

Lab X-2

Investigating Seed Plants

Equipment and Materials

You'll need the following items to complete this lab session. (The standard kit for this book, available from www.thehomescientist.com, includes the items listed in the first group.) Plant the carrot seeds a couple of weeks before you intend to do the rest of this lab session to allow the seedlings to sprout.

Materials from Kit

- | | |
|-------------------------------------|--|
| <input type="checkbox"/> Goggles | <input type="checkbox"/> Seeds, carrot |
| <input type="checkbox"/> Coverslips | <input type="checkbox"/> Slides, flat |
| <input type="checkbox"/> Forceps | <input type="checkbox"/> Stain: eosin Y |
| <input type="checkbox"/> Magnifier | <input type="checkbox"/> Stain: methylene blue |
| <input type="checkbox"/> Pipettes | <input type="checkbox"/> Teasing needles |
| <input type="checkbox"/> Scalpel | |

Materials You Provide

- | | |
|---|--|
| <input type="checkbox"/> Gloves | <input type="checkbox"/> Microscope, stereo (optional) |
| <input type="checkbox"/> Alcohol (ethanol or isopropanol) | <input type="checkbox"/> Microtome (optional) |
| <input type="checkbox"/> Carrot | <input type="checkbox"/> Paper towels |
| <input type="checkbox"/> Flowers (see text) | <input type="checkbox"/> Pencil |
| <input type="checkbox"/> Foam cups | <input type="checkbox"/> Seeds (see text) |
| <input type="checkbox"/> Fruits (see text) | <input type="checkbox"/> Slides, prepared, dicot structures |
| <input type="checkbox"/> Knife, paring | <input type="checkbox"/> Slides, prepared, monocot structures |
| <input type="checkbox"/> Leaves, monocot & dicot (fresh or dried) | <input type="checkbox"/> Slides, prepared, gymnosperm structures |
| <input type="checkbox"/> Leaves, hydrophyte (aquatic plant) | <input type="checkbox"/> Sand or vermiculite |
| <input type="checkbox"/> Microscope | <input type="checkbox"/> Soil (potting or ordinary garden soil) |

Background

In the preceding lab session, we took a close look at “primitive” plants, mosses and ferns. In this and the following lab session, we'll examine *spermatophytes*, or *seed plants*. Spermatophytes

are divided into two major groups: *angiosperms* (flowering plants) and *gymnosperms* (conifers and similar species). Although it's a mistake to think of seed plants as "higher" than mosses and ferns, there's no question that seed plants are structurally more complex than mosses and ferns.

When a seed germinates, the first structure to appear is the primary root, which then branches into a secondary root system. Roots serve to anchor the plant physically to the soil or other substrate and also to absorb water and nutrients. In some species, the root may also serve as a food storage location.

Roots are classified as one of four types: *fibrous roots*, *tap roots*, *adventitious roots*, or *aerial roots*. In a fibrous root system, secondary roots branch from the primary root, eventually reaching similar size. In a tap root system, the primary root becomes the tap root, which is typically much longer and thicker than the secondary roots branching from it. The tap root is longer and heavier because it is a *tuber*, which means that food is stored within it. (Stems in some species also function as tubers.) An adventitious root system is one in which secondary roots develop and grow not only from the primary root, but from other parts of the plant. (For example, if you examine the base of a corn stalk, you'll find that secondary roots are growing from the above-ground portion of the stalk, as well as from the primary root.) Finally, an aerial root system is just what it sounds like: a root system that is partially or completely above ground. As odd as that sounds, aerial roots (which are nearly always also adventitious) are found in many species, ranging from orchids to ivies to mangroves.

Although we don't explore the various types of roots in this lab session, you should use your textbook or Internet resources to familiarize yourself with appearance and characteristics of the various root types.

Aerial roots aside, you can think of stems as basically above-ground roots. Their purpose is to support the leaves and to connect the roots to the leaves. The leaves, of course, are where most of the work is done, using water and nutrients supplied by the roots and stems and combining those with atmospheric carbon dioxide via photosynthesis to produce the saccharides that feed the plant. Leaves vary widely in appearance, from the familiar leaves of trees and bushes to the needles of pine trees to the blades of grass that make up your lawn. Regardless of their appearance, they serve the same function of providing food for the plant (and, ultimately, for the animal kingdom as well).

Transfers of water and nutrients from the root system to the leaves and transfers of saccharides from the leaves to the stems and roots take place via the *vascular system* of the plant, which is analogous to the arteries and veins that make up the circulatory system in animals. Plants have two types of transport tissue, both of which are found throughout the plant. The primary purpose of *xylem* tissue is to transport water within the plant, although it does also transport some nutrients. The most familiar form of xylem tissue is wood. The primary purpose of *phloem* tissue is to transport soluble nutrients via a process called *translocation*, which of course also involves transporting water. The most familiar form of phloem is the inner bark of trees, which lies between the protective outer bark layer and the wood that makes up the trunk (stem).

Although phylogenetics tells us that the concept is not valid for classification, most biologists find it convenient organizationally to group angiosperms into *monocot* and *dicot* species. Those terms refer to the number of cotyledons, or embryonic leaves, contained in the seed, with monocots having only one and dicots two. Although this difference may sound trivial, its implications are profound for the structures of mature plants, which reflect their origins as monocotyledonous or dicotyledonous.

In this session, we'll look at the primary structures of seed plants: roots, stems, leaves, and reproductive structures.

Procedure X-2-1: Observing Germination of a Seed Plant

In this procedure, we'll plant carrot seeds and observe their germination. Once the seedlings have sprouted, we'll examine the structures of the seedlings.

1. Use a pencil or similar object to poke a few small drainage holes in the bottoms of two foam cups. Cover the holes with pieces of paper towel to keep soil in the cups.
2. Label one foam cup "A" and fill it to near the brim with clean sand or vermiculite. Label a second foam cup "B" and fill it to near the brim with potting soil or ordinary garden soil.
3. Place a few carrot seeds just under the surface of the soil in each cup.
4. Water the soil with tap water until it is thoroughly dampened.
5. Place the cups in an area where they will be exposed to daylight but not excessive direct sunlight, and where they will remain near room temperature.
6. Observe the cups at least daily, and record your observations in your lab notebook. In particular, note how long it takes for the first visible evidence of germination to occur and the initial appearance of the seedlings.
7. Water the soil gently every day or two, dampening it each time but not using enough water to turn the soil into mud. Continue observing the cups over a period of two to three weeks, noting any differences between the two cups.
8. After two to three weeks, gently remove one of the seedlings from each cup, making sure not to damage the visible part of the seedling or its root structure. Wash the seedlings gently with a trickle of tap water to remove any soil that is adhering.
9. Use the magnifier (or a stereo microscope, if you have one) to observe the structures of the seedling. Note the size and appearance of the roots, root hairs, stems, and leaves, and note any differences between the seedlings from the two cups.

Procedure X-2-2: Observing Root Structures

In this procedure, we'll examine root structures, comparing and contrasting the similarities and differences between monocots and dicots. To begin, we'll examine the root structure of *Daucus carota sativus*, the garden carrot. The tuberous root structure of the carrot is the part that is ordinarily consumed, and what most people think of as the "carrot" itself.

1. Obtain an ordinary carrot from the supermarket. Choose a large one, if possible, to make the structures more easily visible.
2. Using the scalpel, carefully cut the carrot across its diameter to produce a piece about 10 cm long.
3. Using the scalpel, carefully cut from one end of that piece the thinnest possible cross-section, ideally thin enough to be almost transparent.

If you have a microtome, use it to cut the cross-section. It's much easier to obtain very thin and consistent sections using a microtome than if you cut the section by hand.

4. Transfer the cross section to a flat slide. Add a drop or two of methylene blue stain (sufficient to cover the section) and a similar amount of eosin Y stain.
5. Allow the stains to work for a minute or so, and then rinse off excess stain by flooding the specimen with alcohol from a pipette.

6. Observe the stained cross-section with a magnifier or stereo microscope, noting the *stele* (the core, which contains the xylem and phloem components of the vascular system), the *cortex* (surrounding material where food is stored), and the *epidermis* (skin covering the cortex), and any visible substructures within them. Note your observations in your lab notebook.
7. Use the scalpel carefully to cut a longitudinal (lengthwise) section of the carrot. Repeat steps 4 through 6 to observe the stained longitudinal section.

We'll next examine prepared slides of monocot and dicot root structures, and compare and contrast the analogous structures in each type. As you observe the slides, use appropriate magnifications. For large specimens, all features may not be visible in one field of view even at low magnification, so scan around the slide as necessary to view all points of interest. Use medium and high magnification, as appropriate, to view details. As you work, record your observations in your lab notebook. Make sketches or shoot images to document what you find.

Using prepared slides that contain monocot and dicot structures side-by-side on the same slide makes it easier and faster to compare and contrast the structures. Such slides are available commercially, but most prepared slide sets include monocot and dicot structures on different slides. That's actually a very good reason to make your own slides.

If you have a microtome (or are very skilled at cutting freehand sections), you can prepare your own monocot and dicot sections and stain them using methylene blue and eosin Y. Onions, garlic, and many flowers (such as amaryllis, daffodils, irises, lilies, and tulips) are examples of monocots that are readily available locally. Most garden vegetables—such as beans, peas, pumpkins, squash, and tomatoes—are dicots, as are many common flowers, including daisies, geraniums, marigolds, roses, and snapdragons.

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8. Place a prepared slide of a dicot root cross section on the microscope stage, and scan it at low magnification to locate areas of interest. Identify the stele, cortex, epidermal layer, and root hairs. Note the details of any structural features present in each.

