Leaf Structure and Function

Leaves in most vascular plants are the principal structure for photosynthesis. Although leaves vary tremendously in form and internal structure, most consist of a petiole and a blade. Some of the variation in leaf structure is related to habitat. Aquatic leaves and leaves of dry habitats have special modifications to permit survival in those different habitats. Leaf shapes, margins, tips, and venation patterns are characteristics used to identify different species of flowering plants.

Exercise I  Dicot Leaf Structure

Materials Needed
Prepared slides of:
- *Syringa* leaf, xs or *Ligustrum* leaf, xs
- Monocot and Dicot leaf, xs

Procedure
Examine a prepared slide of a lilac, *Syringa*, or similar leaf. Note the large midvein. As you scan your section locate the many branching veins, some of which will be in longitudinal section while others are in cross section.

Observe a portion of the blade to one side of the mid vein. Identify the:
- Upper epidermis, which has a relatively thin but discernible cuticle, the waxy surface layer secreted exterior to the epidermis cells
- Palisade mesophyll
- Veins, consisting of xylem and phloem conducting tissues, and a surrounding bundle sheath
- Spongy mesophyll containing many air spaces
- Lower epidermis, which also has a cuticle

The palisade and spongy mesophyll are composed of parenchyma cells, which contain many chloroplasts for photosynthesis. Note the presence of intercellular air spaces among the spongy mesophyll cells and the relative distribution of stomata and guard cells in the lower epidermis. Most stomata open into an air space within the spongy mesophyll. CO₂ enters the leaf through the stomata. The mushroom-shaped structures of the epidermis are trichomes, or epidermal hairs.

Xylem tissue, which conducts water, is comprised of thick walled and fairly large diameter vessels and is located toward the upper side of the vein. The solute conducting cells of the phloem (sieve tubes) are oriented towards the lower side of the vein. The bundle sheath is composed of thick walled fibers (sclerenchyma), or, in some of the smaller veins, thinner walled parenchyma cells. The bundle sheath of the large midvein extends from upper to lower epidermis.

Diagram of Dicot Leaf
Exercise II  Monocot Leaf

Materials Needed
Prepared slides of:
Zea (corn) leaf, xs
Monocot and Dicot leaf, xs

Procedure
Observe a corn (Zea mays) leaf section. Note the distribution of veins. Monocot leaves generally have parallel veins rather than the branching network of veins common to dicot leaves. Note too that the corn leaf has a uniform mesophyll region rather than distinctive palisade and mesophyll areas.

In the corn leaf the veins are surrounded by a bundle sheath composed of large parenchyma cells. These cells are involved with C-4 photosynthesis. The larger vascular bundles contain extensions of sclerenchyma that connect to the epidermis for support. Identify the xylem and the phloem regions of the veins.
Exercise III  C-4 Photosynthesis and Leaf Structure
Most higher plants use a photosynthetic pathway known as the C-3 photosynthetic pathway, where the Calvin cycle begins with CO2 (carbon dioxide) combining with ribulose bisphosphate (RuBP) to form the 3-carbon compounds, PGA (phosphoglyceric acid) and G3P (glyceraldehyde-3-phosphate). Both the light reactions of photosynthesis and the Calvin cycle occur within the same chloroplasts in all of the mesophyll cells. The *Ligustrum* or *Syringa* dicot leaf cross section you observed shows the typical leaf structure of a C-3 plant.

Some plants, known as C-4 plants, use a different pathway for carbon fixation, in which CO2 first combines with PEP (phosphoenolpyruvate) to produce 4-carbon acids. The CO2 taken into the leaf can be stored in the form of the 4—carbon acids. This is especially beneficial for plants in hot dry areas, which lose lots of water through their open stomata when CO2 is absorbed. Many C-4 plants can "stockpile" CO2 this way, freeing CO2 from the acids for the Calvin cycle as needed.

Some monocot C-4 plants also separate the reactions of photosynthesis into different chloroplasts within different types of cells, another energy conserving measure. When plants do a lot of photosynthesis, the oxygen produced during the light reactions competes with CO2 for the ribulose bisphosphate (RuBP) enzyme. The light reactions of C-4 plants occur in mesophyll cells that surround the veins’ enlarged and modified bundle sheath cells. The Calvin cycle occurs in chloroplasts of the enlarged bundle sheath cells. This separation of reactions keeps oxygen away from the cells performing Calvin cycle steps. C-4 photosynthesis has several benefits for the plant, resulting in a more efficient rate of photosynthesis. It also results in an interesting modification of the typical leaf anatomy.

Materials Needed
Prepared slide of:
Zea (corn) leaf, xs

Procedure
Corn (*Zea mays*) is a C-4 plant. Look again at the bundle sheath cells that surround the veins. The bundle sheath cells contain the chloroplasts in which the Calvin cycle occurs. The mesophyll cells surround the bundle sheath cells. The light reactions of photosynthesis occur in the chloroplasts of the mesophyll cells. This C-4 leaf structure is known as Kranz anatomy.

Observe the micrographs of the C-4 mesophyll and bundle sheath cell chloroplasts shown below. Note the different chloroplast structures in the two cells. Why does the mesophyll cell have chloroplasts containing lots of grana composed of many thylakoid layers? Why are well-developed grana absent in the chloroplasts of the bundle sheath cell?

Note the many plasmodesmata that connect the two cells shown in the electron micrograph. Why would you expect to see so many plasmodesmata between the mesophyll cells and the bundle sheath cells in the C-4 plant?
Exercise IV  Stomata Structure in Zebrina leaves

The epidermal surfaces of plants are covered with a protective cuticle. However, CO₂ must enter the leaf for photosynthesis and the O₂ produced during photosynthesis must be released from the plant. To solve this dilemma plants have specialized cells in the epidermis, called guard cells, which form stomata (pores) in the epidermis. Stomata can be open or closed, depending on the turgor of the guard cells. When stomata are open, gas exchange can occur. Unfortunately, large amounts of water are lost from the plant through the open stomata as well. (For example, as much as 90% of the water absorbed by the roots of a corn plant growing in Kansas may be lost through the stomata of its leaves.) To avoid excessive water loss, the guard cells have a mechanism to open the stomata during photosynthetic periods (i.e., daylight hours) and close the stomata when photosynthesis is not occurring.

You will observe guard cells and stomata in the lower epidermis of leaves of Zebrina. Since the regular epidermal cells of Zebrina contain anthocyanin (purple) pigments, the guard cells, which contain chloroplasts, are particularly conspicuous.

Materials Needed
Living Zebrina plant
Prepared slides of:
Leaf epidermis

Procedure
Zebrina Epidermal Peel
- Cut a portion of a leaf from a Zebrina plant.
- With your fingernail or a sharp razor blade, peel a portion of the lower epidermis from the leaf, starting at the cut edge. Note: The lower epidermis is purple-pigmented. The upper epidermis is silver and green striped.
- Make a wet mount of the epidermal peel. Try to have the peel flat on the microscope slide; wrinkled portions have too many layers of cells and trap air bubbles.
- Observe your slide with your microscope. After locating guard cells with the lower power magnification, use the 45x objective to observe one of the stomata closely. Can you see the chloroplasts in the guard cells?

Leaf epidermis with stomata and guard cells
Open and Closed Stomata

What is the shape of the guard cells? Note the thickness of the inner walls of the guard cells. Are any of the stomata open?

Recall from your observation of the prepared slide of a leaf that a stoma opens into an air space of the spongy mesophyll. Of what advantage is this arrangement to the plant for photosynthesis?