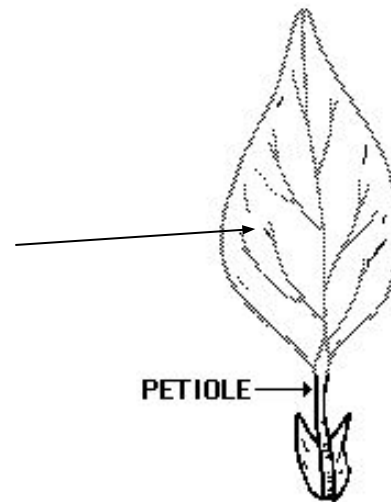


# LEAVES:

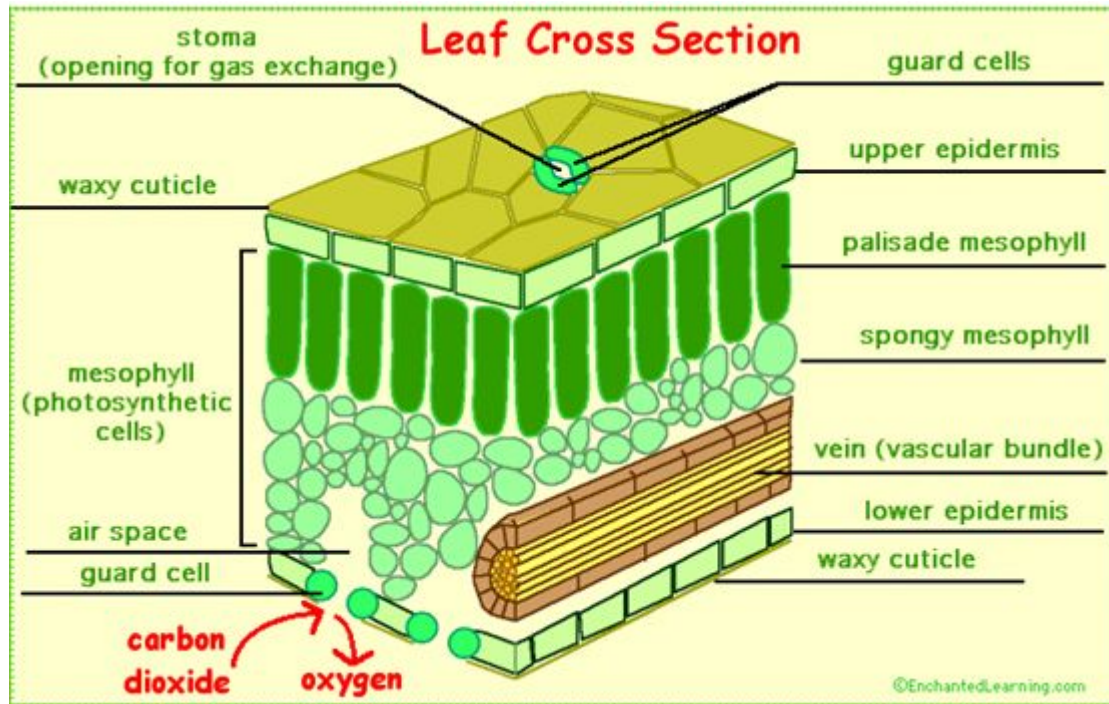
- ‘Photosynthetic factories’ of the plant...
- Function: Photosynthesis – food production for the whole plant
- **Blade:** Flat expanded area
- **Petiole:** stalk that connects leaf blade to stem, and transports materials

BLADE



## Leaf Structure:

- A leaf is made of many layers that are sandwiched between two layers of tough skin cells (called the epidermis). The epidermis also secretes a waxy substance called the cuticle. These layers protect the leaf from insects, bacteria, and other pests. Among the epidermal cells are pairs of sausage-shaped guard cells. Each pair of guard cells forms a pore (called stoma; the plural is stomata). Gases enter and exit the leaf through the stomata.
- Most food production takes place in elongated cells called **palisade mesophyll**. Gas exchange occurs in the air spaces between the oddly-shaped cells of the **spongy mesophyll**.
- Veins support the leaf and are filled with vessels that transport food, water, and minerals to the plant.



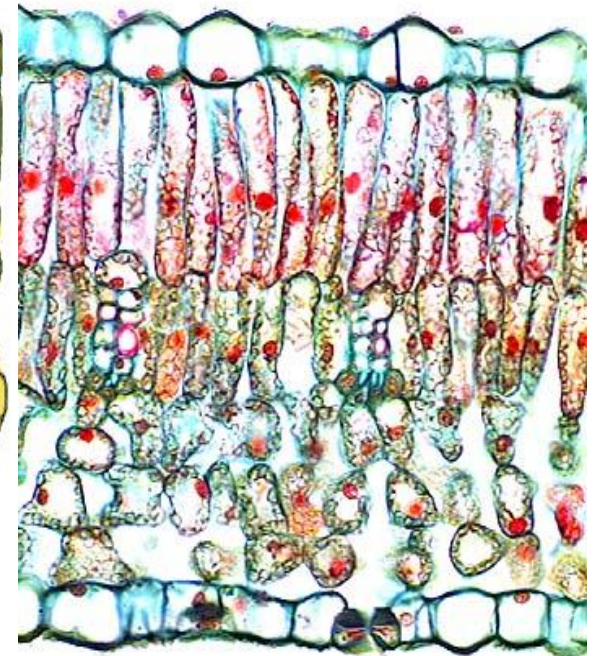
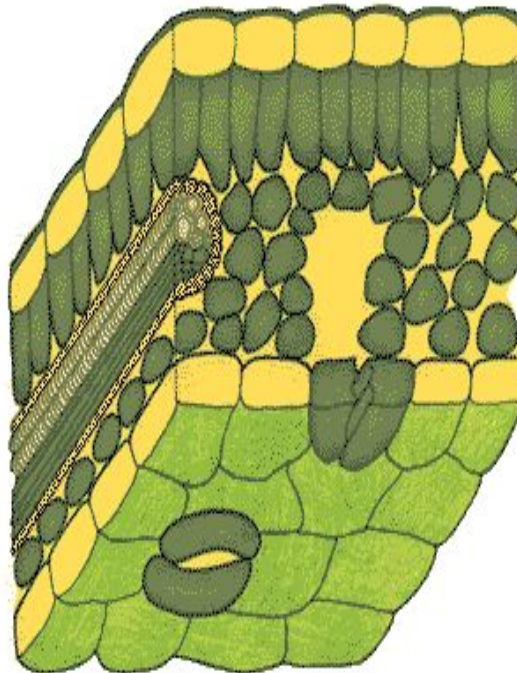
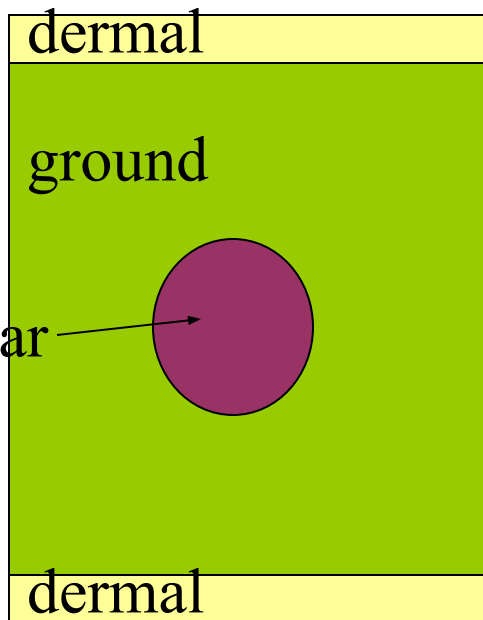
- **Leaf Glossary:**
  - air space** - intercellular gaps within the spongy mesophyll. These gaps are filled with gas that the plant uses (carbon dioxide - CO<sub>2</sub> ) and gases that the plant is expelling (oxygen - O<sub>2</sub>, and water vapor).
- **axil** - the angle between the upper side of the stem and a leaf or petiole.
  - cuticle** - the waxy, water-repelling layer on the outer surface of a leaf that helps keep it from dying out (and protect it from invading bacteria, insects, and fungi). The cuticle is secreted by the epidermis (including the guard cells) and is often thinner on the underside of leaves. The cuticle is generally thicker on plants that live in dry environments.
- **epidermis** - the protective, outer layer of cells on the surface of a leaf. The guard cells (and stoma) are part of the epidermis. The surface of many leaves is coated with a waxy cuticle which is secreted by the epidermis.
  - guard cell** - one of a pair of sausage-shaped cells that surround a stoma (a pore in a leaf). Guard cells change shape (as light and humidity change), causing the stoma to open and close.

