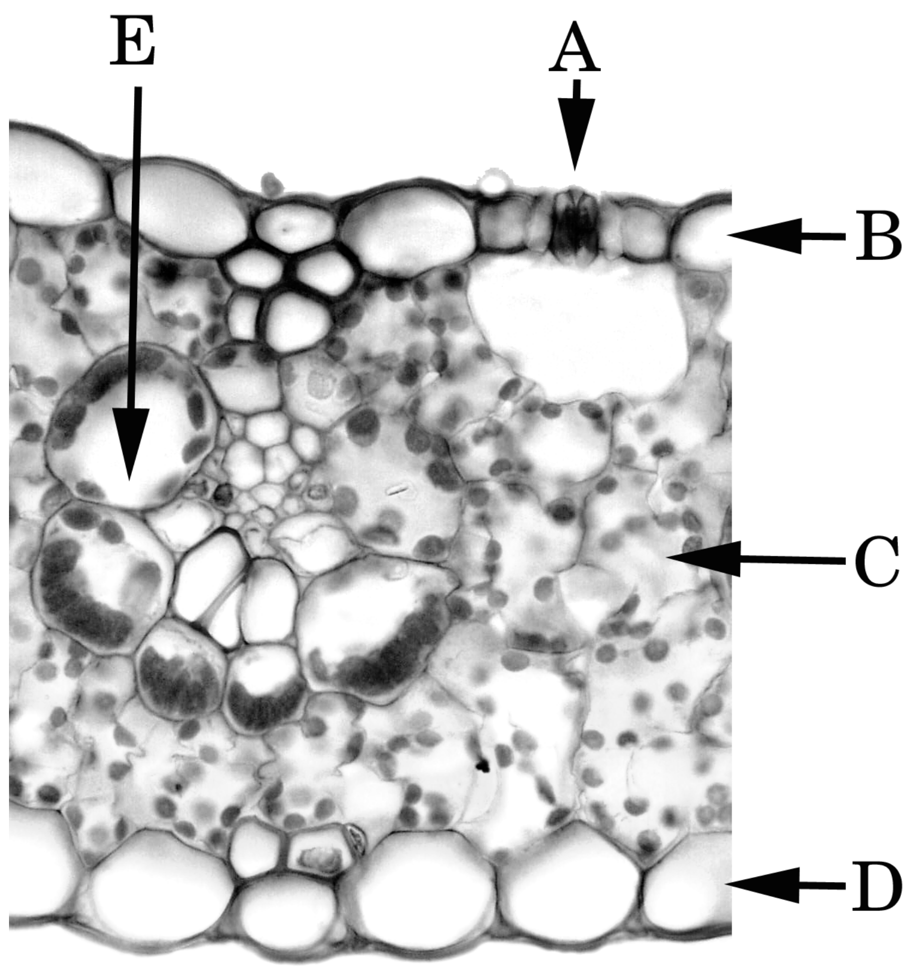
A = _______

B = _______

C = _______

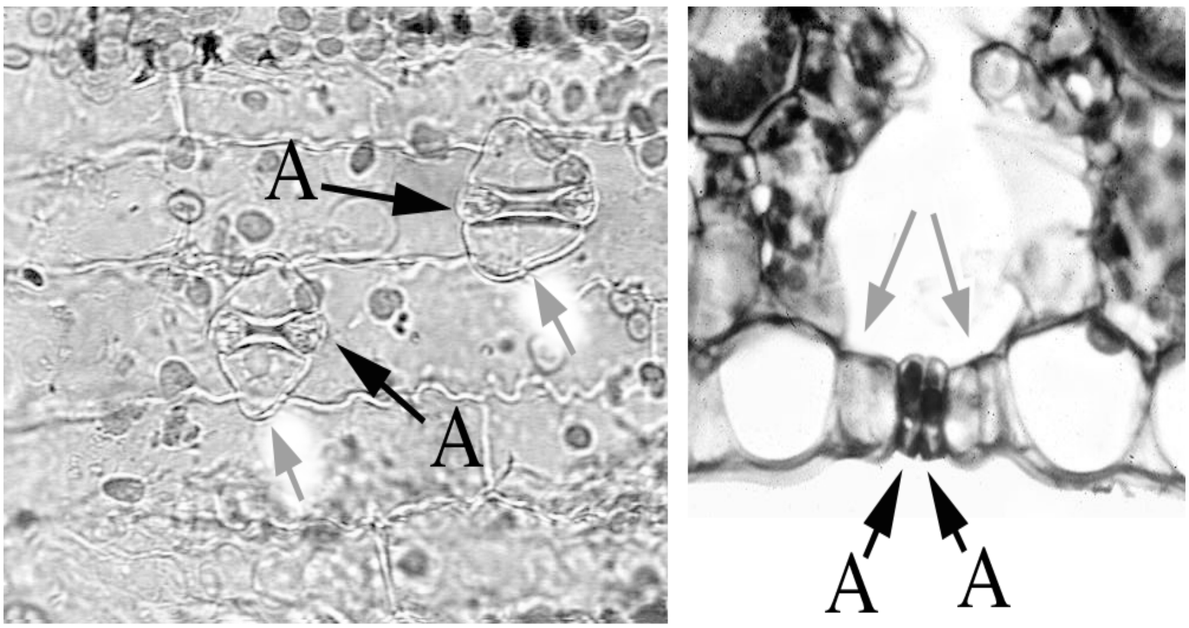
D = _______

E = _______



Cross Section of *Zea* Leaf 1000x

<u>Epidermal Scrape of the Corn Leaf</u>. Share good preparations. Lay a piece of corn leaf flat on a microscope slide.Using a razor blade oriented almost parallel to the leaf blade, scrape away the tissues above the lower epidermal layer. Cut out this region of the leaf and make a wet mount. Note the epidermal cells. Locate a **stoma** and note the **guard cells** with their associated **subsidiary cells**.



Two Views of the Epidermis of a *Zea* Leaf. To the left is a figure of an epidermal scrape, on the right is a cross section through a stoma. Guard cells are indicated by the letter “A”, subsidiary cells are indicated by the gray arrows.

<u>Conifer Leaves</u>

Take a slide of *Pinus* leaf in your box and survey the cross section at 100x. What shape is this whole leaf in cross section?

How does this relate to the to the surface/volume ratio of the leaf?

Locate the stomata of the leaf. How do they differ from the other stomata you have seen in this course?

Can you identify an endodermis in this leaf?

How are these various modifications adaptive? Pines can live on the same type of sites as lilac (*Syringa*

IX. The Role of IAA (indole acetic acid) in Leaf Abscission

<u>Each group to do one treatment as described below.</u>

<u>Introduction</u>. In some plants, leaf abscission is an active process involving the growth of a tissue layer that undercuts the petiole's attachment to the stem. In these plants, the leaf signals its health through the production of IAA which inhibits the growth of the abscission layer. If the leaf is unhealthy this signal is removed resulting in leaf abscission.

The hypothesis we will consider here is....

IAA applied to the plant will only affect the petiole to which it is applied.

<u>Procedure.</u>

Take a *Coleus* plant and remove four leaf blades at two nodes, while leaving the petioles attached to the stem. Either apply IAA in lanolin to the **cut surface of one petiole at each node**, <u>or</u>, to the **cut surface of the petioles both at the upper node**. Label your plants and set them on the light bench.

This hypothesis assumes that IAA will not flow across the petiole to affect other leaves.

Report. After two weeks an oral report will be due from your group on the results of your experiment.

Arrows Point to the Abscission Zone in Maple