For a large dicot specimen, the cross section may be too large to view in one field. For a small specimen, you may need to start at medium magnification rather than low.

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9. Examine the epidermis and root hair at medium and high magnification, noting the distribution, size, and shape of the cells and the cell wall thickness(es).

Insert figure here. Use file 76-bean-root-tubercle-40X.jpg

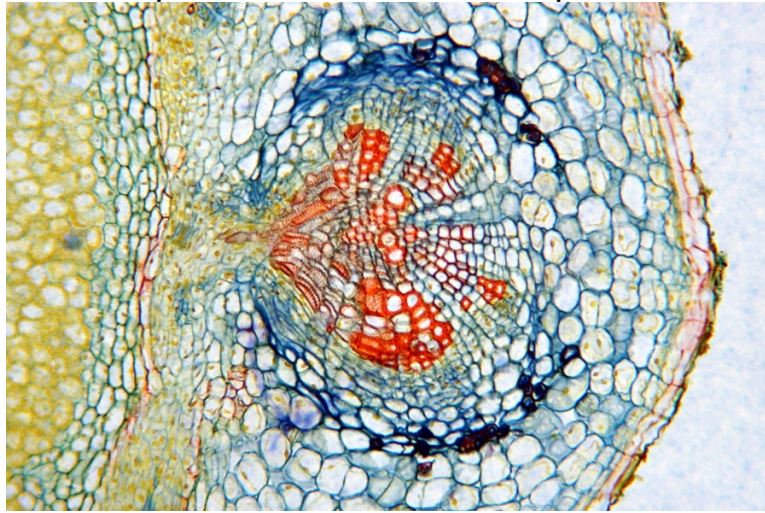


Figure X-2-1. Soybean (Glycine max) root tubercle cs, 40X

10. Observe the cortex at medium or high magnification and note the differences, if any, between the size, shape, distribution, and wall thickness of cortex cells versus epidermal cells and root hairs.
11. Center the stele in the field of view and observe it at low magnification to note areas of interest. Identify the xylem (thick-walled) and phloem (thin-walled) cells and observe them at medium or high magnification to note their size, structure, and arrangement.

The cross-shape arrangement of the larger, thick-walled xylem cells and the position of the smaller, thin-walled phloem cells between the arms of that cross are characteristic of dicot roots.

12. Examine any other dicot root cross sections for which you have slides available, and note the similarities between dicot roots of different species.
13. Place a prepared slide of a monocot root cross section on the microscope stage, and repeat steps 8 through 12 to observe and note its characteristics.

Monocot stems are also characterized by the position and arrangement of their xylem and phloem cells. In monocots, both xylem and phloem cells are scattered in groups or clusters throughout the stele.

Insert figure here. Use file 77-corn-root-cs-100X.jpg

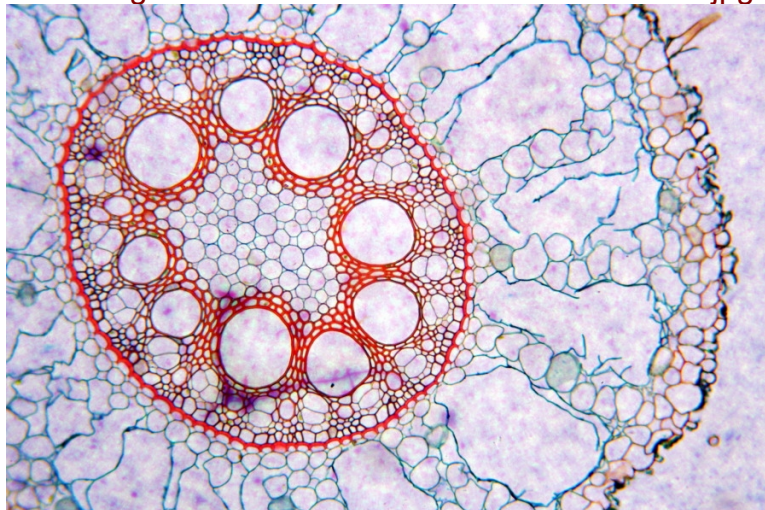


Figure X-2-2. Corn (Zea mays) root cs, 100X

Insert figure here. Use file 84-potato-tuber-sec-40X.jpg

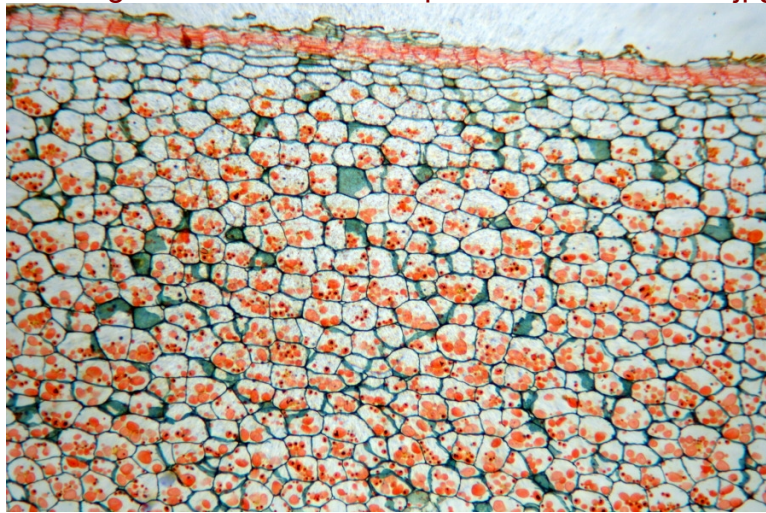


Figure X-2-3. Potato (Solanum tuberosum) section, 40X

Procedure X-2-3: Observing Stem Structures

As is true of root structures, stem structures have characteristic differences between monocot and dicot species. In this procedure, we'll examine prepared slides of monocot and dicot stem structures, and compare and contrast the analogous structures in each type. Again, as you observe the slides, use appropriate magnifications, scanning at lower magnification and then switching, as appropriate, to higher magnification to view details. As you work, record your observations in your lab notebook. Make sketches or shoot images to document what you find.

1. Place a prepared slide of a dicot stem cross section on the microscope stage, and scan it at low magnification to locate areas of interest. Identify the pith (central section), vascular bundles, cortex, and epidermal layer. Note the details of any structural features present in each.
2. Examine the epidermal layer and cortex, and compare them to the analogous structures in the dicot root specimen(s). Note that the cortex is a relatively thin layer separating the pith from the epidermal layer. Note also the arrangement of vascular bundles in a ring toward the outer edge of the pith. This arrangement is characteristic of a dicot stem.
3. Center a vascular bundle in the field of view, and change to higher magnification to observe the details. Note that the vascular bundle comprises a group of larger, thick-walled xylem cells surrounding the smaller, thin-walled phloem cells.
4. Place a prepared slide of a monocot stem cross section on the microscope stage, and repeat steps 1 through 3 to observe and note its characteristics. Figure X-2-4 shows monocot and dicot stem cross sections side-by-side for comparison.

Insert figure here. Use file 86-monocot-dicot-stems-40X.jpg

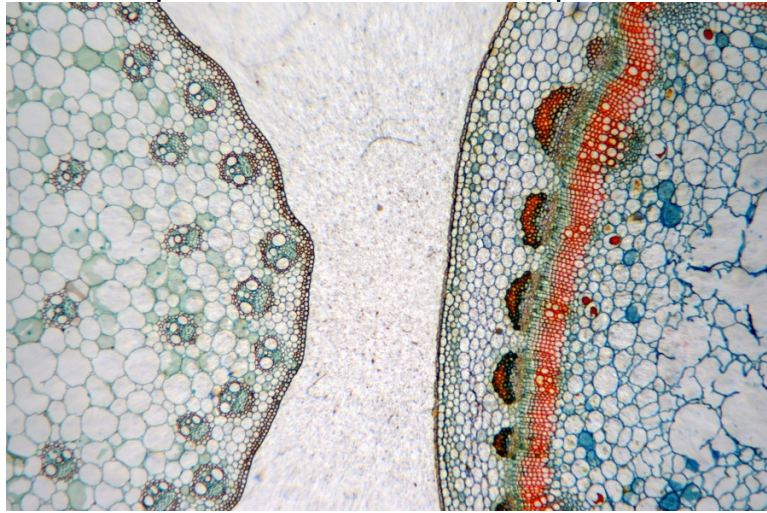


Figure X-2-4. Monocot (left) and dicot stems compared, 40X

5. Examine as many prepared slides or specimens as you have available of dicot and monocot stems in cross section and longitudinal section. Compare and contrast the similarities and differences with your other dicot and monocot specimens.

Figures X-2-5 through X-2-9 show the monocots *Zea mays* (corn) and *Triticum aestivum* (wheat) in cross- and longitudinal sections. Figures X-2-10 through X-2-13 show the dicots *Cucurbita* sp. (squash or pumpkin) and *Hibiscus syriacus* (hibiscus) stems in various cross sections and longitudinal sections.