- **leaf apex** - the outer end of a leaf; the end that is opposite the petiole.  
**mesophyll** - the chlorophyll-containing leaf tissue located between the upper and lower epidermis. These cells convert sunlight into usable chemical energy for the plant.  
**midrib** - the central rib of a leaf - it is usually continuous with the petiole.  
**palisade mesophyll** - a layer of elongated cells located under the upper epidermis. These cells contain most of the leaf's chlorophyll, converting sunlight into usable chemical energy for the plant.

# Leaf Anatomy

- Leaf anatomy is correlated to photosynthesis:

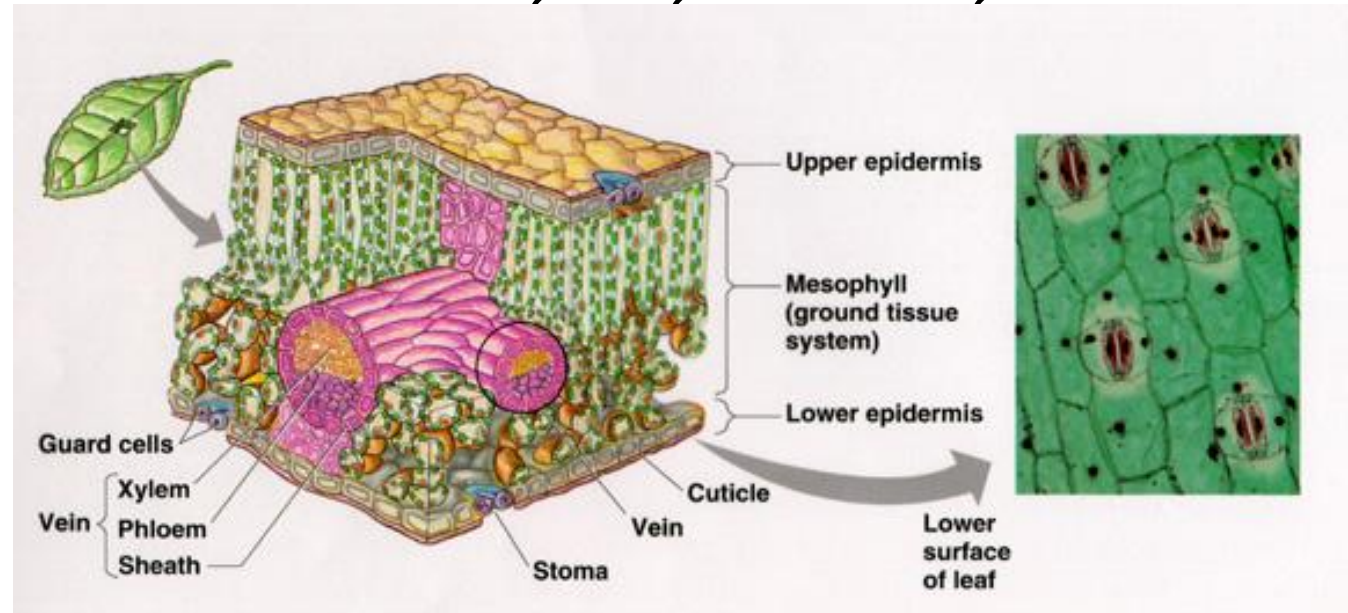
Carbon dioxide + Water  $\rightarrow$  sugars + oxygen





# Leaf epidermis

- Is transparent – so that sun light can go through.
- Waxy cuticle protects against drying out
- Lower epidermis: **stomata** with **guard cells** – for gas exchange ( $\text{CO}_2$ ,  $\text{H}_2\text{O}$  in;  $\text{O}_2$  out)





## Structure of the Stomata

A **stoma or pore** is formed by a **pair of bean-shaped guard cells**. The guard cells have the ability to **open and close** the stoma. The **inner walls** of the guard cells are **thick** and the **outer walls thin**. Guard cells differ from the translucent epidermal cells in that they **contain chloroplasts**.

Stomata communicate with the air chambers in the **spongy mesophyll**.

There are **more stomata on the lower epidermis** of the leaf than the **upper epidermis**.

Certain terminology is associated with their location; **if they occur on both surfaces** of a leaf, the plant is **amphistomatic**; if they occur on the upper surface only, it is **epistomatic**; and lower surface only is **hypostomatic**.

## Functions:

The stomata are responsible for the *interchange of gases for respiration and photosynthesis*.

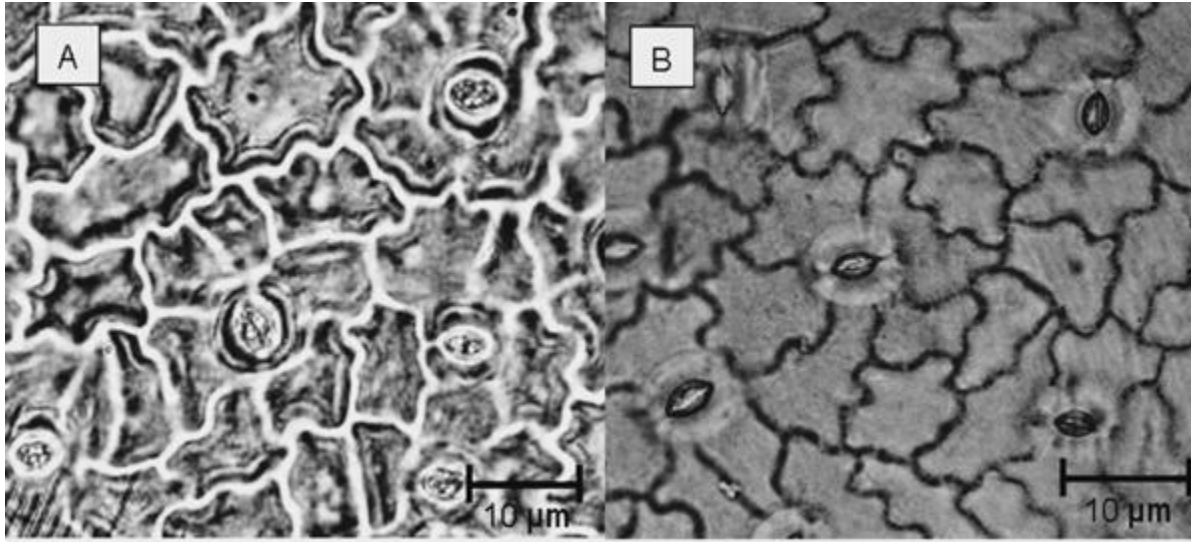
The stomata *allow for the loss of excess water in the form of water vapour*, which also allows for cooling.

