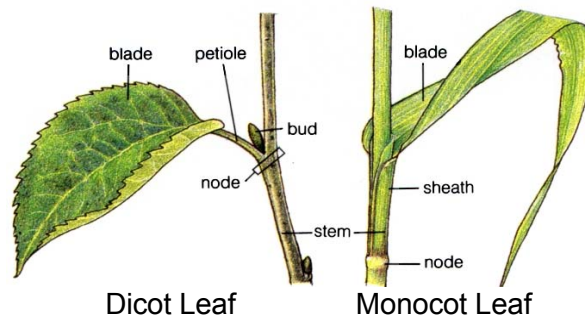


## The Leaf

Leaves are the main appendages of the stem, and in most vascular plants, the principal structure for photosynthesis. Leaves vary tremendously in form and internal structure. 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.

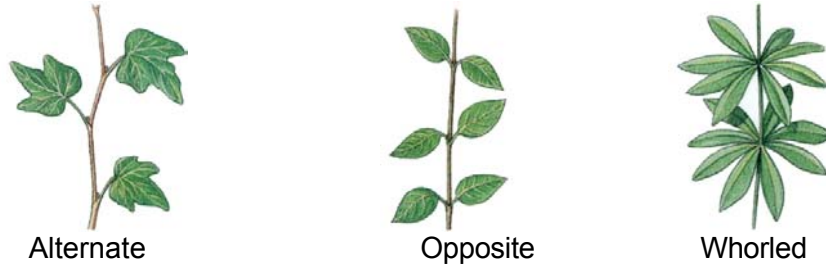
### A. Leaf Morphology

Most leaves do have two common features: a **blade** (or sometimes lamina), the flattened portion of the leaf and a **petiole**, or leaf stalk, which attaches the leaf to the stem. Leaves that do not have a petiole are **sessile**. **Stipules**, small leaf-like growths near the base of the petiole, may or may not be present.



**Venation** patterns are an important distinction between monocots and dicots. Monocots usually have parallel veins; dicots have netted veins, generally with a significant mid vein. Dicot leaves may have **pinnate** venation or **palmate** venation. The *Ginkgo* tree, which is a gymnosperm, has leaves with **dichotomous** venation. It is unique.

The arrangement of leaves, or **phyllotaxy** is determined genetically. Leaves can be alternate, opposite or whorled at nodes.



Leaf blades may be **simple**, dissected or **compound**, composed of leaflets attached to the petiole. A compound leaf can be distinguished from a simple leaf by the location of buds. Compound leaves may be pinnately compound or palmately compound. Compound leaves with three leaflets, such as clover, are said to be **ternate**.



The many variations in leaves provide for better survival in specific habitats. For example, thickened epidermis and epidermal hairs protect and minimize water loss for leaves of dry areas. Large air spaces make floating leaves buoyant. Dissected leaves in water offer less resistance to water force.

Observe the plants available to determine the shape, venation pattern and phyllotaxy of their leaves.

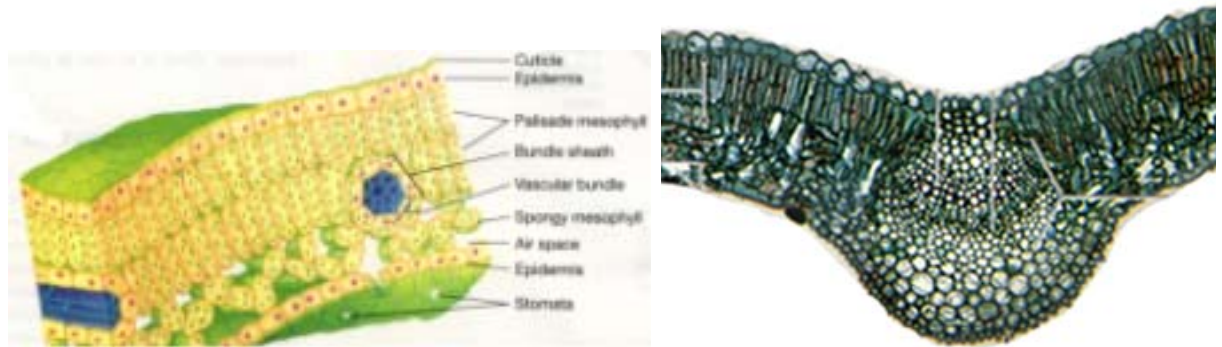
## B. Dicot Leaf Structure

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**
- **Palisade mesophyll**
- The **veins**, with their bundle sheaths of sclerenchyma or parenchyma
- **Spongy mesophyll**
- **Lower epidermis**, which also has a cuticle.

