Topic 14. The Root System

Introduction. This is the first 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, roots fulfill two fundamental roles: **absorption** of water and nutrients, and **anchorage**.

I. Gross Morphology of a Young Root

Grass Seedling Root: Make a wet mount of a grass seedling and observe the seedling root at 40x. Identify the **root cap**. Above the root cap are growing tissues extending up to the root hairs. Growth is due to a combination of cell division and cell elongation. Switch to 400x and carefully observe the root cap. These cells protect the apical meristem as the root is pushed through the soil. Move up the root to the region with the root hairs. Carefully study a root hair at 400x.

Is the root hair multicellular? ______________________

What is its relationship to the basal cxells of the epidermis? _________

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II. Anatomy of an Actively Growing Root Tip

Place a prepared slide of a longitudinal section of *Zea* root on your microscope and observe at 40x. Relate your observations of the whole seedling root with this view of the internal anatomy. Above the tip of the root cap is the apical meristem of the root. The apical meristem of the root produces new cells through cell division. Some derivatives of the apical meristem become part of the root cap and are eventually sloughed off. The tissues, above the apical meristem, include dividing cells. These tissues, together with the apical meristem, constitute the **region of cell division.** Above the region of cell division, cells elongate driving the root tip forward. These cells make up the **region of elongation**. Throughout these two regions, cells differentiate and become organized into **three primary meristematic tissues**: the **protoderm**, the **ground meristem**, and the **procambium**. The protoderm will mature into the **epidermis**; the ground meristem into the **ground tissue**, and the procambium into the **vascular tissue**. If you survey the cells moving up from the root tip you will see that at some point the cells arrive at a uniform size. It is here that elongation ends and where root hairs form. It is also here that the tissues become mature, hence, this region is called the **region of maturation**.

Why is it adaptive for root hairs to develop in the region of maturation?

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Label the Figure

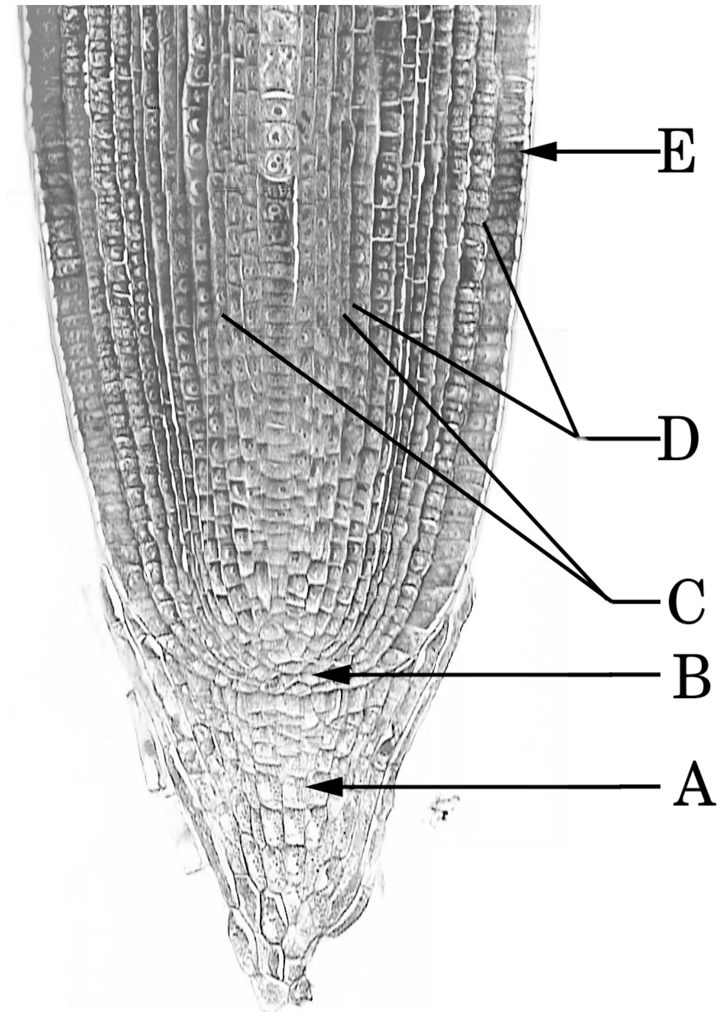
A = _______________

B = _______________

C = _______________

D = _______________

E = _______________



Longitudinal Section of a Root.