**The various types of stomata present in a plant are:**

- 1)Paracytic stomata**
- 2)Diacytic stomata**
- 3)Anisocytic stomata**
- 4)Anomocytic stomata**
- 5)Actinocytic stomata**

## Stomata type

**Anomocytic:** The stomata are anomocytic in which the guard cells are not surrounded with any subsidiary cell (surrounded by five unspecialized epidermal cells)

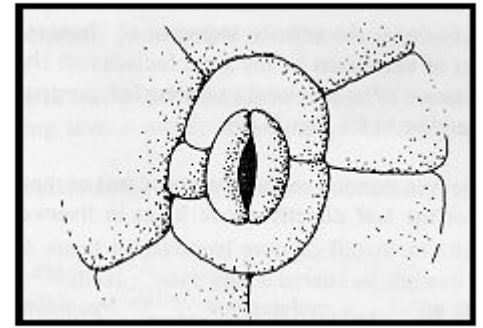


**Species included:** *Aerva javanica* (Burm.f.) Juss., *Amaranthus graecizans* L., *Amaranthus viridis* L., *Pupalia lappacea* (L.) Juss. *Cassia holosericea* Fres., *Parkinsonia aculeata* L. (Caesalpiniaceae), *Lactuca remotiflora* DC., *Euphorbia hirta* Forssk., *Phyllanthus niruri* L. (Euphorbiaceae), *Enicostemma verticillatum* (L.) Engler (Gentianaceae), *Salviasantolinaefolia* Boiss. (Labiatae), *Anagallis arvensis* L. (Primulaceae), *Zizyphus nummularia* (Burm.f.) (Rhamnaceae), *Datura alba* Nees, *Lycium europium* L., *Tribulus terrestris* L., *Zygophyllum simplex* L. (Zygophyllaceae).



**Anisocytic:** In anisocytic type the guard cells are surrounded by three unequal sized subsidiary cells, the common wall of which is at right angle to the longitudinal axis of stoma.

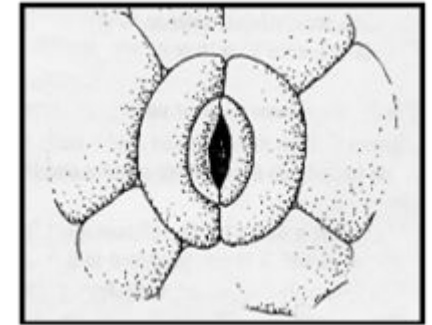
**Species included:** *Farsitia jacquemontii* Hook.f. et. Thoms.  
(Cruciferae)



**Paracytic:** In the paracytic type guard cells are accompanied by two subsidiary cells, the longitudinal axis of which are parallel to that of the guard cells and aperture.

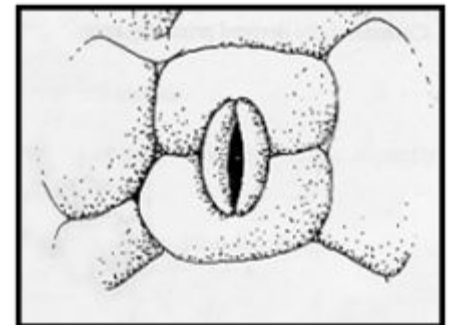
**Species included:** *Cleome brachycarpa* Vahl (Capparidaceae),  
*Convolvulus glomeratus*(Convolvulaceae), *Andrachne aspera* Spreng.

(Euphorbiaceae), *Oxalis corniculata* L. (Oxalidaceae),  
*Phaseolus trilobus* (L.) DC.(Papilionaceae).



**Diacytic:** Diacytic stomata are those in which one or more pairs of subsidiary cells enclose the stoma and the common wall of subsidiary cells are at right angles to the guard cells.

**Species included:** *Blepharis sindica* Stocks ex T. Anderson.,  
*Ruellia tuberosa* L.,  
*Ruellia patula* Jacq. (Acanthaceae).



**Parallelocytic:** In parallelocytic stomata, an alternating complex of three or more cshaped subsidiary cells is present.

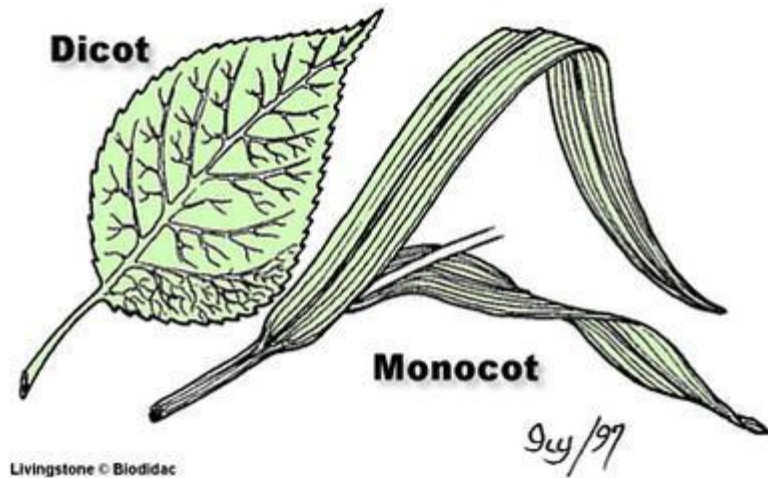
**Species included:** *Portulaca oleracea* L.  
(Portulacaceae).

**Cyclocytic:** In cyclocytic type two or more subsidiary cells form one or two narrow rings around the guard cells.

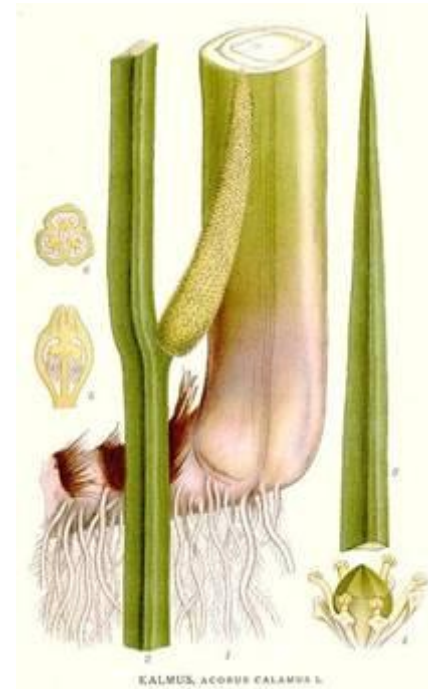
**Species included:** *Ipomoea carnea* Jacq.  
(Convolvulaceae)

- Leaf **facial symmetry** and insolation response; some plants grow their leaves with distinctly different sides for sun or shade exposure. **Plants that hold one leaf face to flat to the sunlight usually have stomata only or mostly on the underface (abaxial).** The abaxial surface of a leaf is the underside or side facing away from the stem. The sunward adaxial surface has a thicker waxy coating and typically has fewer stomata.