The palisade and spongy mesophyll are composed of parenchyma cells that 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. The mushroom-shaped structures of the epidermis are **trichomes**, or **epidermal hairs**.



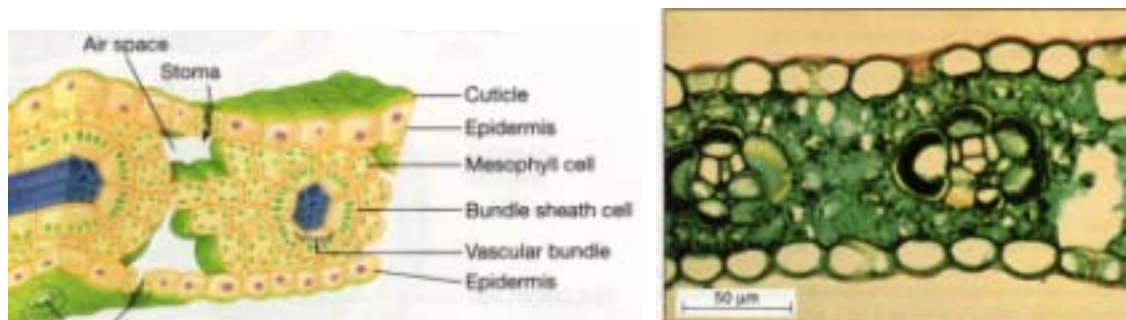
Dicot Leaf Cross Section

## C. A Monocot Leaf

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 sheath composed of large parenchyma cells. These cells are involved with C<sub>4</sub> photosynthesis. The larger vascular bundles contain extensions of sclerenchyma which connect to the epidermis for support. Identify the xylem and the phloem regions of the veins.

Where are the stomata and guard cells located in the corn leaf?



Monocot Leaf Cross Section

## D. Environmental Adaptations of Leaves

### 1. Xeromorphic Leaves

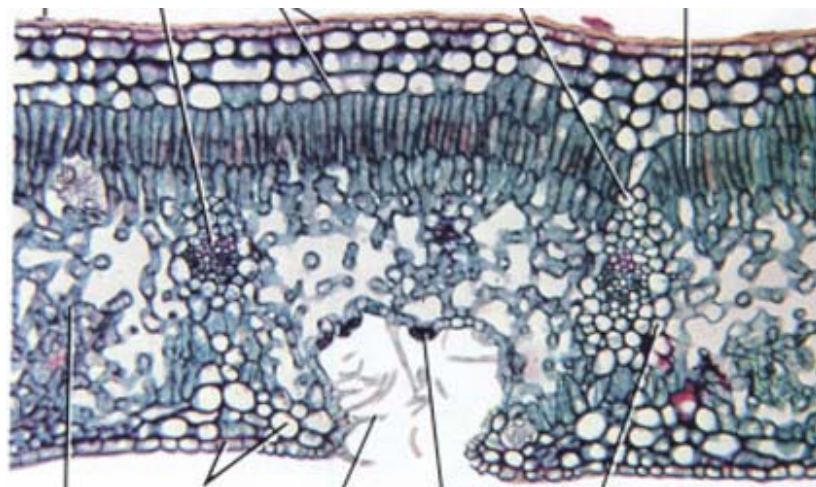
Plants that live in arid environments are subject to drought, and often, intense sunlight. Such plants are called xerophytes. These plants are subjected to intense evaporation of water, a resource which is often in short supply. Many such plants have a number of modifications which minimize water loss through transpiration, the evaporation of water from the plant surfaces. Some plants drop their leaves during periods of drought; cactus plants photosynthesize with modified stem tissue, and lack leaves entirely. Those plants which do produce and retain leaves often have special features which we associate with the xeromorphic leaf. *Nerium oleander* is a good example of a plant with xeromorphic leaves.

#### *Nerium oleander*

Examine the prepared slide of *Nerium oleander* leaf, xs. Note the very thick **cuticle** as you focus on the **upper epidermis**. The epidermis is several layers thick, too. The **palisade parenchyma**, beneath the epidermis layers, is in two layers. The **spongy mesophyll** is loosely packed and quite wide. The unusual structures seen in the spongy mesophyll are a type of crystal, called **druses**.