All the tissues of this root are either cells of the apical meristem of the root, or else were derived from that meristem. Tissues derived from apical meristems are called **primary tissues**.

III. Growth Response in Roots - Positive Gravitropism

Unlike animals, plants typically do not move rapidly. However, plants do respond to environmental stimuli through growth. **Growth** is an irreversible increase in size. In the root tip, growth is a phenomenon of cell division and cell elongation. To survive, a plant's roots must grow downwards to provide the plant with anchorage, and to absorb water and minerals. This response is facilitated by the differential elongation of the cells in the region of elongation. In a horizontal root, the cells on top will tend to elongate more than those on the lower side resulting in the tip of the root bending downwards. How gravity is "felt" by the plant, and how this signal is translated isn't completely understood, but seems to involve the root cap and plant growth substances. Observe the demonstration of positive gravitropism at the front.

IV. Anatomy of Mature and Immature Eudicot Roots

We will now observe two cross sections of a root at two different regions of maturation.

Place a slide of a mature *Ranunculus* (buttercup) root on your microscope. Survey the entire section at 40x. Note that the organization of the tissues here is quite different from those we observed earlier in the dicot stem. The vascular tissue is in the very center of the root. The ground tissue surrounding the vascular cylinder forms a **cortex**. An epidermis surrounds the entire root. The central region of vascular tissue is termed the **vascular cylinder**.

In terms of the stresses placed on a root how might this tissue arrangement be adaptive?

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Note that the cell walls of the innermost layer of cells of the cortex stain red. These cells make up the **endodermis**. The endodermis is the innermost layer of the ground tissue. All the tissues inside the endodermis are derived from procambium. **Xylem** fills the very middle of the vascular cylinder and its boundary is marked by ridges and valleys. The valleys are filled with strands of phloem. There are as many strands of phloem as there are ridges of xylem. Note that each **phloem** strand has one enormous sieve tube element. Immediately below the endodermis, is a layer of undifferentiated cells called the **pericycle.** The pericycle gives rise to lateral roots.

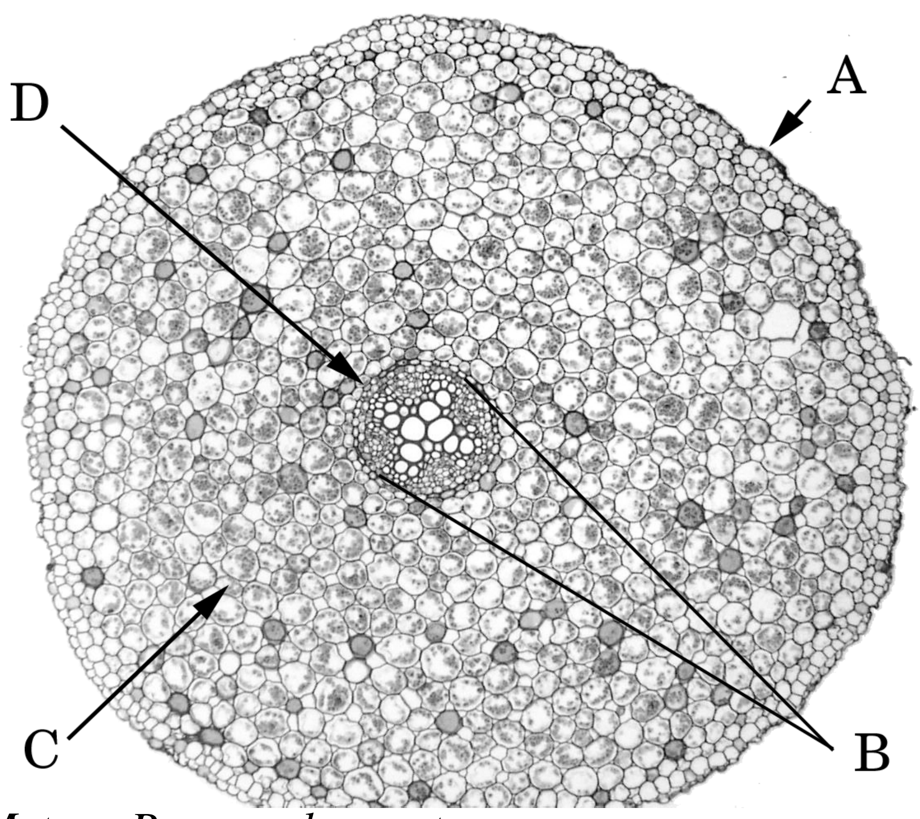
Lable the figure.