**Unifacial leaves** are both abaxial sided with plentiful stomata. The leaves hang vertically to expose less area directly to the drying sun. They have ~equal numbers of stomata on both faces of the leaf.

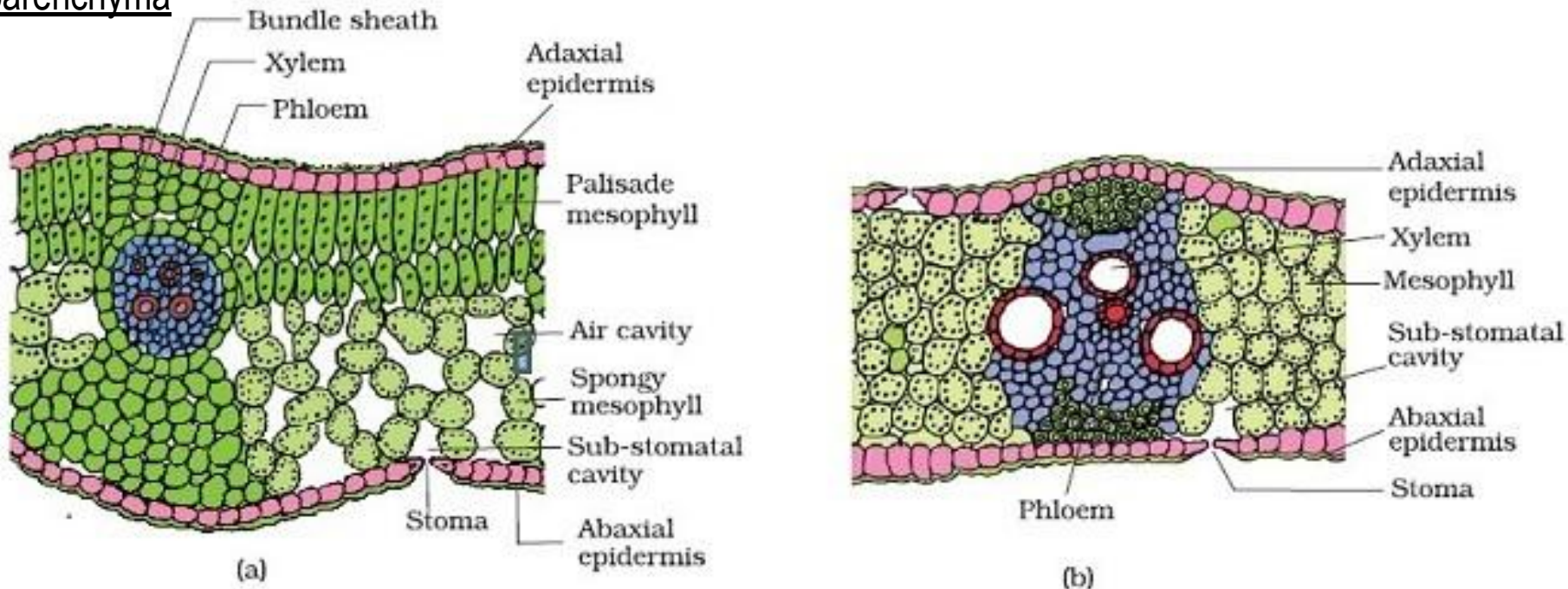


Livingstone © Biodidac



The vertical section of a dorsiventral leaf through the lamina shows three main parts, namely, epidermis, mesophyll and vascular system. The **epidermis** which covers both the upper surface (**adaxial epidermis**) and lower surface (**abaxial epidermis**) of the leaf has a conspicuous cuticle. The **abaxial epidermis** generally bears **more stomata** than the adaxial epidermis.

The anatomy of isobilateral leaf is similar to that of the dorsiventral leaf in many ways. It shows the following characteristic differences. In an **isobilateral leaf**, the **stomata are present on both the surfaces of the epidermis**; and the mesophyll is not differentiated into palisade and spongy parenchyma



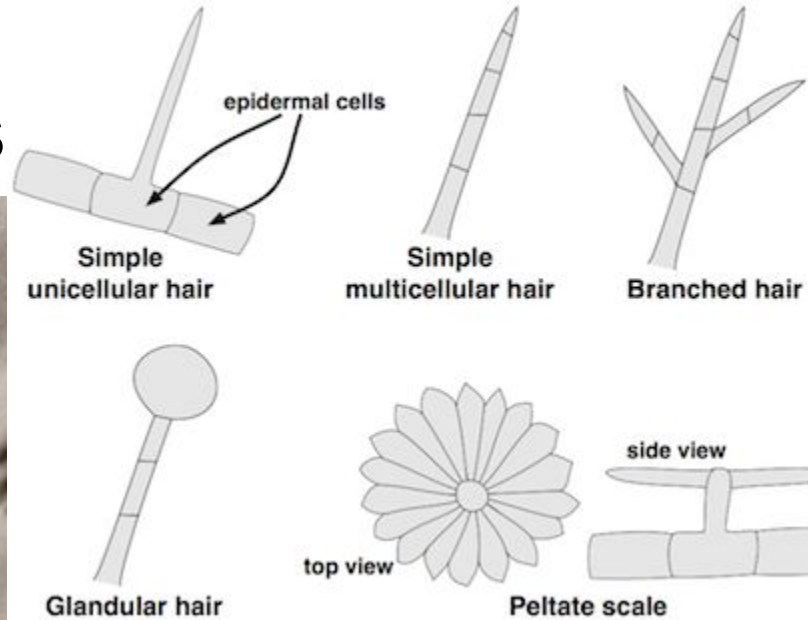
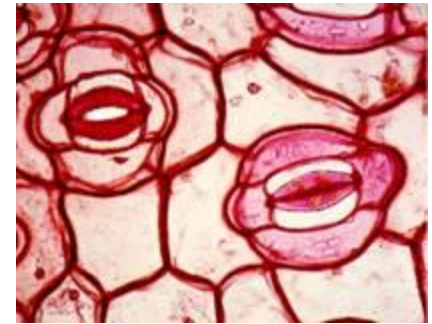
**Figure 8.** T.S. of leaf : (a) Dicot (b) Monocot

<b>Features</b>	<b>Dorsiventral leaf</b>	<b>Isobilateral leaf</b>
Cuticle	Thick at upper epidermis and thin at lower epidermis	Uniform cuticle
Stomata	More on lower surface	Equal number of stomata on either side.
Mesophyll	Differentiated into palisade and spongy parenchyma.	Not differentiated into palisade and spongy parenchyma.

