

wrong	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
right	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	
score	100	98.8	97.5	96.3	95.1	93.8	92.6	91.4	90.1	88.9	87.7	86.4	85.2	84.0	82.7	81.5	80.2	79.0	

Morphology & Anatomy Name _____

The purpose of this exercise is to briefly examine a few plants to become familiar with their external morphology (study of form) and internal anatomy (how they are put together inside). But before we begin, let us first determine what organism is meant by the word "plants." Unfortunately the concepts of organisms and species have changed drastically through the years. In the dark ages, botanists were blissfully ignorant and woefully unequipped to see the structure of plants. Leeuwenhoek had not yet invented the microscope. Scientists considered only two types of organism: animals and plants. It was easy to tell a plant from an animal in those days: animals were not usually green and could move while plants were usually green and could not move. Of course we now know that not all plants are green and many can move. Moreover some animals are green and many do not locomote. Thus, in ancient times many organisms such as blue-green algae, fungi, and algae were considered plants. We now know that these are not true plants and will not consider them in this exercise. Instead our examination is limited to the vascular plants: organisms possessing three vegetative organs: root, stem, and leaf.

Throughout this exercise you will be asked to make drawings. These are not to be artistic renderings of the subject, but are to be functional diagrams. You should bring with you and use a sharp pencil to make the drawings. You should draw the outline shape of the objects you observe without any type of shading or color. Your drawing should be LARGE so that all of the important fine structures are clearly rendered. Every important structure must be labeled. In this exercise, the structures to be labeled are indicated in **bold** type. Before handing your drawings to the instructor for examination, BE SURE that you have labeled all of the structures indicated. Spend no more than 20 minutes making each drawing.

I. Morphology of the bean plant: *Phaseolus vulgaris*.

A. The **leaves** are broad at the **blade** and are attached to the stem by means of a stalk-like **petiole**. The leaf may be simple (have only one blade per petiole) or compound (usually three blades per petiole). There may be two **simple leaves** or one **compound leaf** attached at a spot on the stem called a **node**. The **veins** of each leaf blade are arranged into a complicated network. Where the stem and leaf join, there is a swollen area of the petiole (**pulvinus**) that is responsible for leaf movements. At night the bean leaves fold together and down toward the soil; at dawn the leaves unfold and are lifted into the sun. You may see this process dramatically on the sensitive plant (*Mimosa pudica*). These leaves rapidly fold in response to touch and vibration and then unfold over about 20 minutes in bright sun. Some plants operate their leaves quickly enough to trap insects (*Dionea muscipula*, the Venus flytrap, and *Utricularia*, the bladderwort, are examples). So who says plants cannot move?

Two special leaves may still be attached to your bean plant. These are the **cotyledons** or seed leaves. These leaves are very fleshy and are used by the plant to store starch and other complex molecules in the seed for the later nourishment of the growing plant. On your plant, the cotyledons may be withering due to loss of starch and may have turned green to help produce more nutrient through photosynthesis. The cotyledons may have been completely used up and abscised (fallen off). The portion of the stem below the cotyledons is called the hypocotyl.

B. The bean **stem** is quite long and the **internodes** between leaf attachments (**nodes**) are quite obvious. The lowest portion of the stem is below the cotyledons and is called the **hypocotyl**. The stem terminates at the top of the plant in the **apical bud**. **Lateral buds** are found in the axils of each leaf just above the node. This bean plant is a "bush" variety that has shorter stems than the wild-type "pole" beans. The stem tips of pole beans grow very rapidly in a twisting manner and "whip around" at several cycles per day. When the stem

touches an object, changes in the production of plant hormones cause the stem to twist tightly around and grow up the object. This twining habit is called circumnutation and is common among vines like pole beans. How did we get bush beans from wild pole beans? They resulted from a plant with a chance mutation in a gene coding for a plant hormone involved with stem growth. They cannot produce enough gibberellic acid for extensive stem growth.

- C. The **roots** of the bean plant are mostly fibrous, although a single main root (the **taproot**) is larger than the others. The taproot forms many fine **lateral roots** that make up the bulk of the mineral absorption area. Some plant roots are contractile; they shorten to pull the plant around in the soil. In one case (*Oxalis*) the roots can pull the plant 60 cm through the soil in one year. While they operate very slowly, these roots prove that plant locomotion is possible. Many plant species have contractile roots, but they usually serve only to pull the stem deeper into the soil, not across the soil.
- D. In the space provided below, make a **diagram of a bean plant**. Label the diagram completely using the words printed in **bold** type by connecting the structures of your diagram with lines to the labels.

apical bud

lateral bud

blades } **compound**
petiole } **leaf**

veins

pulvinus

stem { **node**
internode
node
hypocotyl

blade } **simple**
petiole } **leaf**

cotyledon (or scar)

taproot

lateral roots

II. Plant Anatomy (Internal Structure)

Now that you have some idea of the external parts of a plant, you will examine some internal parts. You will briefly examine the internal anatomy of a typical vascular plant.