A = ____________

B = ____________

C = ____________

D = ____________



Mature *Ranunculus* root

Place the slide of an immature root of *Ranunculus* on your microscope and survey the section at 40x. This cross section was made closer to the apical meristem of the root, and has immature tissues. Note that the tissue in the very center is procambium that will mature into xylem.

Are there any mature vessel elements in this cross section?

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Where are they located?

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Based on your observations of both mature and immature roots, in which direction does differentiation progress in the procambium fated to become xylem?

Circle One: **from the inside out** or **from the outside in**

The movement of materials through the immature root: Carefully observe the endodermis of the immature root. Note that walls of these cells are not uniformly stained red as seen in the mature root. However, two of the four walls seen in cross section do have an area that stains red. These regions of the cell wall and middle lamella are **casparian strips**. They prevent water from moving between the endodermal cells. To get into the vascular cylinder water must cross through the protoplasts of the endodermis.

Label the Figure

A = _________

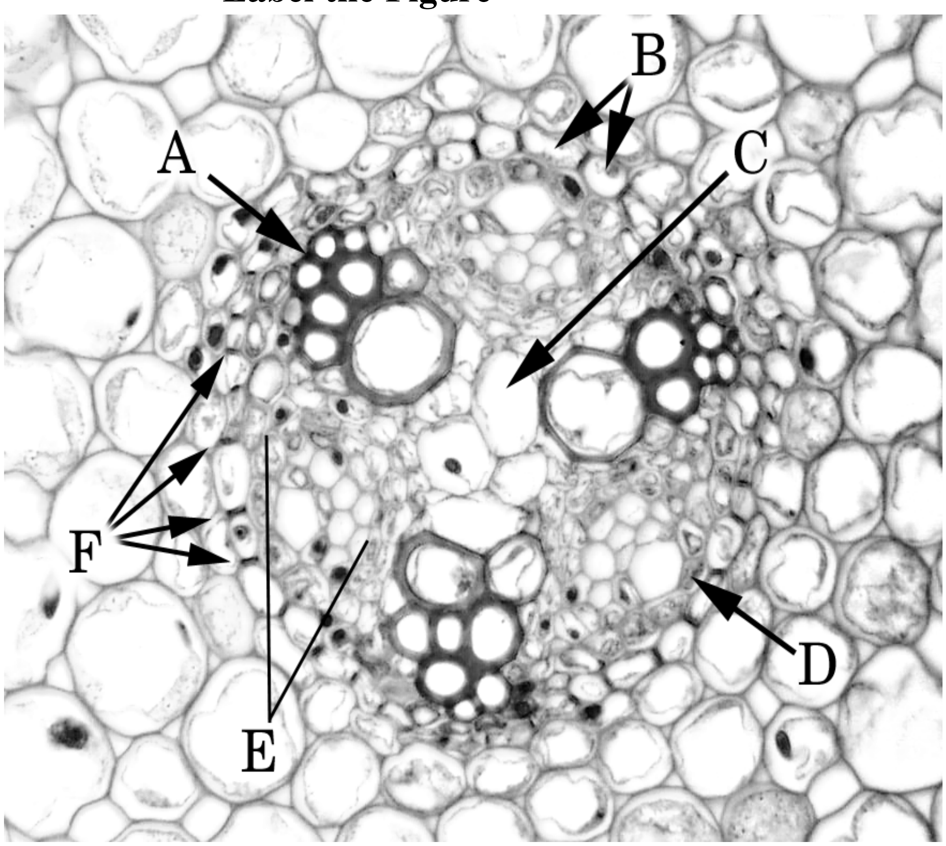
B = _________

C = _________

D = _________

E = _________

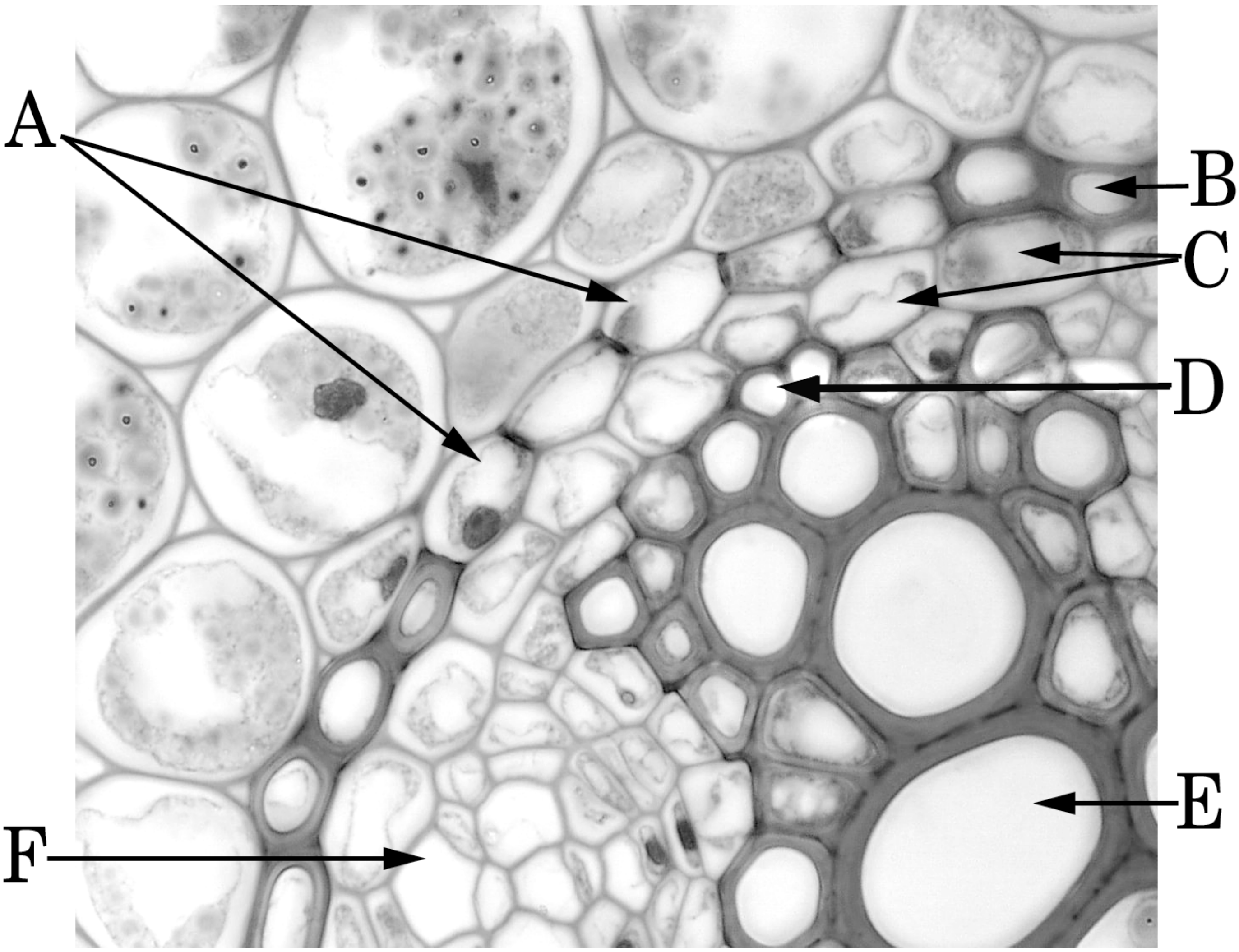
F = _________



Immature *Ranunculus* Root

Another look at the mature root: Switch back to the slide of the mature root and observe the vascular cylinder. It should now be clear that the tissue at the ridges of the xylem matured before the tissue in the center. Closely observe the endodermis. Most of the endodermal cells have a secondary wall consisting of a layer of wax and suberin that stains red. These secondary walls block all water movement to the underlaying membranes. For these cells, materials can only enter and exit via plasmodesmata. However, the endodermal cells near the ridges of the xylem do not have this secondary wall. Water can still pass through these cells via the cell membranes. These cells are called **passage cells**.