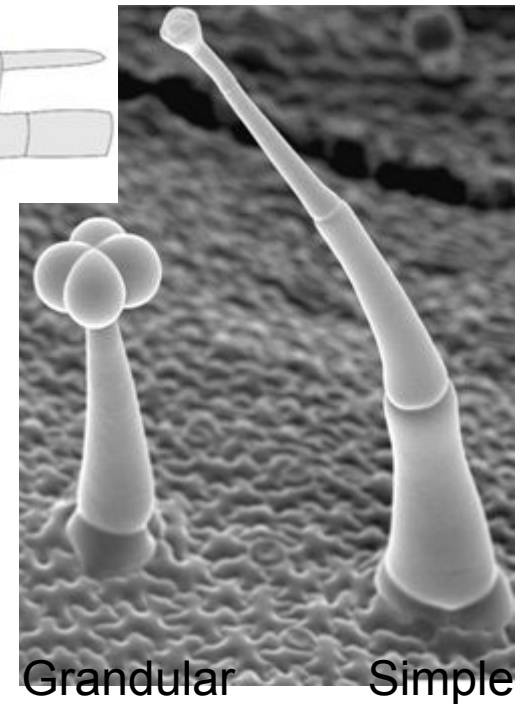
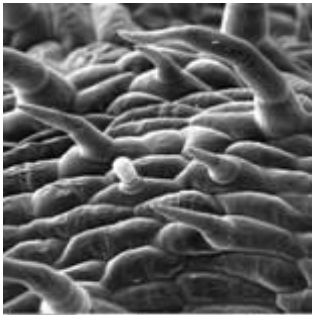


# Leaf epidermis

- Trichomes



(“Panda plant”)





# Leaf Mesophyll

- Middle of the leaf (meso-phyll)
- Composed of photosynthetic ground cells:
- **Palisade** parenchyma  
(long columns below epidermis;  
have lots chloroplasts for  
photosynthesis)

**Spongy** parenchyma  
(spherical cells)  
with **air spaces** around,  
(for gas exchange)



- **Functions of the Mesophyll**

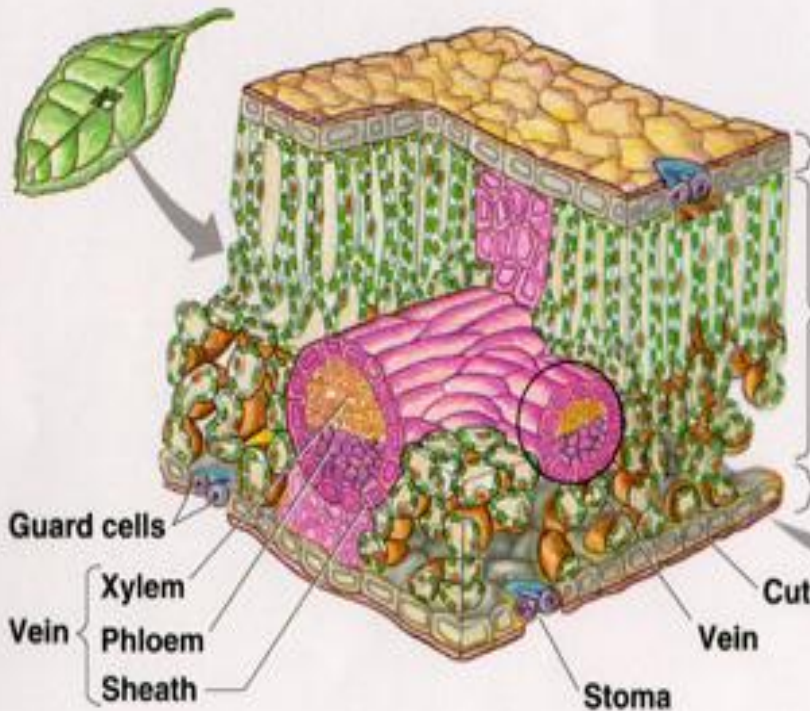
- The palisade cells are *responsible for photosynthesis* because they contain chloroplasts.
- The spongy mesophyll, together with the intercellular air spaces, *allow for the interchange of gases*.

# Leaf vascular tissue

- **VEINS** □ vascular tissue of leaves.
  - Veins are composed of **xylem** (water transport) **phloem** (food transport)

and **bundle sheaths**, cells surrounding the xylem/phloem for strength & support

The lignified xylem cells are situated towards the **upper epidermis** and the phloem towards the **lower epidermis**.



# • Venation

- **pinnate** - single main (primary) vein with secondary veins branching from it like a feather
- **palmate** - several primary veins arising from a common point
- **parallel** - primary and secondary veins parallel to one another. The parallel venation in monocot leaves is reflected in the near similar sizes of vascular bundles (except in main veins) as seen in vertical sections of the leaves
- **net or reticulate venation** - general term for pinnate or palmate pattern of veins.

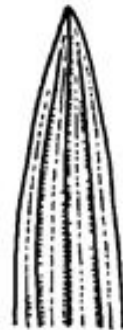
## VENATION



ARCUATE



PALMATE



PARALLEL



PINNATE



RETICULATE

# VENATION



**Arcuate**  
secondary veins  
bending toward apex



**Cross-Venulate**  
small veins connecting  
secondary veins



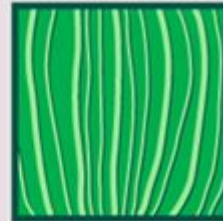
**Dichotomous**  
veins branching  
symmetrically in pairs



**Longitudinal**  
veins aligned mostly  
along long axis of leaf



**Palmate**  
several primary veins  
diverging from a point



**Parallel**  
veins arranged axially,  
not intersecting



**Pinnate**  
secondary veins  
paired oppositely



**Reticulate**  
smaller veins  
forming a network



**Rotate**  
in peltate leaves,  
veins radiating

## Structure of leaves

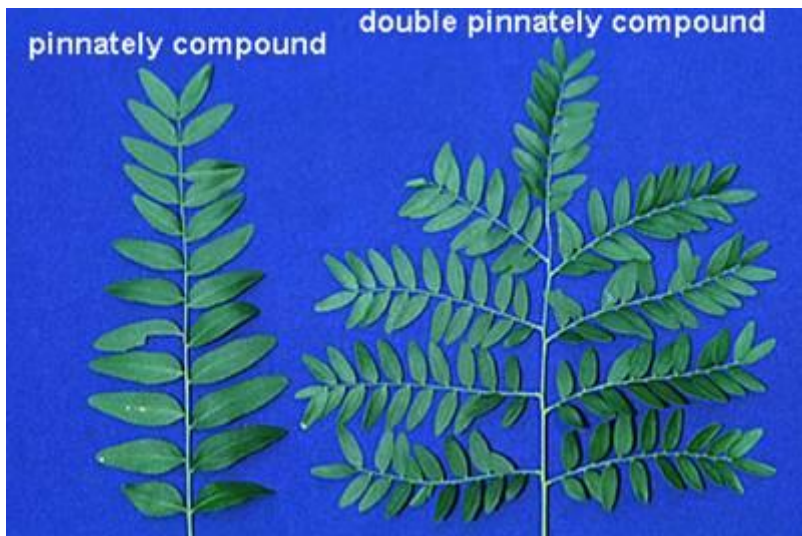
<b>Adaption</b>	<b>Purpose</b>
<b>Epidermis is thin and transparent</b>	<b>To allow more light to reach the palisade cells</b>
<b>Thin cuticle made of wax</b>	<b>To protect the leaf without blocking out light</b>
<b>Palisade cell layer at top of leaf</b>	<b>To absorb more light</b>
<b>Spongy layer</b>	<b>Air spaces allow carbon dioxide to diffuse through the leaf, and increase the surface area</b>
<b>Palisade cells contain many chloroplasts</b>	<b>To absorb all the available light</b>