The parts inside of a leaf, stem, or root are very small, so the examination would normally require the use of a microscope. This optical device is used to examine structures that are in the range of one millimeter or smaller in diameter. It can, for example, easily detect the individual fibers that make up the paper of this page. The period at the end of this sentence could easily cover the complete field of view through a microscope. In the absence of suitable microscopes, your instructor will show you some photographic slides taken through a microscope. If microscopes are available, remember the microscope is a delicate instrument and should be handled carefully. Your instructor will demonstrate the parts and use of the microscope for you. Please do not manipulate the microscope until you are sufficiently familiar with it.

Vascular plants have an advanced form of vascular (conductive) tissue consisting of xylem and phloem tissues. These two tissues are arranged in a characteristic pattern that we shall soon examine. These tissues are typically surrounded by a tissue known as ground parenchyma. Each plant organ is covered by a single layer of cells known as the epidermal tissue. The cells of these plant tissues typically have cellulosic walls, true nuclei, numerous chloroplasts, prominent vacuoles, and store starch. You should be able to observe these cellular structures in some of the cells you will observe today with your microscope or from the photomicrographs. The colors you will observe in specimens are artificial. The thin sections of plant organs have been dyed with a series of dyes (green, red, and purple) that are absorbed by structures containing particular chemicals. The red dye, for instance, stains areas rich in fatty, oily, or waxy chemicals, whereas the green dye stains cellulose (a polysaccharide). Sections of living plant tissues would typically not have any color except yellow or green in the chloroplasts (chlorophyll is a green pigment, carotene is a yellow pigment) or red colors in the vacuole (anthocyanin pigments found typically only in flower or fruit tissues).

In making your drawings, do NOT draw in every cell you observe; if a region is composed of many cells, outline the region and draw only a few cells (5 or 6) in detail. DO NOT draw in hundreds of tiny imperfect circles!! Your instructor will demonstrate a good drawing early in the laboratory period. Every important structure should be labeled. In this exercise, the structures to be labeled are indicated in **bold** type. Before handing your drawings in for examination, BE SURE that you have labeled all of the structures indicated. Spend no more than 20 minutes making each drawing.

A. The leaf. Obtain a prepared slide of a leaf cross section and examine it carefully with your microscope. Locate the three major layers of the leaf.

1. The epidermis surrounds the inner tissues. Notice how the **upper epidermis** has very few stomata compared to the **lower epidermis**. The epidermis is covered with a waxy material called **cutin** which prevents evaporation and water loss. The cutin picks up the red dye and should appear as a thin pinkish layer on the outer surface of the leaf. Thus, the only meaningful openings for gas exchange are the stomata surrounded by **guard cells**. The guard cell pairs work in a special manner involving light, hormones, and ion pumps to fill up with water by osmosis and open the **stoma**, or to lose water by osmosis and close the stoma.
2. The mesophyll consists of large cells (parenchyma) filling up the bulk of the leaf mass. This is subdivided into the upper **palisade mesophyll** and the lower **spongy mesophyll** layers. The palisade layer is a parallel array of columnar cells each containing many chloroplasts. The spongy layer has nearly isodiametric cells arranged in a loose network. Both areas of mesophyll carry out photosynthesis for the plant and need good gas exchange to do this. You will notice that each cell in the mesophyll is largely surrounded by an apparent **gas space**. The gases produced as

waste in the cell (e.g.: oxygen) can be exchanged for essential gases (e.g.: carbon dioxide) in the gas space. The gas space, in turn, might exchange gases with the external atmosphere through the stomata. How might you test this hypothesis?

Hypothesis: The apparent space is really gas, the gas passes through stomata, and there are more stomata in the lower epidermis.

Prediction: If _____
then _____
when _____

Experiment: Use a pair of tongs to plunge an entire bean leaf completely under water that is almost boiling and hold it submerged. Observe both leaf surfaces as they are submerged in the water and **record your results:**

Upper Epidermis: _____

Lower Epidermis: _____

So far, was this an experiment?

yes	no
-----	----

What would be the suitable control? _____

Record your observations of the control situation:

Upper Epidermis: _____

Lower Epidermis: _____

Analysis: Do the results agree with the prediction?

yes	no
-----	----

Decision: The hypothesis:

is rejected	cannot be rejected
-------------	--------------------

3. Now return to your examination of the leaf cross section at the microscope. The **veins** pass through and across the section of leaf tissue on your slide. The veins consist of two bundles of elongated cells, each bundle like a handful of straws. The cells are bundled side to side, but are connected end to end along the length of the vein. The two bundles in each vein are distinct.

a. The bundle of cells closer to the upper epidermis is the **xylem** tissue. This tissue consists mostly of dead, elongated cells, attached end to end, with the endwalls missing or perforated. The side walls of the xylem cells are heavily thickened with lignin (a brittle crystalline material giving mechanical strength). Lignin picks up the red dye so the walls appear pinkish. Water and minerals from the soil come into the leaf through these xylem cells. The water is brought there mostly by evaporative forces generated by gas exchange at the epidermis.