Insert figure here. Use file 82-corn-stem-cs-40X.jpg

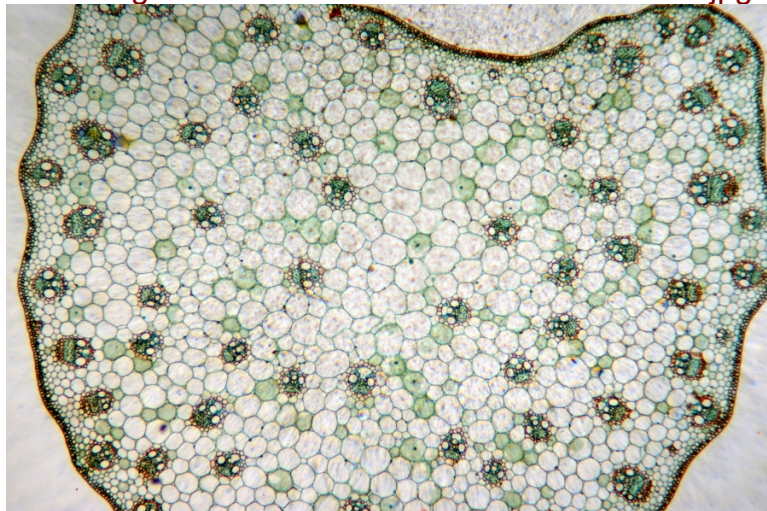


Figure X-2-5. Corn (Zea mays) stem cs, 40X

Insert figure here. Use file 82-corn-stem-cs-detail-400X.jpg

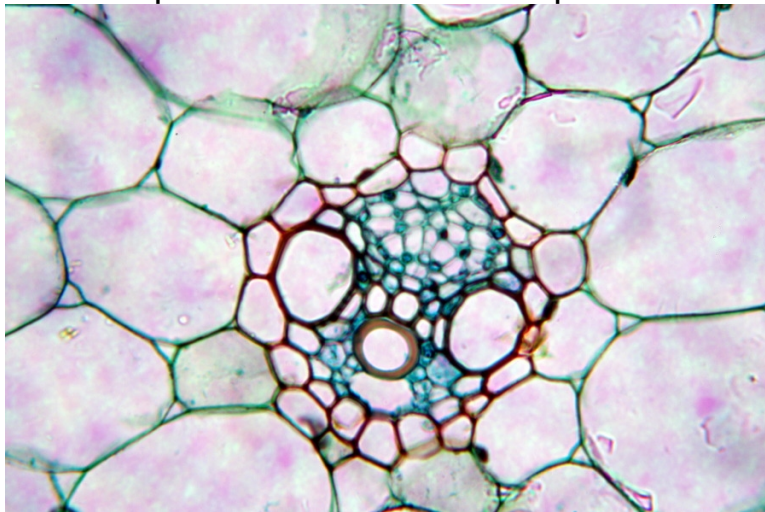


Figure X-2-6. Corn (Zea mays) stem cs detail, 400X
Insert figure here. Use file 83-corn-stem-ls-40X.jpg

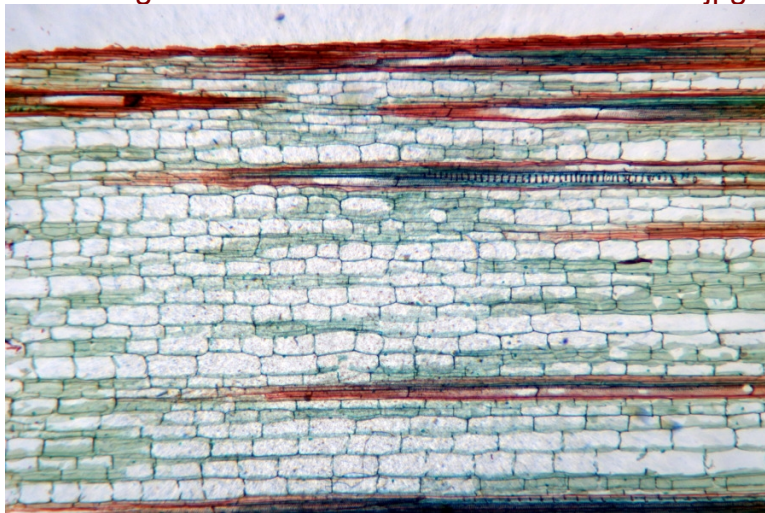


Figure X-2-7. Corn (Zea mays) stem ls, 40X
Insert figure here. Use file 85-wheat-stem-cs-40X.jpg