**Veins** may have bundle sheath extensions in addition to the bundle sheath layer. Look for the mid vein. It has phloem on both sides of the xylem, which is unusual.

As you turn to the **lower epidermis**, note that it, like the upper epidermis, has several layers and a thickened cuticle. As you move your slide along the lower epidermis, note the deep invaginations of the epidermis layer into the lower leaf. These invaginations are called **stomatal crypts**. There are a number of epidermal hairs in the crypts, along with the stomata. All of the stomata are located in the crypts. Why do you think this is?



*Nerium oleander* leaf, xs.

#### *Ficus* sp. (Fig) Leaf

Compare a *Ficus*, sp. leaf xs. with the *Nerium oleander* leaf you just observed. Both have xeromorphic adaptations.

#### Succulent Leaf

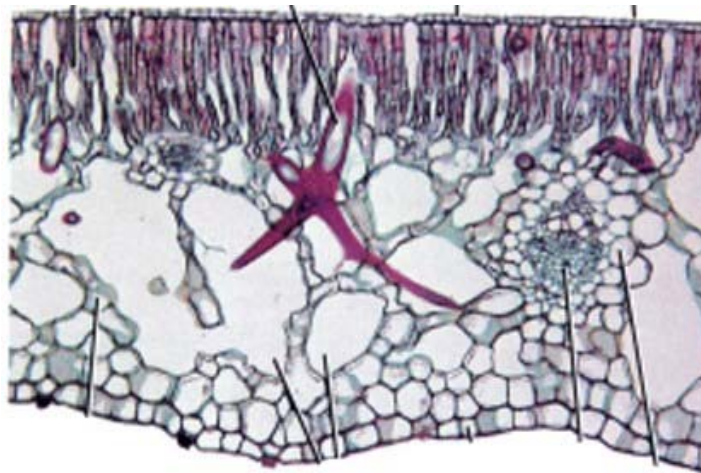
Now examine a slide of *Aloe*, *Sedum*, *Agave* or similar succulent leaf. Which tissue is modified for water storage in the leaf? Note too, the location of stomata and the cuticle layer on the epidermis.

**2. Hydromorphic Leaves**

The leaves of the water lily (*Nymphaea*) float on the surface of ponds and lakes, although the water lily is rooted in the lake bottom. Examine a prepared slide of *Nymphaea* leaf, xs, to observe modifications water lilies have for flotation.

Look first at both **epidermis** layers. Where do you find stomata? Why? Look for small hairs in the lower epidermis layer. Now refocus on the upper epidermis layer. Can you find the **cuticle**? It is very thin. Below the epidermis cells the **palisade mesophyll** consists of three or four overlapping layers of cells, which are fairly loosely packed, allowing for gases to enter from the upper epidermis. Note the huge **intracellular spaces** in the **spongy mesophyll** layer. The buoyancy of the water lily comes from these large air spaces. The spongy mesophyll also contains large, branching, thick-walled **sclerids** for support. There are crystals within the sclerids, too.

Note the reduced size of the **veins** in *Nymphaea*, compared to most leaves. The vascular tissue, especially the xylem, is minimal in most hydromorphic leaves. You should find more phloem than xylem in the vascular tissue as you observe the scattered veins.



*Nymphaea* leaf, xs

Compare the adaptations of the hydromorphic and xeromorphic leaves with the typical mesomorphic dicot leaf, such as *Syringa*.

Ecological Leaf Type	Adaptive Structures	Environment
Mesomorphic: <i>Syringa</i>		
Xeromorphic: <i>Nerium</i>		
Hydromorphic: <i>Nymphaea</i>		

3. **Conifer Needle – *Pinus* sp.**

Many conifers live in areas of cold winters and dry summers. Moreover, most conifers do not drop their leaves (needles) at the end of each growing season; they are “evergreens”. The conifer needle also has many xeromorphic adaptations.

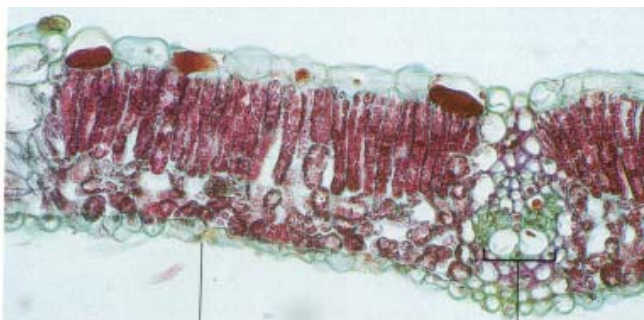
Observe a prepared slide of a pine needle, *Pinus* sp. Most pine leaves are in fascicles (or bundles) of two – five needles each. The shape of a needle reflects the number of needles in a fascicle.