Label the Figure



Detail of the Mature *Ranunculus* Root

A = ____________________

B = ____________________

C = ____________________

D = ____________________

E = ____________________

F = ____________________

V. Root Pressure

When the rate of transpiration is high, the pressure inside the xylem is less than the surrounding air pressure. When transpiration rates are low, however, pressure can build up in the xylem. This pressure is generated osmotically . Endodermal cells actively move mineral nutrients into the vascular cylinder of the root. This lowers the concentration of water in the xylem relative to the water concentration in the cortex resulting in the movement of water across the endodermal cells into the xylem.

Guttation: One consequence of root pressure is guttation. See the demonstration of guttation on the side bench.

What is dew and how is this different? ____________________________

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Observing the Consequences of Root Pressure and Transpiration in Tomato Plants

Each group to conduct this experiment

The process that generates root pressure occurs 24 hours a day though guttation appears only at times of reduced transpiration. In the following activity we will determine if pressure can build up in the xylem during transpiration: Consider the hypothesis -

In herbaceous plants the xylem of the root is under positive pressure even during transpiration.

Procedure:

- You will work in groups (three groups per section).
- Observe the pot provided with two tomato plants. Check to see that each is healthy. Water the soil in the pot.
- Remove the top part of each shoot from each plant.
  - From one plant, cut off enough of the shoot to remove all of the leaves.
  - From the second plant, cut off only the very top of the shoot so that three or four leaves remain below the cut.

- The cut stumps must be sized so that a piece of latex tubing will fit tightly around each. Make both cuts at an angle as this will help with the next step.

- <u>Fit latex tubing attached to a .2 ml graduated pipette to each cut stump and add color dye</u>.

  - For this experiment to work, you must tightly fit a piece of latex tubing to each stump. Several sizes of tube are available. Choose a size that conforms to each stump.

  - Once you choose a size that seem appropriate, attach a .2 ml pipette to one end of each latex tube. Then, after lubricating the tube with glycerine, push the other end of the latex tube over the cut stump. Now, fill each latex tube with its attached pipette with dye. **Your TA will show you how**. Seat the pipette in the knuckle attached to the ring stand. Repeat with the other plant.

- <u>Record the volume in your pipette</u>.

  If your pipette is completely full when you initially set it up, pinch the latex tube in the middle to push out some of the liquid. Record your data in the table.

Plant	start	2 minutes	5 minutes	10 minutes	20 minutes
With leaves					
No leaves					

Do your results support the hypothesis?

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What factor influences the pressure most in the xylem of the plant without leaves?

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What factor influences the pressure most in the xylem of the plant with leaves?

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VI. Promotion of Root Growth by a Synthetic Auxin

Only one group to do this.