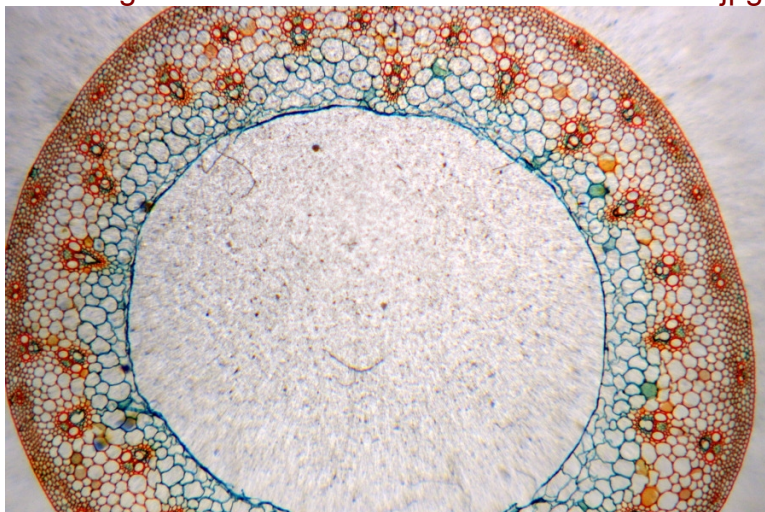


Figure X-2-8. Wheat (Triticum aestivum) stem cs, 40X

Insert figure here. Use file 85-wheat-stem-cs-detail-100X.jpg

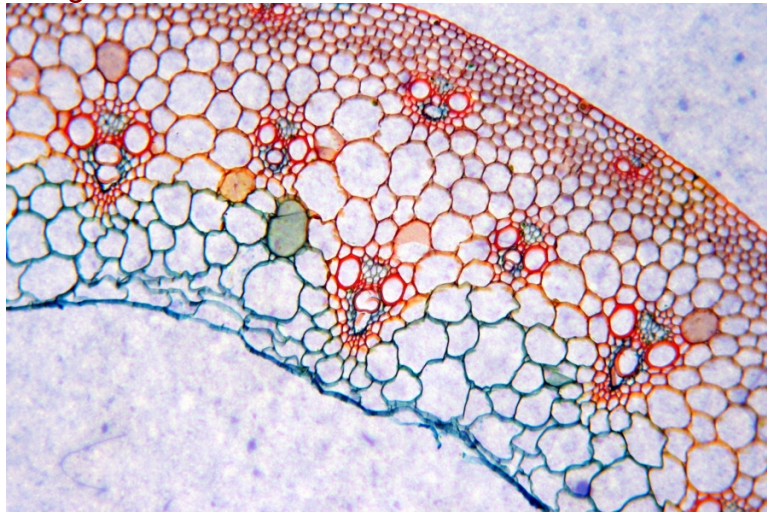


Figure X-2-9. Wheat (Triticum aestivum) stem cs detail, 100X

Insert figure here. Use file 78-cucurbita-stem-cs-40X.jpg

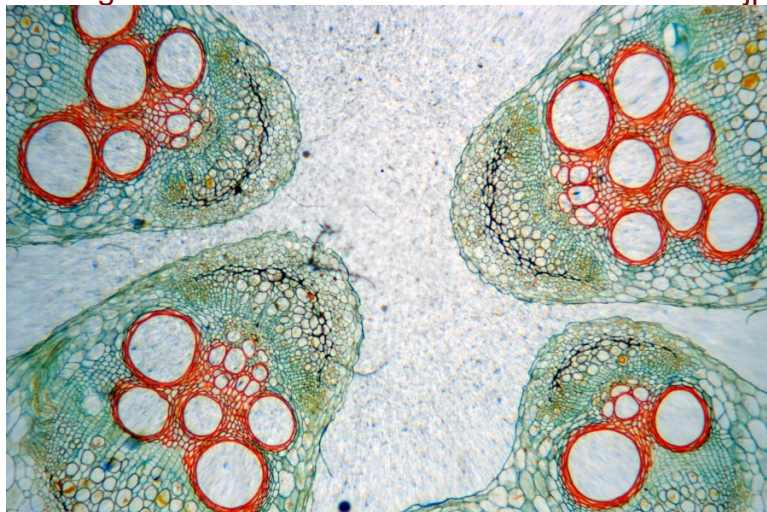


Figure X-2-10. Squash (Cucurbita sp.) stem cs, 40X

Insert figure here. Use file 79-cucurbita-stem-ls-40X.jpg

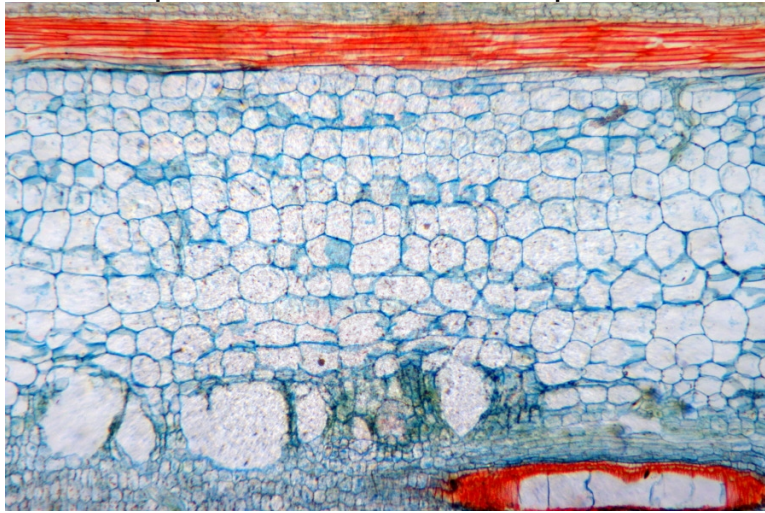


Figure X-2-11. Squash (Cucurbita sp.) stem ls, 40X

Insert figure here. Use file 80-hibiscus-stem-cs-40X.jpg

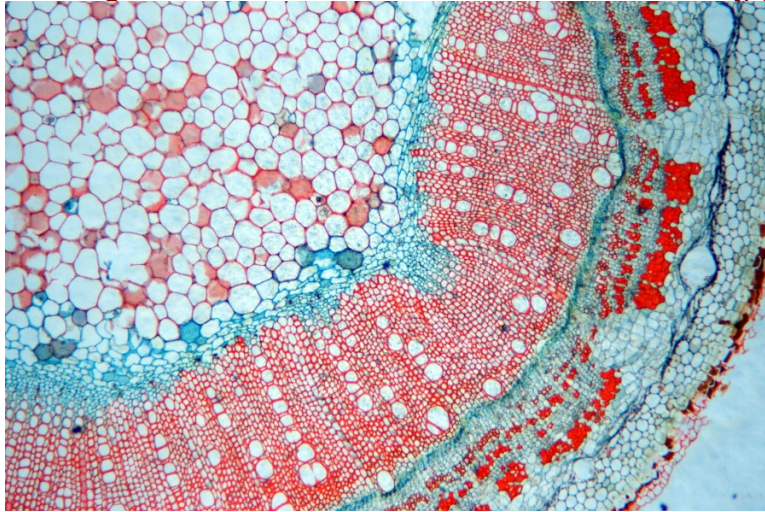


Figure X-2-12. Hibiscus (Hibiscus syriacus) stem cs, 40X

Insert figure here. Use file 81-hibiscus-stem-ls-40X.jpg



Figure X-2-13. Hibiscus (Hibiscus syriacus) stem ls, 40X

6. Many angiosperms have herbaceous (soft) stems, which die off each year. Other angiosperms like trees and bushes have woody (hard) stems, which remain alive from year to year, growing by adding annual layers, called growth rings. If you have prepared slides or specimens available, compare and contrast the similarities and differences in the structures of one or more angiosperm woody stems with those you've examined of angiosperms with herbaceous stems. If possible, examine cross sections of woody stems of different ages and note the growth rings. Figures X-2-14 through X-2-16 are cross sections of basswood stems showing annual growth rings.

Insert figure here. Use file 87-basswood-1-year-stem-cs-40X.jpg

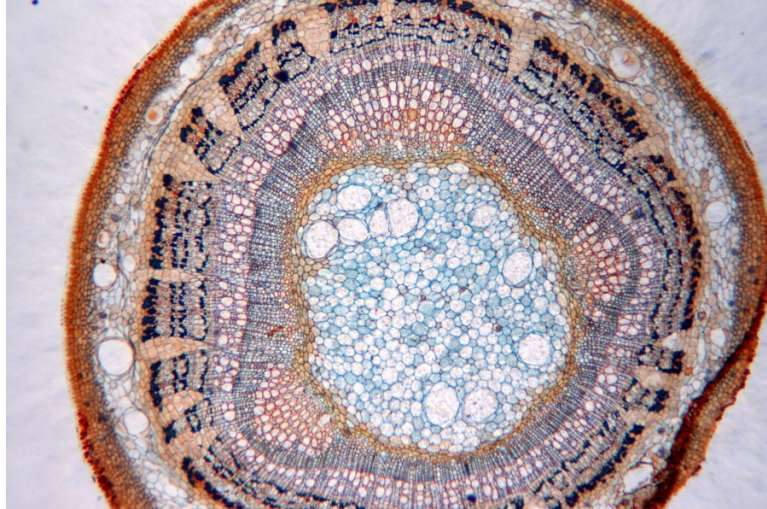


Figure X-2-14. Basswood (Tilia sp.) 1-year stem cs, 40X

Insert figure here. Use file 87-basswood-2-year-stem-cs-40X.jpg

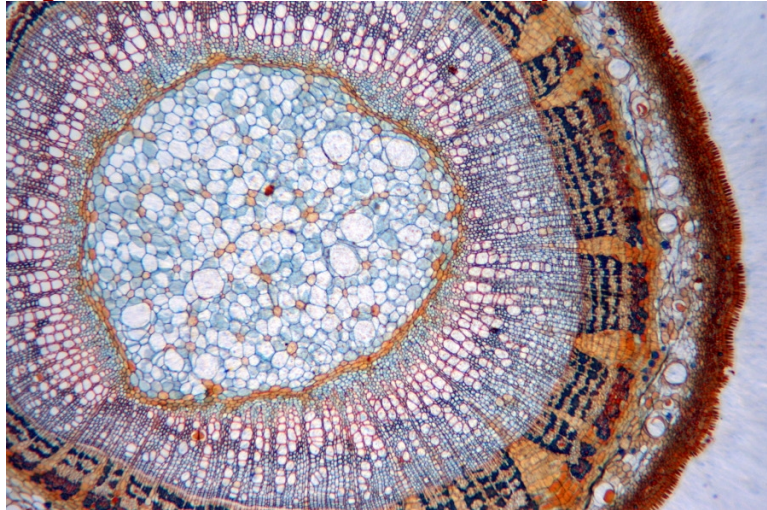


Figure X-2-15. Basswood (Tilia sp.) 2-year stem cs, 40X

Insert figure here. Use file 87-basswood-3-year-stem-cs-40X.jpg

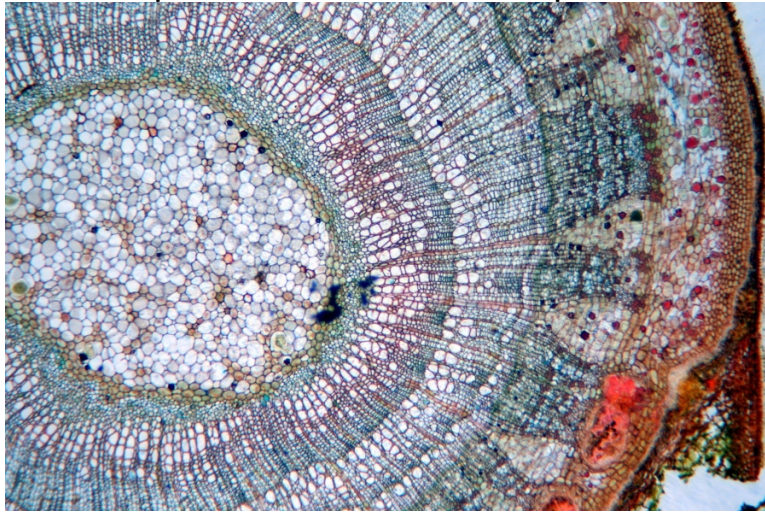


Figure X-2-16. Basswood (Tilia sp.) 3-year stem cs, 40X

Although the majority of seed plants that surround us are angiosperms (flower-bearing seed plants), gymnosperms (cone-bearing seed plants) are also familiar to all of us, most commonly as conifers such as pines, cedars, cypresses, and related species.

7. If you have prepared slides or specimens available, compare and contrast the similarities and differences in the woody stem structures of one or more angiosperms against those of one or more gymnosperms. If possible, examine cross sections of woody stems of different ages and note the growth rings. Figures X-2-17 through X-2-21 are cross sections of basswood stems showing annual growth rings.

Insert figure here. Use file 72-cedar-stem-cs-40X.jpg

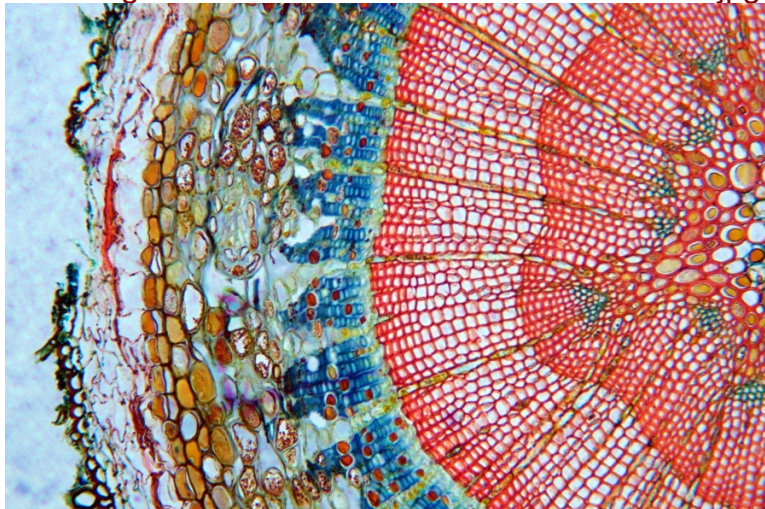


Figure X-2-17. Cedar (Cedrus sp.) stem cs, 40X

Insert figure here. Use file 72-cedar-stem-cs-detail-100X.jpg



Figure X-2-18. Cedar (*Cedrus* sp.) stem cs detail, 100X

Insert figure here. Use file 73-young-pine-stem-cs-40X.jpg

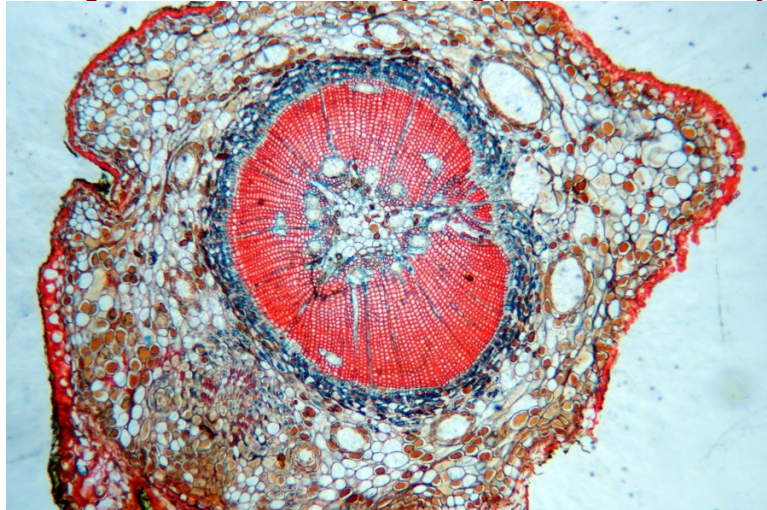


Figure X-2-19. Young pine (*Pinus* sp.) stem cs, 40X

Insert figure here. Use file 73-young-pine-stem-cs-detail-100X.jpg



Insert figure here. Use file 74-pine-older-stem-cs-showing-annual-growth-ring-40X.jpg