- b. The bundle of cells closer to the lower epidermis is the **phloem** tissue. This tissue consists mostly of living, elongated cells, attached end to end, with perforated endwalls. The sidewalls of phloem cells are relatively thin and pick up only the green dye. With these observations, test the hypothesis:

Hypothesis: Phloem cell walls contain lignin.

Prediction: If _____
then _____
when _____

Experiment: The results are before you on the prepared slide.

What do you observe? _____

How do you know the stain "took"? _____

Analysis: Are the data consistent with the prediction? yes no

Decision: The hypothesis: is rejected cannot be rejected

Having made your decision, what is your **conclusion** (note difference)?

Phloem cell walls do do not contain lignin.

The phloem carries the chemical products of photosynthesis and other chemical reactions from the mesophyll to the rest of the plant via the stem.

4. In the space provided below, diagram a portion of the **cross section of a leaf**. You need only show the layers and a few cells (less than 10) in each region. Label your diagram by connecting lines to your drawing from the provided labels.

Cutin

Upper Epidermis

Palisade Mesophyll

Vein { **Xylem**
Phloem

Spongy Mesophyll

Gas Space

Lower Epidermis

Guard Cell

Stoma

B. The stem. The stem is largely a supporting structure and it holds a display of leaves to the sun. It is also a conductive structure. The stem transfers water and minerals from the soil to the upper parts of the plant. The stem also transfers water and photosynthetic products from the leaves to the rest of the plant. Its structure is very similar to a leaf and has three fundamental parts. Obtain a slide of a stem cross section and examine it carefully using your microscope.

1. The epidermis. You will notice that there is an outer layer of epidermis. Of course the stem is usually round, so there is no inner and outer or upper and lower distinctions. The epidermis, like that in the leaf, is responsible for preventing water loss except through stomata. The stem epidermis will also have guard cells that regulate loss through the stomata, they are *rare*, however.

Do you observe any cutin on the epidermis?

yes	no
-----	----

2. The cortical parenchyma filling up the stem volume is roughly equivalent to the mesophyll parenchyma of a leaf. In many species the stem is green and the outer layers of the cortex contain the chloroplasts necessary for photosynthesis. The outer cortex area may also contain some cortical collenchyma. These cells have unevenly thickened walls and are responsible for mechanical support.

Embedded in the cortex are veins or vascular bundles as discussed below. Near the center of the stem cross section is more parenchyma. This inner area is called the pith region.

3. The vascular bundles are equivalent to the veins of a leaf. Since these are oriented primarily up and down the length of the stem, the stem cross section shows only slices of these elongated cells. Each bundle consists of two major tissues as in the leaf. The cells with green cell walls located toward the epidermis are the phloem cells. The cells with red cell walls grouped toward the center of the stem are the xylem cells. The tissues are separated by the cambium and surrounded by fibers. Test the following hypothesis:

Hypothesis: Xylem actually conducts water and dissolved chemicals up the stem.

Prediction: (Hint: some chemicals are colored)If _____

then the stem _____

and the leaf _____

when _____

What color is the stem tissue before treatment? _____

Why is this stem color an important selection criterion for this test? (hint: some stems are purple)

Experiment: Cut off the bean shoot near the potting soil and stand the shoot in the beaker containing 1% Eosin Y stain dissolved in water. Observe the plant carefully. What are the results...