<b>Characters</b>	<b>Dicot leaf</b>	<b>Monocot leaf</b>
<b>1. Nature of orientation</b>	<b>Typically dorsi-ventral</b>	<b>Typically iso-bilateral</b>
<b>2. Stomata</b>	<b>Hypostomatic</b>	<b>Amphistomatic</b>
<b>3. Motor cells</b>	<b>Absent</b>	<b>Present in the upper epidermis</b>
<b>4. Mesophyll</b>	<b>Differentiated into palisade and spongy parenchyma</b>	<b>Undifferentiated</b>
<b>5. Veins</b>	<b>Irregularly scattered</b>	<b>Parallely arranged</b>
<b>6. Xylem vessels</b>	<b>Many protoxylem and metaxylem vessels in each bundle</b>	<b>Two protoxylem and two metaxylem vessels in each bundle</b>
<b>7. Bundle sheath extensions</b>	<b>Made up of collenchyma</b>	<b>Made up of sclerenchyma</b>

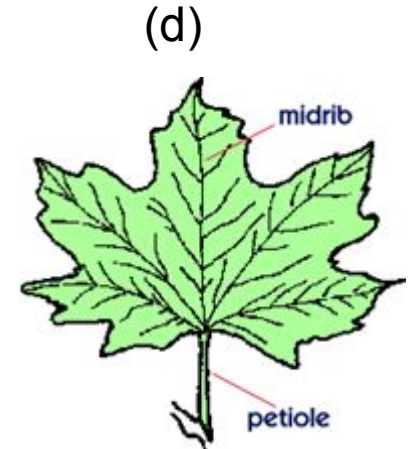
# Morphology

- **simple leaf** - a single blade, not divided into sections.
- **compound leaf** - leaf blade is divided into leaflets, all the way down to the midrib (which is called the **rachis** in a compound leaf).





© Current Biology 1996



## Leaf structure

**simple** - leaf blade all one section (a)

**lobed leaf** - the margin of the leaf is indented, but not all the way to the midrib (d)

**dissected** - leaf divided into very fine, somewhat indistinct segments (C)

**parted (or cleft)** - the margins between the irregular teeth go more than halfway to the midrib (b)

**compound** - leaf blade divided into smaller sections called leaflets

**leaflet** - section of a compound leaf

**rachis** - stalk that supports leaflets in a compound leaf; central axis

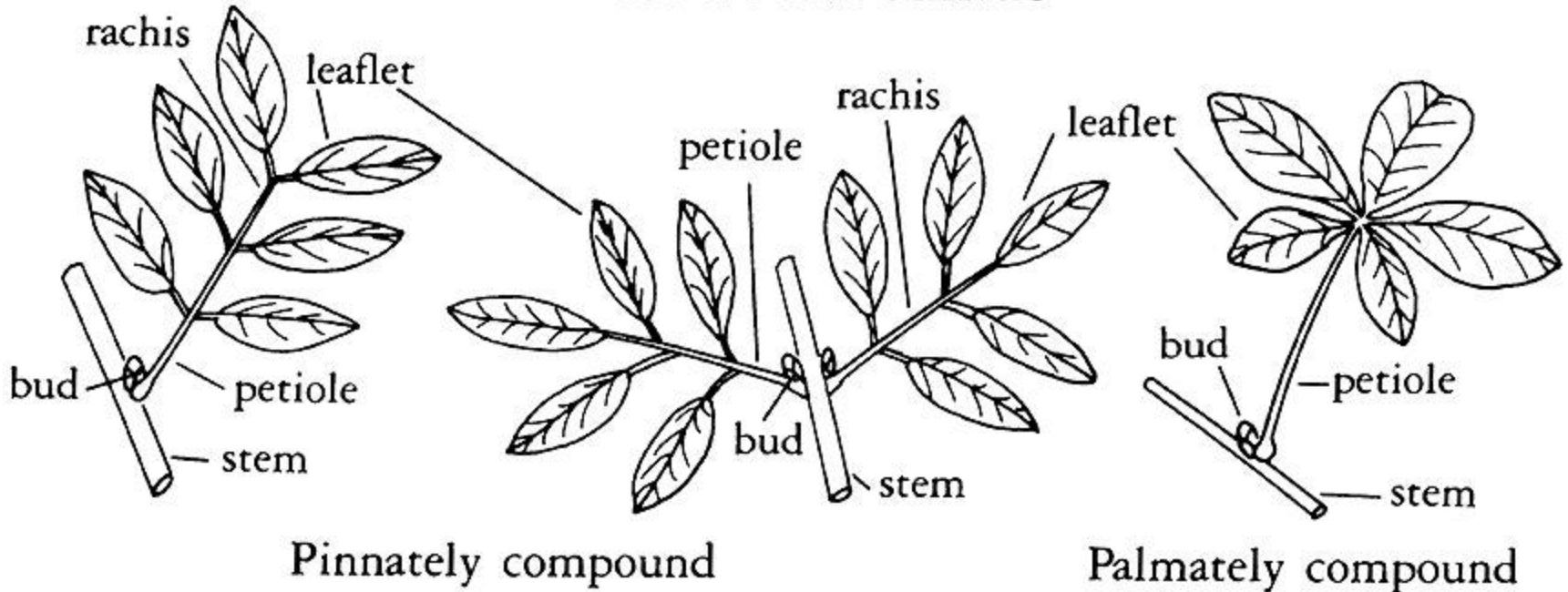
**rachilla** - stalk that supports lateral leaflets