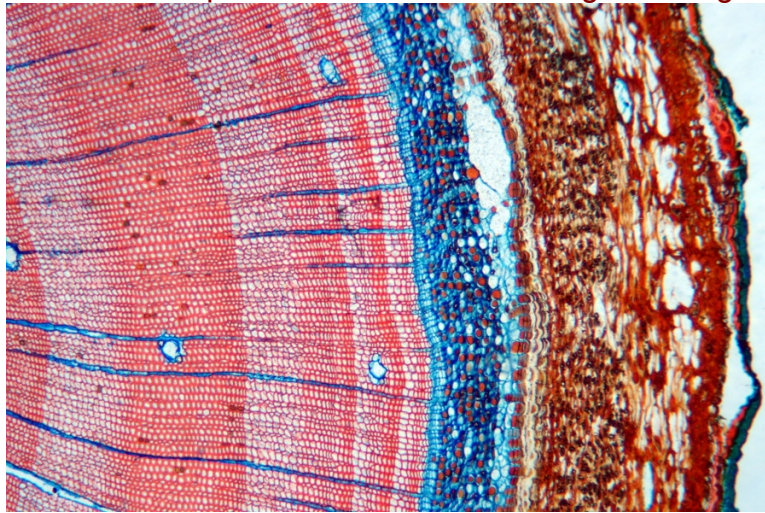


Figure X-2-21. Older pine stem showing annual growth ring, 40X

Procedure X-2-4: Observing Leaf Structures

Like root and stem structures, leaf structures exhibit characteristic differences between monocot and dicot species, most obviously shape and venation pattern. In this procedure, we'll examine the macroscopic and microscopic characteristics of monocot and dicot leaf structures, and compare and contrast the analogous structures in each type. As you work, record your observations in your lab notebook. Make sketches or shoot images to document what you find.

1. Obtain as large a variety as possible of fresh and/or preserved leaves from monocot and dicot species.
2. Using your naked eye and the magnifier or a stereo microscope, examine the gross structural features of each specimen. Examine both the top and bottom surfaces. Note the size, shape, and arrangement of the leaf, the margin (edge) pattern, the vascular system arrangement, and the size, pattern, and density of stomata. Typical monocot leaves are narrow and have parallel venation (see Figure X-2-22). Typical dicot leaves are broader and have branching venation (see Figure X-2-23).

Use your textbook or another reference source to locate a chart of leaf morphology. You can find an excellent leaf morphology graphic at http://en.wikipedia.org/wiki/File:Leaf_morphology.svg.

Insert figure here. Use file grass-leaf-vascular-structure-40X.jpg

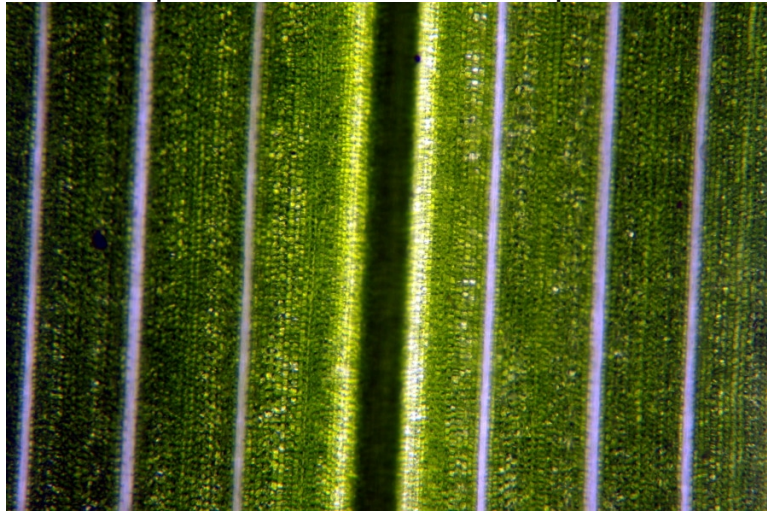


Figure X-2-22. Parallel vascular structure of a monocot (lawn grass) leaf wm, 40X

Insert figure here. Use file oak-leaf-vascular-structure-40X.jpg

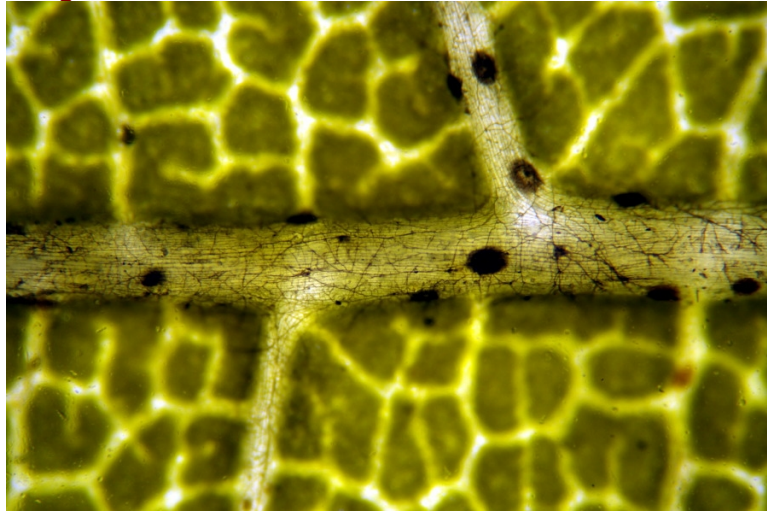


Figure X-2-23. Branched vascular structure of a dicot (silver maple) leaf wm, 40X

3. Examine prepared slides of cross sections of monocot (Figure X-2-24) and dicot (Figure X-2-25) leaves. For each, identify the following structural features: cuticle, epidermal cells, mesophyll cells, air spaces, vascular bundles and their sheathes, and stomata and their guard cells. For your dicot specimen, locate and identify spongy mesophyll cells and palisade mesophyll cells. Contrast their appearance with the monocot mesophyll cells.

Insert figure here. Use file 96-monocot-leaf-cs-100X.jpg

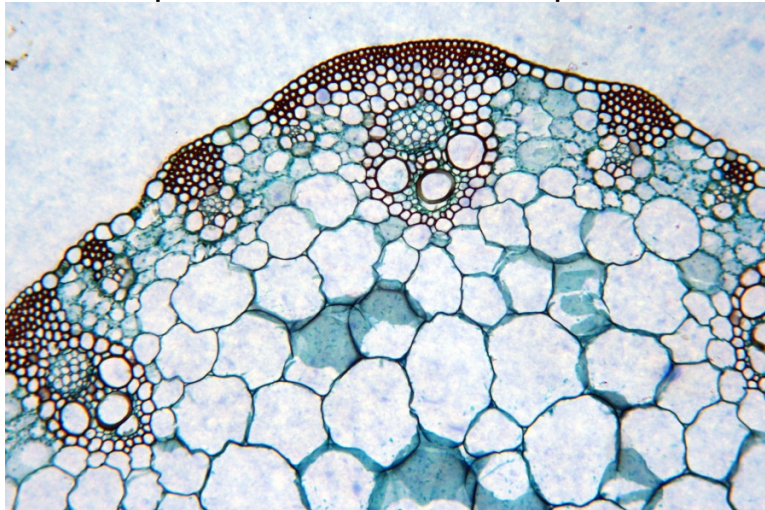
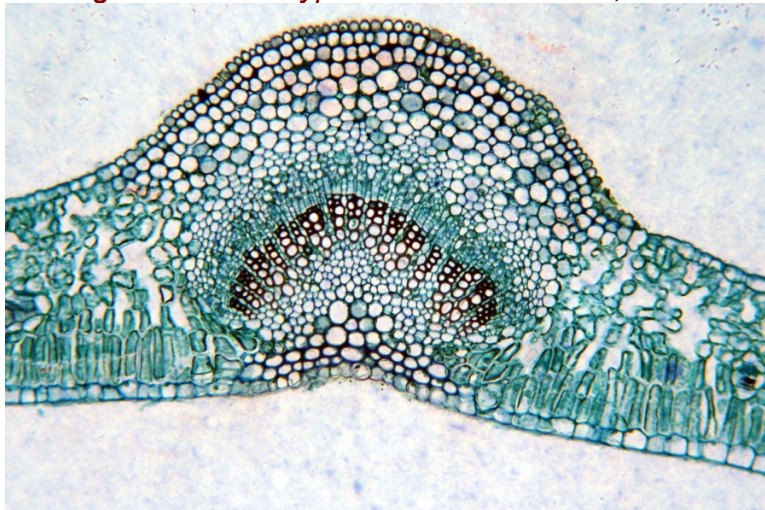


Figure X-2-24. Typical monocot leaf cs, 100X



Insert figure here. Use file 96-dicot-leaf-cs-100X.jpg

Figure X-2-25. Typical dicot leaf cs showing obvious spongy and palisade mesophyll cells, 100X

4. Examine as many other monocot and dicot leaf cross sections as you have access to, comparing and contrasting their structures, and attempt to identify the specimens as monocot or dicot based on their appearances in cross section. The correct answer isn't always obvious. For example, Figure X-2-26 shows a camellia (dicot) leaf cross section, in which the spongy and palisade mesophyll cells aren't as obvious as in the preceding image.