...in the stem: _____

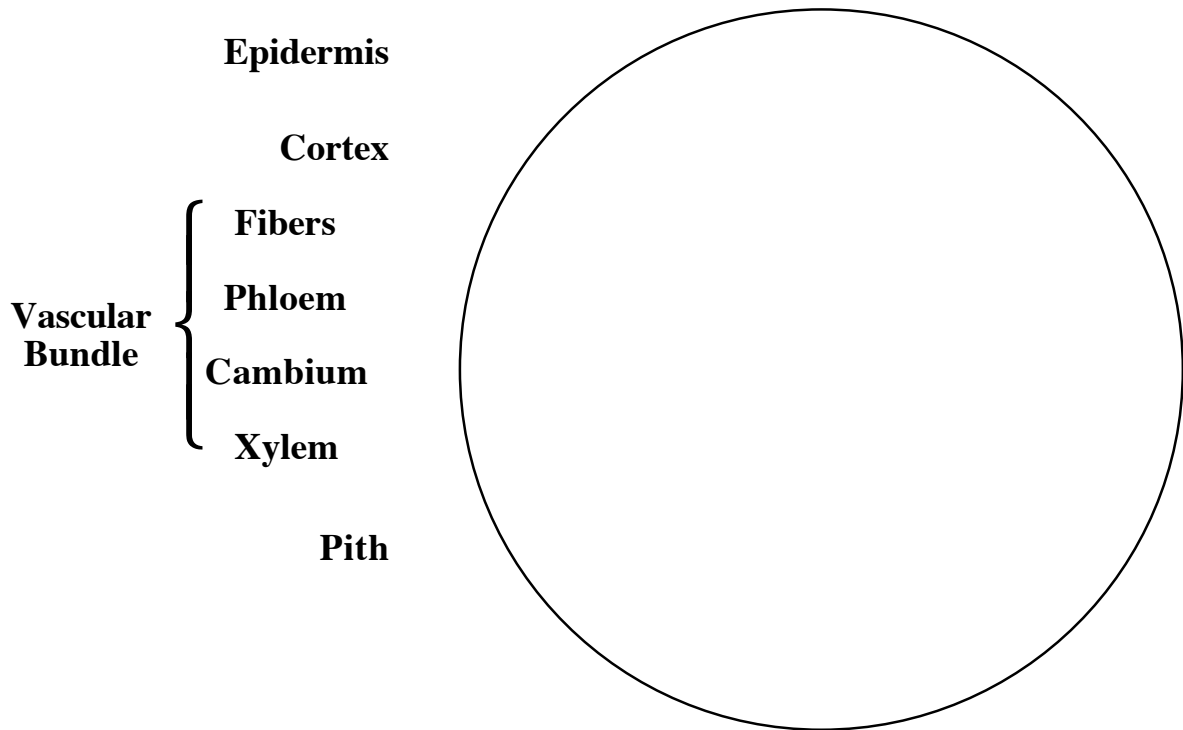
...in the leaf: _____

What would be the control for this manipulation? _____

Analysis: Are the results consistent with the prediction? yes no

Decision: The hypothesis: is rejected cannot be rejected

4. In the space provided below, diagram the **cross section of a stem**. You need only show the layers and a few (less than 10) cells in each region. Label your diagram by connecting lines to your drawing from the provided labels.



C. The root. The root has an even more primitive structure than the stem. There is still a single-cell layer of epidermis and a cortical region of ground parenchyma, but the vascular bundles are coalesced into a single solid cylinder. Obtain a prepared slide showing a **root cross section**. Identify the regions described below.

1. The root **epidermis** is equivalent to that in the stem and leaf, but both cutin and stomata are absent in young portions of the root.

Why would root tips not need protection from water loss? _____

Why would stomata not be of any use to a root? _____

What cellular process in a root would require gas exchange? _____

2. The ground parenchyma is represented by only an outer layer of **cortex**. This region typically lacks collenchyma.

Why would a root not need the mechanical support offered by collenchyma?

3. The vascular tissue is partially coalesced into a solid **vascular cylinder**. In the cross section you see a circle representing these tissues. The cells again are very elongated and you observe only slices of them. The central portion of tissue comprises the coalesced **xylem** areas. Name ways to tell that this area is xylem.

Cell Wall Thickness	<input type="text" value="thin"/> <input type="text" value="thick"/>	Cell Wall Color	<input type="text" value="red"/> <input type="text" value="green"/>	Cell Size	<input type="text"/>	Cytoplasm	<input type="text"/>
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Near the periphery (edge) of this central disc of vascular tissue you will find discrete (uncoalesced) bundles of **phloem**. Name ways to tell that these areas are phloem.

Cell Wall Thickness	<input type="text" value="thin"/> <input type="text" value="thick"/>	Cell Wall Color	<input type="text" value="red"/> <input type="text" value="green"/>	Cell Size	<input type="text"/>	Cytoplasm	<input type="text"/>
				Cell Size	<input type="text"/>	Cytoplasm	<input type="text"/>

4. Between the vascular tissues and the cortex is a single layer of cells known as the **endodermis**. In these cells, a portion of the radial walls, both longitudinal and transverse, contains lignin and suberin (waterproofing substances). This band around the wall is called the Casparian strip.

What color does the Casparian strip stain? _____

Between the endodermis and the vascular tissues is the **pericycle**, the origin of branch roots and root bark. This endodermis is critical to active transport and uptake of minerals from the soil water. Aside from mechanical anchorage, *selective mineral uptake is the single most important function of the root.*

5. In the space provided below, diagram a **cross section of a root**. You need only show the layers and a few (less than 10) cells in each region. Label your diagram by connecting lines to your drawing from the provided labels.