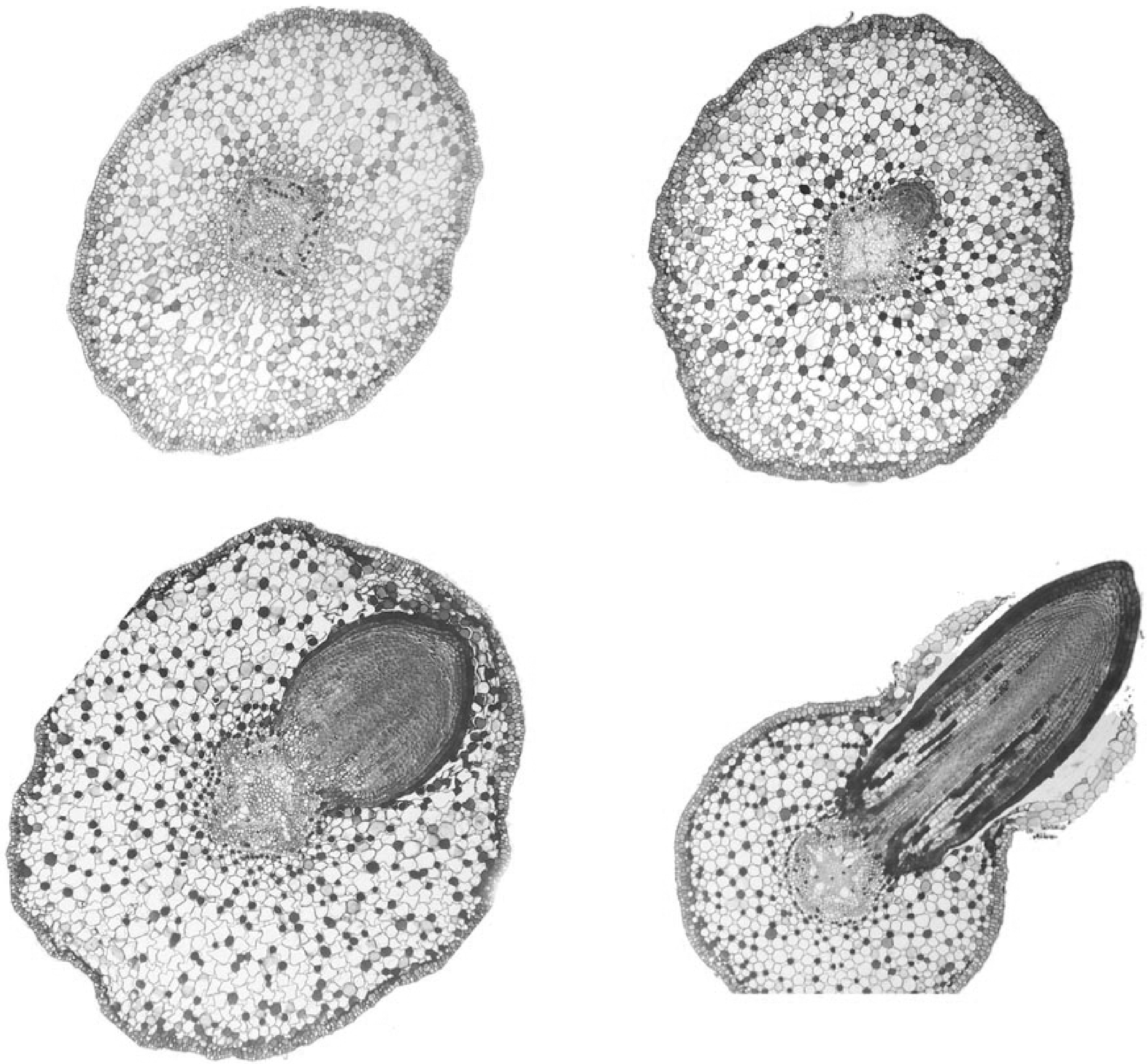
Auxins are plant hormones produced by the apical meristems of shoots. Auxins move downwards through the shoot to the roots. A vigorous shoot system will stimulate the growth of a vigorous root system via the auxins produced. Auxins can hasten the formation of adventitious roots, and are commonly used by horticulturalists to propagate plants from cuttings. In this exercise we will evaluate the effect of Indole-3-butyric Acid, a synthetic auxin, on the formation of roots in *Coleus*.

Procedure: Cut two lateral shoots from a *Coleus* plant. Remove the leaves from the bottom nodes leaving a bare stem not terminating with a node. Dip the part of the stem below the leaves of one shoot into water, and then into a dry compound of Indole-3-butyric acid. Insert the cut stump into one of the cups provided, and fill with water saturated peat moss. Label this cup “Auxin.”