Insert figure here. Use file 94-camellia-leaf-cs-100X.jpg

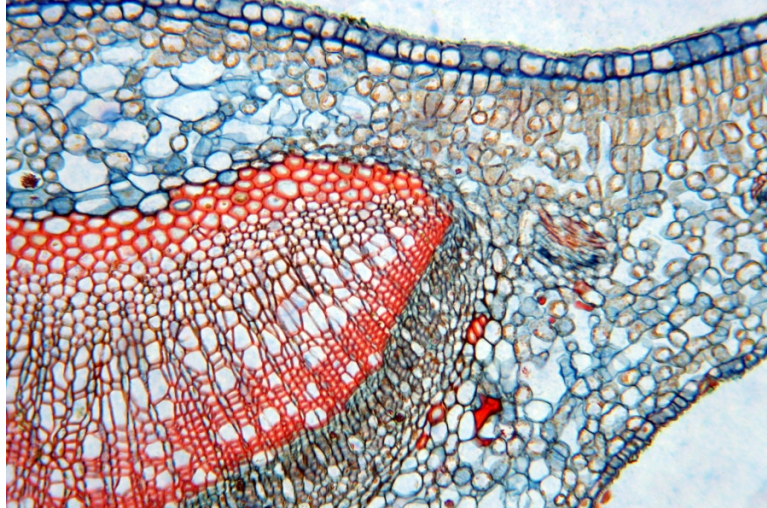


Figure X-2-26. *Camellia* (*Camellia* sp.) leaf cs, 100X

5. Examine as many whole-mount leaf epidermis slides as you have available. Use low magnification to find the significant features and then increase magnification to view details of the venation, stomata, chloroplasts, and so on. Compare and contrast the similarities and differences between your specimens. Examine two specimens of the same type of leaf, one which has recently been exposed to bright sunlight and the other kept in the dark. Note any differences in the appearances of the stomata. Figures X-2-27 through X-2-30 are whole-mount epidermis images of various monocot and dicot species.

It's easy to make your own whole-mount epidermis slides from leaves you obtain locally. Simply cut two small pieces of the leaf and make a wet mount with one piece obverse-side up and the other reverse-side up. If the leaves curl so much that a simple wet mount with a coverslip is insufficient to keep them flat, substitute a second microscope slide for the coverslip.

Many leaves are thin enough that they can be observed by transmitted light if you set the illuminator to its brightest setting. Others are opaque and will require reflected light. Use a high-intensity desk lamp or other top illumination to view those leaves. (We use an LED Mighty Bright book-reading light, which can be clamped to the microscope stage and has a flexible stalk that allows the light to be directed as necessary.)

Insert figure here. Use file 88-wheat-leaf-epidermis-showing-stomata-100X.jpg

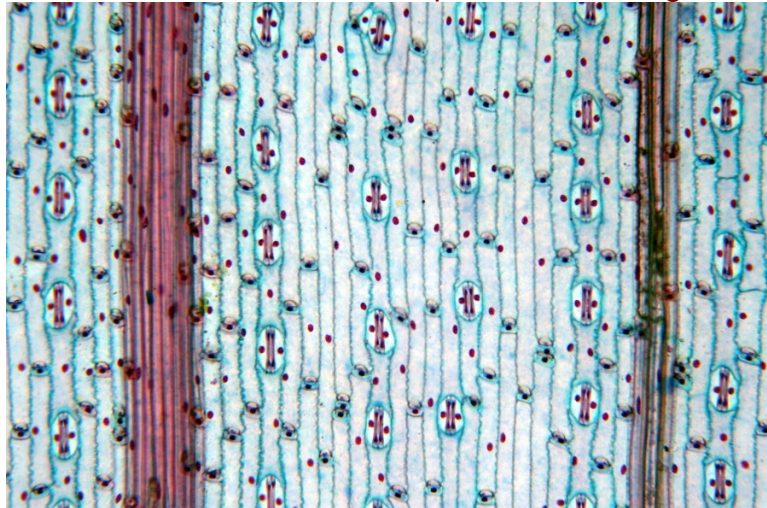


Figure X-2-27. Wheat (Triticum aestivum leaf epidermis wm showing stomata, 100X

Insert figure here. Use file 90-iris-leaf-epidermis-showing-stomata-400X.jpg

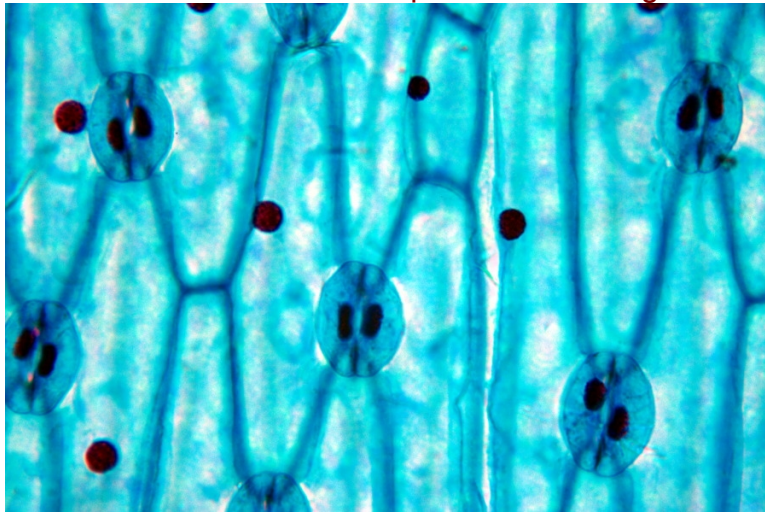


Figure X-2-28. Iris (Iris sp.) leaf epidermis wm showing stomata, 400X

Insert figure here. Use file 91-sedum-leaf-epidermis-showing-stomata-400X.jpg

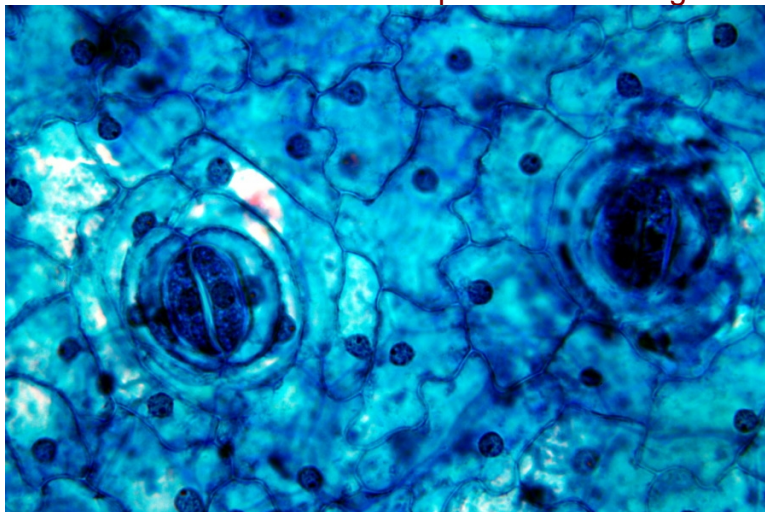


Figure X-2-29. Stonecrop (Sedum sp.) leaf epidermis wm showing stomata, 400X

Insert figure here. Use file 92-broad-bean-leaf-epidermis-wm-showing-stomata-400X.jpg

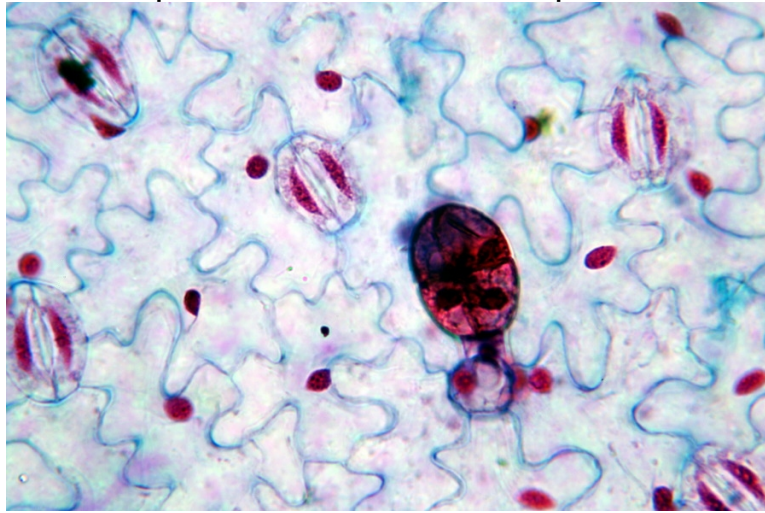


Figure X-2-30. Broad bean (Vicia faba) leaf epidermis showing stomata, 400X

Aquatic plants (also called **hydrophytic plants** or **hydrophytes**) are those that have adapted to living in aquatic environments, whether freshwater or saltwater. True aquatic plants are vascular plants (which excludes algae), and may be ferns or angiosperms, both monocots and dicots.