You should note the **hypodermis** layer beneath the epidermis, and the sunken stomata. Pine needles also have an **endodermis** separating a region of **transfusion** tissue from the mesophyll cells. The vascular tissue is located within the transfusion tissue. **Resin canals** are also visible in the mesophyll region. Resin canals are found in leaves, stems and roots of conifers. They are not found in other groups of plants.

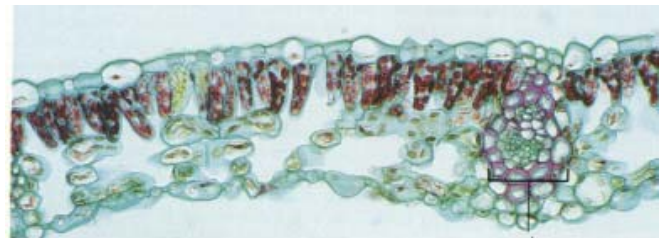


4. **Sun and Shade Leaf Structure**

Obtain a prepared slide of sun and shade leaves. Compare the mesophyll layers and chloroplasts in the leaf exposed to full sun and the leaf grown in shade. This is a good example of the influence of environment on genetic expression.



Leaf from full sun, xs.



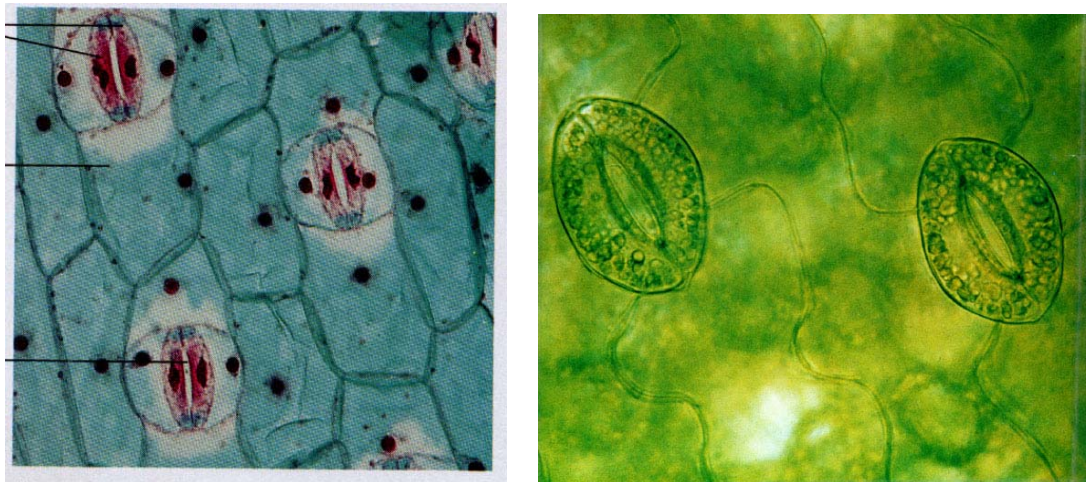
Leaf from shade, xs

## E Stomata Structure

The epidermal surfaces of plants are covered with a protective cuticle. However, CO<sub>2</sub> must enter the leaf for photosynthesis and the O<sub>2</sub> 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 may be lost through the stomata of its leaves.) To avoid excessive water loss, 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, or when the plant is under severe water stress. Stomata may also close when exposed to toxic substances such as ozone and sulfur oxides in the atmosphere. You may recall that one mechanism some plants have to minimize water loss is reverse stomatal operation, in which stomata are open in the evening and close in the daytime. Such plants have a metabolic way to “trap” the diffusing CO<sub>2</sub> by combining it with 3-carbon acids so it can accumulate in the leaf tissue to be released and available during photosynthesis.

You can 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.



Leaf epidermis showing stomata and guard cells

### ***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?
- 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?

**F. Leaf Abscission**

Obtain a slide of the abscission zone of a leaf. The abscission zone is located at the base of the petiole and has two layers: a separation layer and a protection layer. The cell walls of the protection layer contain suberin. The protection layer forms the leaf scar visible on the surface of young twigs after the leaf has abscised.

