Topic 14. The Shoot System

Introduction. This is the second of two labs that focus the three higher plant organs (root, stem, leaf). There are two basic objectives for these labs: recognition of how the tissues are organized in each of the three different plant organs; and evaluating how each of these organs function as a whole to ensure the plant's survival in its environment.

In most plants, stems serve to support the leaves which act as solar collectors that produce food. The tissues of the stem must conduct water up 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. At the tip is the apical meristem of the shoot. Behind the meristem are a series of leaf primordia that define the nodes. Note that the internodes become increasingly elongated as one moves down the stem. Inspect 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?

___________________________

Now focus on the tissues represented on your slide. Identify the three primary meristematic tissues (protoderm, ground meristem, procambium) behind 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 in the stem (leaf traces) diverge from 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. This is one of the defining characteristics of megaphylls (remember the leaves we are considering in these anatomy exercises are fundamentally different from those found in the phylum Lycophyta! - microphylls are not even thought to be homologous to megaphylls). To gain a clearer picture of the structure of these leaf gaps study the model of the Coleus shoot tip at the front.

Observe and label the figure on the next page
Longitudinal Section of Coleus Shoot Tip.

Identify all labels. 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
IIa. Growth Response in Shoots - Negative Gravitropism

The Effect of Seedling Age on Positive Gravitropism

(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 lower 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 this response is mediated by auxin.

Procedure. Take two seedling tomatoes of different ages, measure their length and make a drawing of each to scale. Lay them both on their sides in one large saucer. Place them on the side bench with a note card indicating your section number, the time and date. Next lab make another drawing to scale indicating exactly where on the plant the stem began to curve upwards.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Older</th>
<th>Younger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from the soil to the point where bending starts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion of the total stem above the point where bending starts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IIb. Growth Response in Shoots to Dark Conditions

(three groups to do this per section)

For a seedling plant to survive, when planted deeply, it will need to elongate more than a plant nearer the surface.

Plant three bean seeds in vermiculite 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 that the first foliage leaves of your light-grown seedlings have emerged, remove your dark-grown seedlings from their enclosure and compare the growth form of the beans subject to each treatment.
What is the average length of the dark grown seedlings?

________________________

What is the average length of the light grown seedlings?

________________________

Describe other difference between the dark and light grown seedlings.

_________________________________________________________________

_________________________________________________________________

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?

_________________________________________________________________

_________________________________________________________________

_________________________________________________________________


**Introduction.** Plants exhibit varying degrees of apical dominance. Among trees, in one extreme, we see examples with a pyramidal habit that manifest one central leader such as pines. In the other extreme, are trees 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 concentrations of IAA or may be both. In this activity we will explore this idea.
Each table of students will do a separate experiment. One group will use sunflower. 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 in that 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 auxin.**

and

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

**Procedure.**

For **sunflower and tomato**, 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....simply place the capsule with the lanolin mixture over the cut stump.

For **Coleus**, 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.** In two weeks an oral report will be due from your group on the results of your experiment.

Gibberellic acid is a plant growth substance associated with cell elongation. Dwarf peas have lost the capability to synthesize GA.

**Procedure.** One group to do this. At the front is a pot of genetically dwarf plants. Next to it is a dropper bottle of GA. Treat your pot by placing three drops of GA solution on each plant. Allow the plants to dry; label the pot with your section number, and place your pot on the light bench in your room. Over the next two weeks note the difference in the growth of the treated plants vs. the untreated control.

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

III. 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 the circular arrangement of three or more vascular bundles embedded in the ground tissue be more structurally adaptive for a stem than the arrangement of one strand of vascular tissue in the center found in the root?

**Hint.** What forces is the stem subject to that the root is not?

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. These smallest vessels are protoxylem vessels and the larger vessels, towards the cortex, are metaxylem vessels.
How does the direction of differentiation of the xylem in this stem differ from that of *Ranunculus* root studied earlier in Topic 12 (inside out vs. outside in)?

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 protophloem and is filled with fibers. Along with sieve tube members, companion cells and parenchyma cells, phloem often includes fibers as seen here.

Observe and identify the labels that follow

**Details of the Medicago Stem**

A = ________

B = ________

C = ________
Study the area 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. Also, cambia form in the ground tissue situated between the vascular bundles. These cambia, together with the fascicular cambia, form one continuous cylinder of **vascular cambium**.