Hydrophyte structures—roots, stems, and leaves—often differ significantly from those of land plants. Hydrophytic roots, for example, are often small and feathery compared to those of land plants, because they don't have to anchor or support the plant and because water can diffuse directly into the leaves rather than being supplied by the root system. Similarly, stems are often smaller and finer than those of land plants, because most of the mass of the plant is supported by the surrounding water. In floating aquatic plants, roots or stems (or both) contain air channels, which both aid buoyancy and provide a channel for exchanging gases between the surfaced and submerged portions of the plant.

But the greatest differences between aquatic plants and land plants are often visible in the leaves, which are highly adapted in most hydrophytes to suit them for their environments, submerged in or floating on liquid water. The cuticle in most hydrophyte leaves is very thin because a thick cuticle is needed only to conserve water, which is not an issue for hydrophytes. Similarly, the stomata in most hydrophytic leaves are numerous, present on both surfaces of the leaves, and open all or nearly all the time, in contrast to land plants, which close their stomata to conserve water when photosynthesis is not occurring. Finally, hydrophytic leaves are often relatively large and flat and contain air pockets and air-trapping hairs, all of which aid in increasing buoyancy to support the plant.

You can obtain leaves from an aquatic plant from any nearby pond or aquarium. Common species include various water lilies, duckweed, water cabbage, lotuses, and various aquatic grasses. Many species of aquatic plants are fast-growing, invasive, and considered weeds, so you'll probably have no trouble getting permission to harvest specimens.

6. To begin, use the magnifier or a stereo microscope to observe the macroscopic features of your aquatic plant leaf specimen(s). Observe both surfaces of the leaf, and pay particular attention to the number, size, and distribution of stomata on the surfaces.
7. If you have a prepared slide available of a **hydrophytic leaf** cross section, examine it and compare and contrast its structural features against those of your land plant specimens. Compare and contrast the structural similarities and differences against your section slides of land plant leaves. Figure X-2-31 shows a hydrophytic leaf in cross section at 100X.

Insert figure here. Use file 93-hydrophytic-leaf-cs-40X.jpg

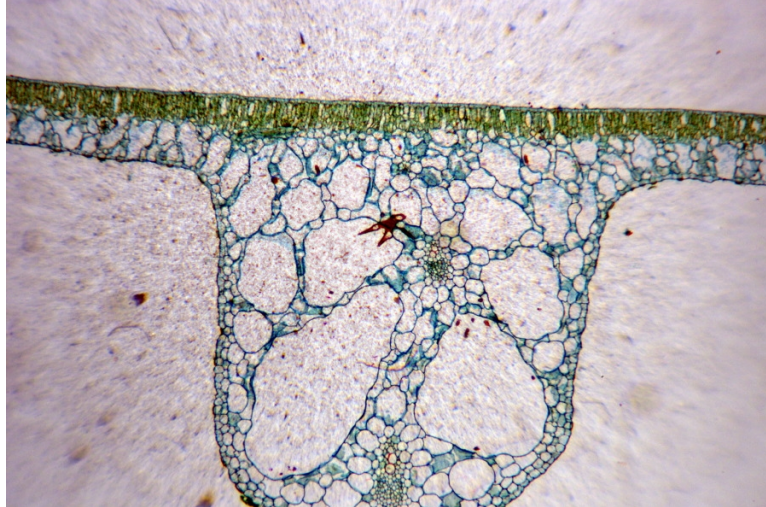


Figure X-2-31. Hydrophytic leaf (Nymphaea tetragona georgi) cs, 40X

Like other seed plants, gymnosperms have leaves with full vascular systems and complex internal structures. The difference from angiosperms is that the leaves of most gymnosperms are highly modified. For example, leaves of the most familiar gymnosperms, the pine family, are needle-shaped.

8. Obtain a gymnosperm leaf specimen and examine it with the magnifier, with a stereo microscope, or with a standard microscope at low magnification using reflected light. Identify the major structural features, and compare and contrast them with your angiosperm leaf specimens.
9. Using prepared slides or cross and longitudinal sections you prepare yourself, compare and contrast your gymnosperm leaf sections against both your angiosperm leaf sections and your gymnosperm root and/or stem specimens. Figure X-2-32 shows a cross section of a pine leaf (needle) at 100X.

Insert figure here. Use file 75-pine-needle-cs-100X.jpg

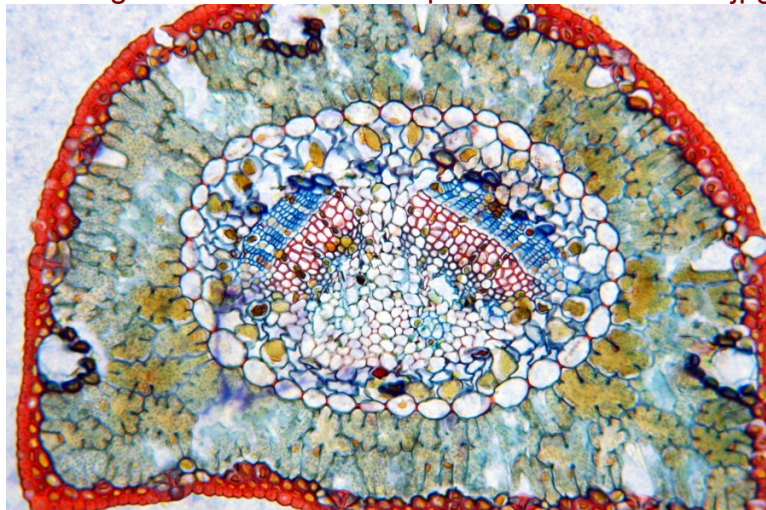


Figure X-2-32. Pine (Pinus sp.) leaf (needle) cs, 100X

Procedure X-2-5: Observing Reproductive Structures

In this procedure, we'll dissect and examine the reproductive structures of angiosperms: flowers, fruits, and seeds. Flowers are the primary reproductive structures. Flowers are hugely diverse in shape, color, size, and other characteristics, but all produce the fruits and seeds from which new plants originate.

It's useful to have a wide selection of live flower, fruit, and seed specimens available. Here are some good choices for each:

Flowers

Any live flower can be used for dissection, but it's easier to work with flowers whose internal structures are relatively large. (Flowers like carnations and daisies, despite their large petals, have small internal structures.) Gladioli are a good choice, as are azaleas, daffodils, lilies, roses, or tulips. You can find suitable specimens at a florist, the supermarket, or perhaps in your yard.

Fruits

If possible, have a range of fruit types available for dissection. Good candidates include a berry (grape, tomato, or banana) and a pepo (melon, squash, or pumpkin), a drupe (apricot, cherry, nectarine, olive, peach, or plum) and a polydrupe (strawberry or blackberry), a hesperidium (lemon, lime, or orange), and a pome (apple or pear).

Seeds

The easiest seeds to dissect are those that are large enough to be easily manipulable and lack a hard shell. You will probably obtain some seeds suitable for dissection when you dissect the fruit specimens. If you want additional specimens you can easily obtain them at the supermarket. Good candidates include beans, peas, popcorn, whole pumpkin or sunflower seeds, peanuts in the shell, pecans, and pistachios.

1. Begin by examining your flower specimen with your naked eye and the magnifier. Using your textbook or another reference source, identify as many as possible of the following structural features: anther, filament, ovary, ovule, petals, pistil, pollen, receptacle, sepal, stamen, stigma, and style. (Not all of these features will be visible in all flowers.) As you work, record your observations in your lab notebook. Make sketches or shoot images to document what you find.
2. Determine where possible if each flower: is monocot or dicot; is complete or incomplete; is composite or simple; is male, female, or both; possesses a superior or inferior ovary; and possesses a single ovule or multiple ovules.
3. Using the scalpel and forceps, carefully section the flower by cutting vertically through the ovary area from the top of the flower downwards. Observe the structures revealed by this longitudinal section, and identify as many as possible of the structures and characteristics mentioned in steps 1 and 2.
4. Repeat steps 1 through 3 with any other flower specimens you have available.
5. View prepared slides of flower structures, particularly the carpel and stamen and their substructures. Figure X-2-33 shows a *Lilium* anther (part of the stamen) in cross section at 40X. Also view at least one slide of pollen, like the *Lilium* pollen shown in Figure X-2-34.

If you don't have a prepared slide of pollen available, it's easy to make your own. Simply touch the stamen tip of a live flower with your forceps, transfer the pollen that adheres to it to a flat slide, add a drop of water, and position a coverslip. Pollen from different species varies greatly in appearance and size, from less than 5 μm to more than 250 μm . (At about 120 μm , the *Lilium* pollen shown in Figure X-2-34 is actually rather large; pollen from other species may appear almost dust-like even at 400X.)