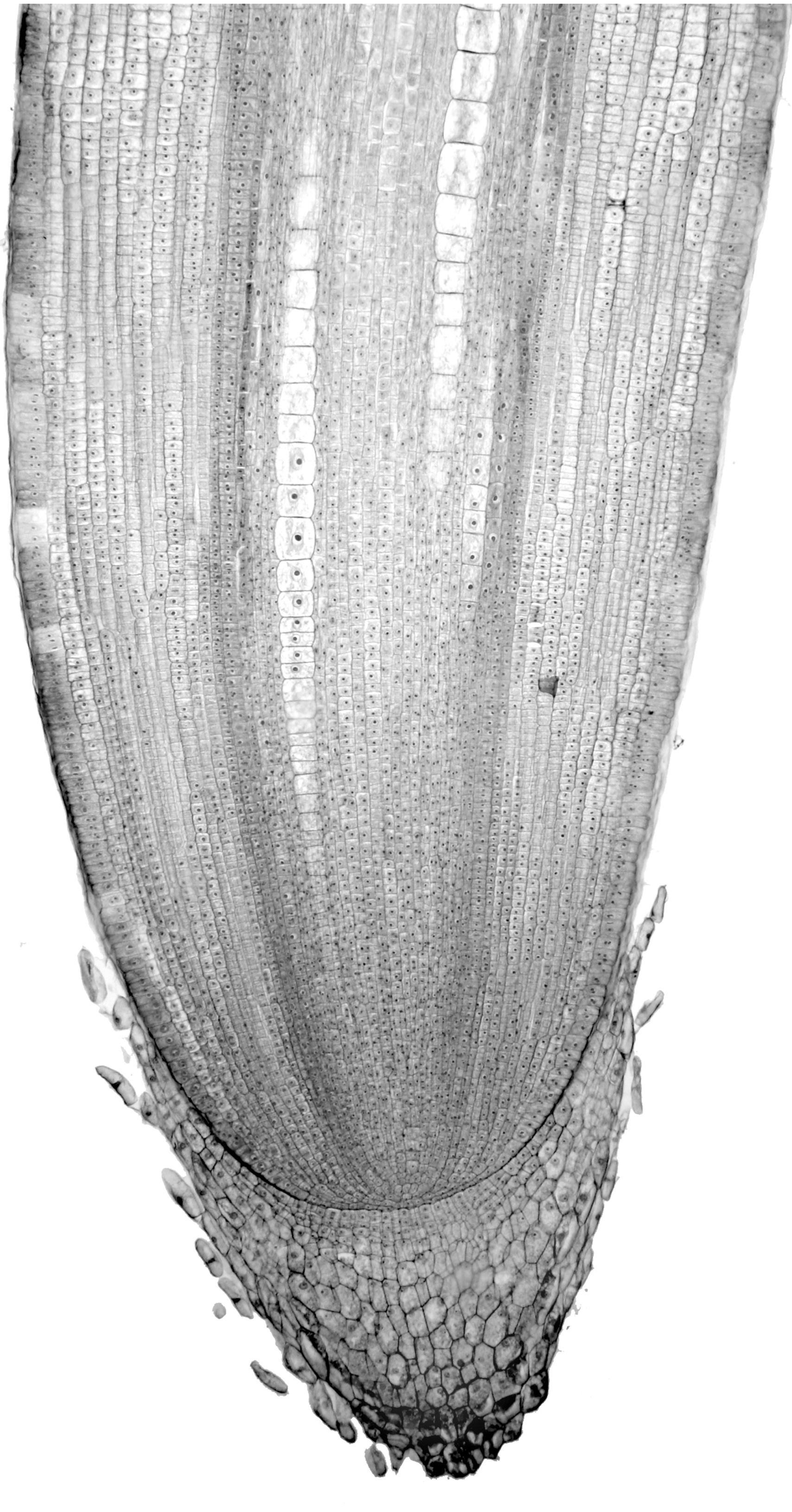
Repeat this step with a second shoot but do not treat it with Indole-3-butyric acid. Simply plant it, as described above. Label this cup “control”. Enclose each cutting in a plastic bag and place in the window sill. In two weeks remove these cuttings from the peat moss and compare the differences in their development of adventitious roots. Make a sketch below:

VII. Origin of Branch Roots

Roots don't have leaves, nodes or axillary buds. In roots, branching occurs from within. Specifically, branch roots form from the pericyle. Observe the demonstration series of slides on the side bench of lateral branching in*Salix* (Willow).



Lateral Root Formation in Willow (*Salix)*



Zea Root Tip l.s.