Detail of *Medicago* Stem Cross Section with Cambium. Identify all labels.

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

IV. 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 is this stem structured differently from that of Medicago?

Because of the arrangement of the vascular bundles the ground tissue is not clearly divided into different regions. Hence, we do not use the terms cortex or pith and we simply use the generic term “ground tissue”.

Switch to 400x and closely examine a vascular bundle. First identify 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. Now note the sclerenchyma surrounding the bundle. This is a closed bundle with no area of cambium. Typically monocots do not have secondary growth, and, in the few cases where they do, the pattern of that growth is entirely different from that observed in Eudicots.

Draw the phloem tissue. Label sieve-tube elements and companion cells.
V. 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. While expanding, the leaf tissues are made up of procambium, ground meristem and protoderm. As these tissues mature, usually no apical meristems form in the mature leaf. New growth in shoots typically arises from buds. As covered in our first lab, a simple leaf can be distinguished from a leaflet of a compound leaf by the location of the axillary bud.

Va. The Lilac (Syringa) Leaf

**Cross Section.** Survey the prepared slide of the cross section of Syringa leaf with your microscope at 40x. Note the blade and the midvein as viewed in cross section. Switch to 400x and carefully study an area of the blade away from the midvein. Note the three tissue systems. The dermal tissue is represented by the upper and lower epidermis. The ground tissue of the leaf is the mesophyll, and here is represented by an upper layer of elongated, vertically arranged cells (the palisade parenchyma) and a lower layer of horizontally arranged cells (the spongy parenchyma). The vascular tissue is restricted to the veins. Every cell
is in close proximity to a minor vein. This is critical because the veins ultimately move water to and also move photosynthate out of each and every cell. 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?

Now 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?

**Identify all labels on the next page.**
Cross Section of Syringa Leaf Blade 1,000x

A = ________________  B = ________________

C = ________________  D = ________________
The Lilac (*Syringa*) Leaf Continued.

**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.

**Vb. 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 of *Syringa* in that the mesophyll (ground tissue) include palisade and spongy layers. However, each has major differences in that one is adapted to dry conditions while the other is adapted to wet conditions. Observe these leaves (*Nerium* and *Nymphaea*) and write down at least two modifications, with sketches, that you observe for each that is adaptive to their environment. You should also discuss ideas about these adaptations with your TA.
Cross Section of Leaf of *Nerium oleander*

Notes & Sketches for *Nerium oleander*
Notes & Sketches for *Nymphaea oderata*

**Vc. Zea Leaf Cross Section**

We have already observed corn leaf cross sections during our laboratory on photosynthesis. We now will study this leaf as 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. This is typical of grasses.

How might this arrangement of the ground tissue be related to the natural orientation of grass leaves?
Observe one of the veins at 400x and identify the xylem vessel members. In the phloem identify sieve tube members and companion cells. Note the bundle sheath. C-3 plants also have bundle sheaths (as you should have observed earlier). In corn and other C-4 plants, however, these cells have become physiologically differentiated from the mesophyll cells.

Where does carbon fixation initially occur?

Where does the Calvin Cycle occur?

**Label the figure.**

**Cross Section of Zea Leaf 1000x**

A = ________

B = ________

C = ________

D = ________

E = ________
Epidermal Scrape of the Corn Leaf. Share good preparations. Lay a piece of corn leaf flat on a microscope slide, and 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.

Vd. Conifer Leaves

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 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?

This leaf is adapted to cope what major environmental challenge related to its evergreen habit?
Ve. The Role of IAA (indole acetic acid) in Leaf Abscission

Each group to do one treatment as described below.

**Introduction.** Leaf abscission is the active removal of a leaf by the growth of a tissue layer that undercuts its attachment to the stem. If a leaf is unhealthy it is adaptive to the plant to remove the leaf before it becomes a source of infection. In *Coleus*, and in other plants, the leaf signals its health by the production of IAA. The auxin inhibits the growth of the abscission layer and the leaf remains attached.

**Procedure.**

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**, or to the **cut surface of the petioles both at the upper node**. Label your plants and set them in a location where you can locate the plants during the following two weeks. The hypothesis we will consider here is....

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

This hypothesis assumes that IAA can flow in one direction, down the petiole, and, while it may move down the stem, it will not move back up to an abscission zone to affect a petiole in a lower tier of leaves or across a node.

Label your pot with your section and table number and place your pot in a window sill.

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