**pinnately compound** - like a feather

**palmately compound** - like the fingers on your hand

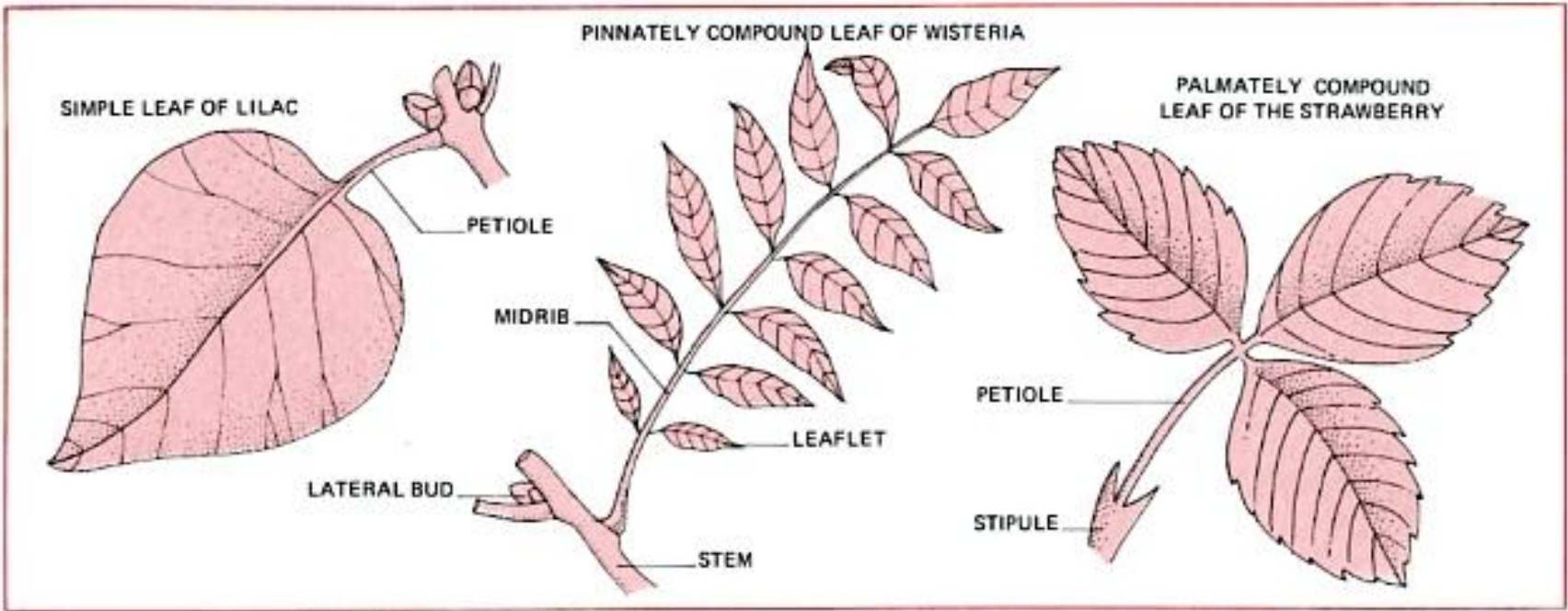
**petiole** - a leaf stalk; it attaches the leaf to the plant.

### ONCE COMPOUND LEAVES



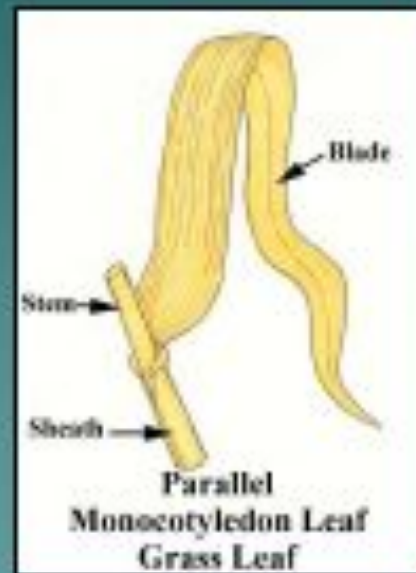
Pinnately compound

Palmately compound

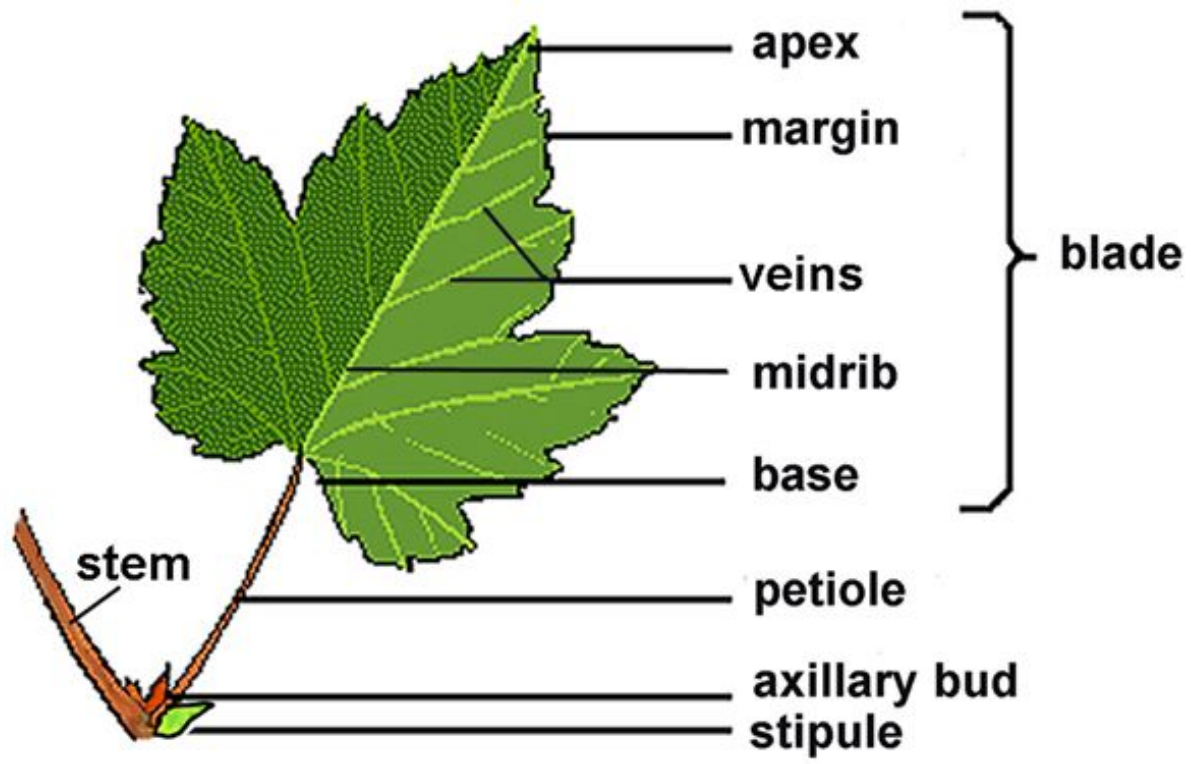




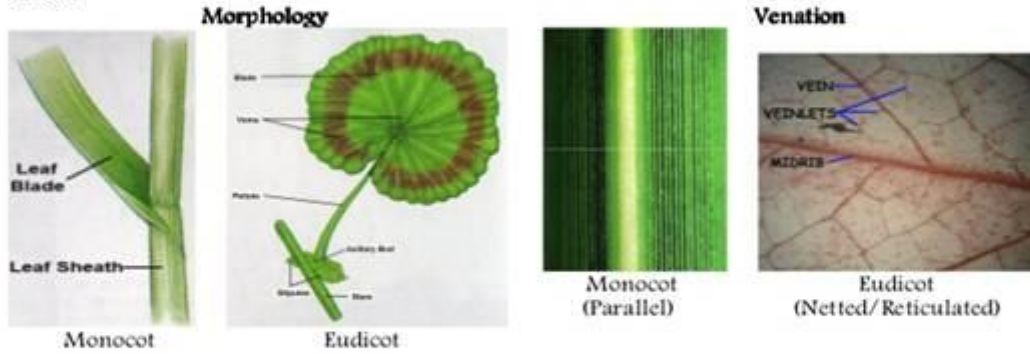
# Basic leaf structure







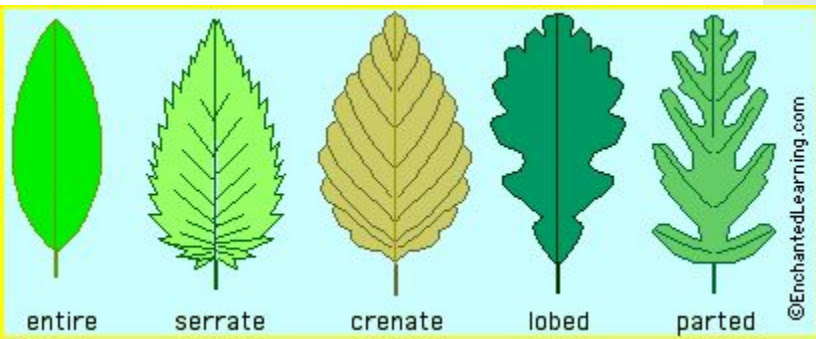
**C. Leaf**



# MARGIN

## Leaf Margins:

Leaves come in many sizes and shapes; they are often used to help identify plants. Some leaves are flat and wide; others are spiky and thin. Plant spines (like cactus spines) are actually modified leaves.