Insert figure here. Use file 97-lilium-anther-cs-40X.jpg

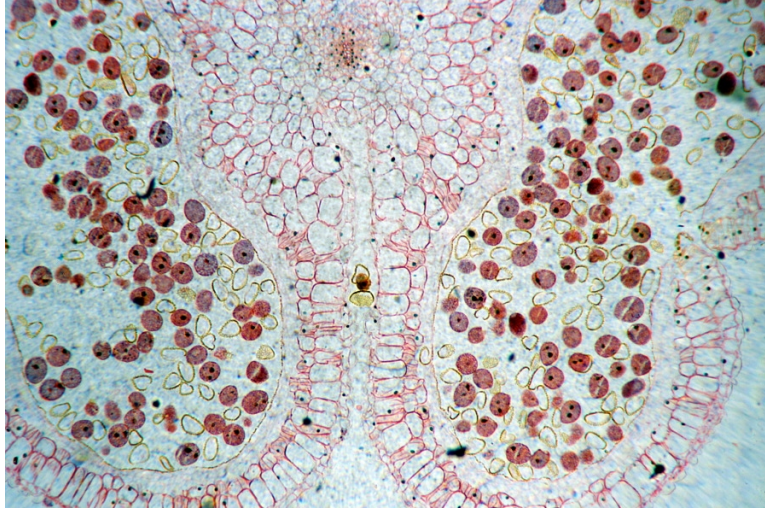


Figure X-2-33. Lily (Lilium sp.) anther cs, 40X

Insert figure here. Use file 98-lilium-pollen-400X.jpg

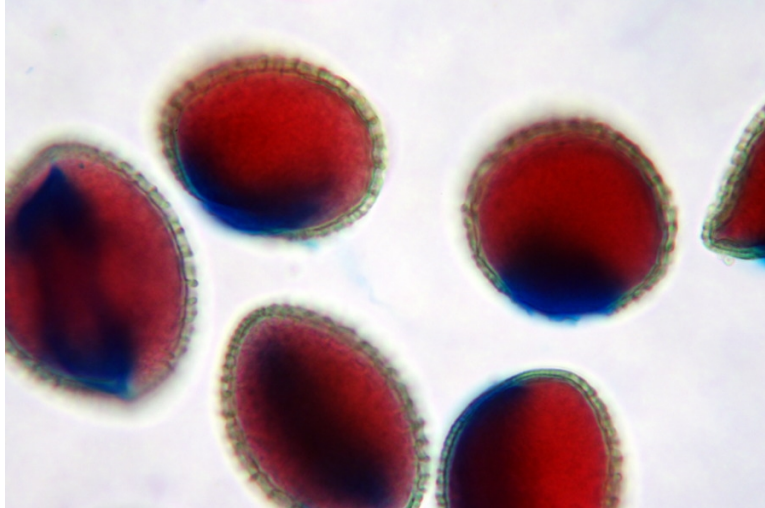


Figure X-2-34. Lily (Lilium sp.) pollen wm, 400X

The function of flowers is to produce fruits, which are ripe ovaries that contain a seed or seeds. Fruits are classified into two major types: **Simple fruits** develop from one ovary, which contains one or more chambers that contain ovules and (rarely) other flower parts. **Compound fruits** develop from multiple ovaries, from one or multiple flowers. Each of those ovaries contains one or more chambers that contain ovules and (usually) other flower parts. Compound fruits are further subdivided into **aggregate fruits**—in which one flower has several ovaries, each of which develops into a small fruit that is joined tightly with the fruits of other ovaries to produce a larger fruit cluster—and **multiple fruits**, in which the ovaries of multiple flowers develop into small fruits that fuse into a larger fruit.

In berries and drupes, the seeds are surrounded by the **pericarp**, which forms the edible portion of the fruit. The pericarp is typically divided into three distinct layers.

Exocarp

The *exocarp* (sometimes called the *epicarp* or, in citrus fruits, the *flavedo*) is the outer layer, the skin or peel of the fruit.

Mesocarp

The *mesocarp* (sometimes called the *sarcocarp* or, in citrus fruits, the *albedo* or *pith*) is the middle layer, which often makes up the bulk of the fruit and is usually the edible part.

Endocarp

The *endocarp* is the inner layer that surrounds the hollow ovary and seeds, bounded on the exterior by the mesocarp and on the interior by the *endopericarpal layer*, which contains the seeds.

In *accessory fruits*—such as apples, pears, strawberries, and figs—some or all of the flesh derives from structures other than the ovaries, such as the *receptacle*, *calyx*, or *hypanthium*. In the fruits of grasses—such as barley, rice, and wheat—the pericarp and seed wall are fused into one layer.

6. Begin by examining a whole fruit specimen with your naked eye and the magnifier, if necessary. Locate the *pedicel* (stem) and carefully use the paring knife and/or scalpel, as appropriate, to cut a vertical section through the entire fruit, transecting the pedicel.
7. Using your textbook or another reference source, identify as many as possible of the following structural features, not all of which are present in all fruits: endocarp, endopericarpal layer, exocarp, mesocarp, ovary (including outer and inner layers, if present), ovary wall, pedicel, receptacle, and seeds. Also note the presence or absences of any remaining flower parts.
8. Repeat steps 5 and 6 with any other fruit specimens you have available.

A typical seed consists of the plant *embryo* surrounded by *endosperm* (food for the embryo) with those components in turn surrounded by the *seed coat*, which contains and protects the embryo and endosperm. The embryo is a multicellular diploid structure that represents the plant in its earliest stage of development, following initial cell division but preceding germination. Dissecting seeds gives us the opportunity to view these structures *in situ*.

Use extreme care when dissecting seeds, particularly those that are small and/or have a hard seed coat. Work on a non-slip surface, and always use forceps to hold the seed while you are dissecting it.

Some seeds, particularly nuts and pits, have extremely resistant seed coats. For safety, you may prefer to open these seeds as carefully as possible using a nutcracker. The cutting blade on needle-nose pliers also works well for this purpose.

Many seeds are easier to dissect if you soak them first in warm water to soften the seed coat.

9. Begin by examining a whole seed specimen with your naked eye and the magnifier. Identify the point where the seed was attached to the ovary, called the *hilum*, and the point where the pollen tube entered the ovule, called the *micropyle*.
10. Working under a stereo microscope, if available, or with the magnifier, grip a seed with the forceps and carefully use the scalpel or a single-edge razor blade to section the seed longitudinally. (You may find it helpful to recruit an assistant to hold the seed with forceps while you use the magnifier with one hand and use the scalpel with the other.) For some seeds, this section will suffice to reveal all of the structures of the seed. If not, section additional seeds into cross and lateral sections.

Some seeds, particularly nuts, may require more than one or two simple sections to reveal all of their structures. You may need to “disassemble” such seeds piece-by-piece to view the details of their structures.

11. Identify the endosperm, *cotyledon* or cotyledons (embryonic pseudo-leaves), and embryo. Within the embryo, locate and identify the *radicle* (embryonic root), *hypocotyl* (embryonic stem), and *epicotyl* (embryonic true leaves).
12. Repeat steps 10 and 11 with any other seed specimens you have available, comparing and contrasting their structures with the other seeds you have dissected.

Review Questions

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1. Your two seedlings were grown in different environments. The sand or vermiculite contains no nutrients, while the potting or garden soil contains nutrients. Did you expect to see any differences between the seedlings from the two environments? Why or why not? Did you observe any differences?

Answers will vary, but the seedlings grown in the two environments should appear very similar. The presence or absence of nutrients in the soil is immaterial at the early germination stage, because the seed itself contains sufficient nutrients for germination and early growth of the seedling.

2. What structures were you able to identify in your carrot seedlings?

Answers may vary, but the beginnings of the root structure should be visible, along with a stem and leaves.

3. Based on your observation of the seedlings, is the carrot a monocot or dicot? Why?

The carrot is a dicot because there are two cotyledons (embryonic leaves) present in the seed, which during germination appear as two tiny leaves.

4. The arrangement of xylem and phloem cells in monocots and dicots differs, and is characteristic of each type. Did you observe any similar characteristic differences between monocots and dicots in their epidermal or cortex cells?

Answers will vary, but allowing for variations between species, the epidermal and cortex cells are similar in structure and appearance across monocots and dicots. (We have seen some prepared slides of monocot stems in which the arrangement of xylem and phloem cells seemed less random than usual, but that was an artifact of that particular slide rather than being indicative of actual differences.)

5. What adaptation to root epidermal cells increases their surface area? What is the benefit of this increase in surface area?

Root hairs are individual epidermal cells that have “stretched” into filamentary structures, greatly increasing their surface areas relative to a compact epidermal cell. This increased surface area benefits the plant by increasing the area available to absorb water and nutrients from the soil.

6. The cross sections of both monocot and dicot roots and monocot and dicot stems show that each of the four has an epidermal layer that bounds the structure, and yet the functions of those layers differs between roots and stems. Knowing what you do about plants, which specific characteristic do you think differs between roots and stems? What structural difference(s) between roots and stems supports your speculation?

In most plants, the roots absorb water and nutrients, and therefore the epidermal cell layer must be permeable to water and small molecules. This is supported by the generally larger size and proportionately thinner cell walls present in roots, along with root hairs, which are essentially greatly stretched versions of single epidermal cells. Conversely, it's important for stems to prevent water from escaping as the vascular system of the plant carries water and nutrients to the entire plant, so stem epidermal cells tend to be smaller, more tightly packed, and with proportionately thicker cell walls.

7. What primary difference did you observe between dicot and monocot stems?

In the dicot stem, the vascular bundles are arranged in a ring adjoining the cortex layer. In a monocot stem, the vascular bundles are distributed more randomly throughout the pith.

8. When you examined whole mounts of similar leaves kept in sunlight and darkness, what major difference did you observe? What does that difference indicate?

Answers may vary, but in the leaf recently exposed to sunlight the stomata are open, indicating that photosynthesis is occurring. In the leaf kept in darkness, the stomata are closed, indicating that photosynthesis is not occurring.

9. When you examined the whole mounts and cross sections of hydrophytic plant leaves and compared them to those of land plants, what significant differences, if any, did you observe?

Answers will vary depending on the particular species observed, but in general the hydrophytic leaf or leaves should have smaller and more numerous stomata than the other specimens, and those stomata will probably be present on both sides of the hydrophytic leaf. Although it is not exclusively a feature of hydrophytes, the hydrophytic leaf is more likely to have hairs. In cross section, the cuticle of the hydrophytic leaf will probably be visibly thinner than that of the other specimens, and the guard cells surrounding the stomata are often smaller relative to those of land plants.