**Ciliate**  
with fine hairs



**Crenate**  
with rounded teeth



**Dentate**  
with symmetrical teeth



**Denticulate**  
with fine dentition



**Doubly Serrate**  
serrate with sub-teeth



**Entire**  
even, smooth throughout



**Lobate**  
lobed, but not to midline



**Serrate**  
teeth forward-pointing



**Serrulate**  
with fine serration



**Sinuate**  
with wave-like indentations

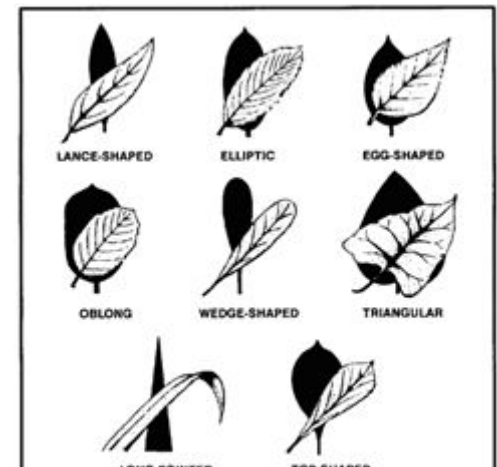


**Spiny**  
with sharp stiff points



**Undulate**  
widely wavy

- Leaves showing various morphologies. Clockwise from upper left: tripartite lobation, elliptic with serrulate margin, peltate with palmate venation, acuminate odd-pinnate (center), pinnatisect, lobed, elliptic with entire margin
- acuminate: long-pointed, prolonged into a narrow, tapering point in a concave manner.
- acute: ending in a sharp, but not prolonged point
- cuspidate: with a sharp, elongated, rigid tip; tipped with a cusp.
- emarginate: indented, with a shallow notch at the tip.
- mucronate: abruptly tipped with a small short point, as a continuation of the midrib; tipped with a mucro.
- mucronulate: mucronate, but with a smaller spine.
- obcordate: inversely heart-shaped, deeply notched at the top.
- obtuse: rounded or blunt
- truncate: ending abruptly with a flat end, that looks cut off.



- **Arrangement**

Leaves may be found only at the base of the plant (basal, **rosette**, as in dandelion) or along the stem (cauline) or some combination. Leaves are attached at nodes:

- **alternate** - one leaf per node
- **opposite** - two leaves per node; help remember temperate woody plants with opposite leaves (M=maple; A=ash; D=dogwood)
- **whorled** - more than two leaves per node; not common in temperate woody plants

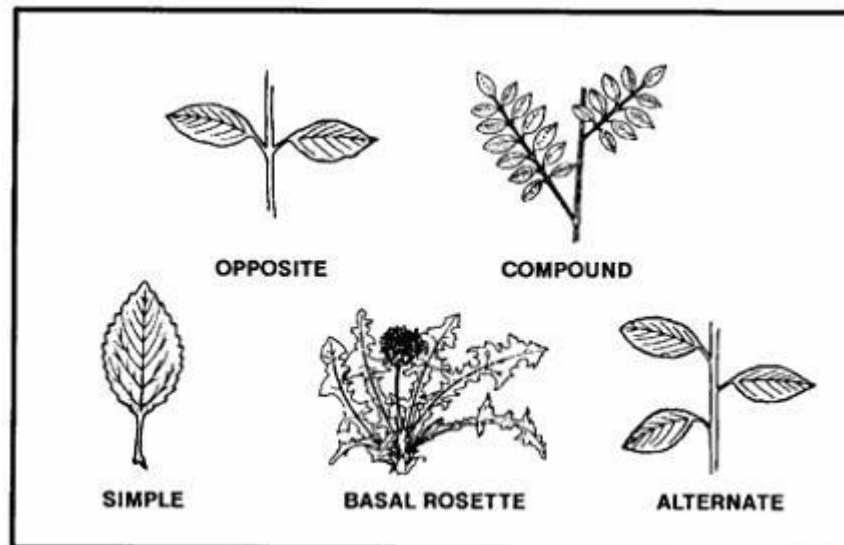


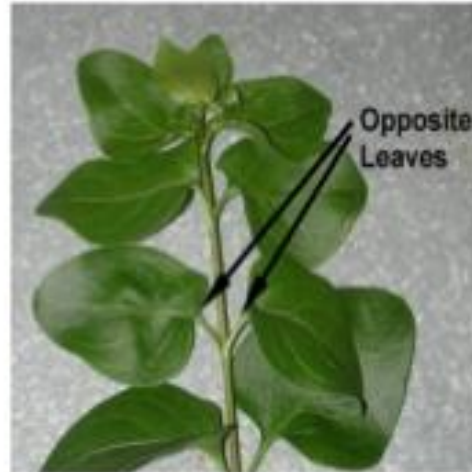
Figure 9-3. Leaf arrangements.

**BIO 101 Laboratory**  
*This serves as a supplement in the laboratory.*  
*Don't use this in your lecture class.*

### Leaf Arrangement



**Alternate**

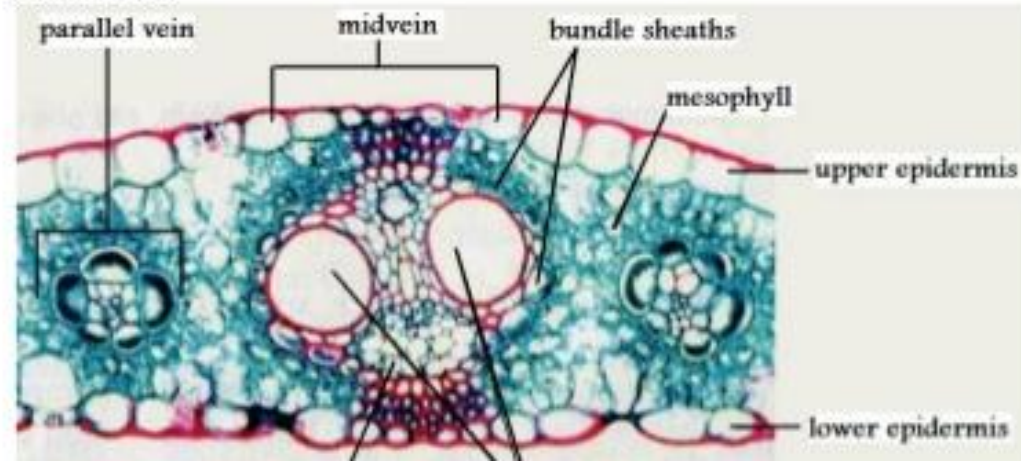


**Opposite**



**Whorled**

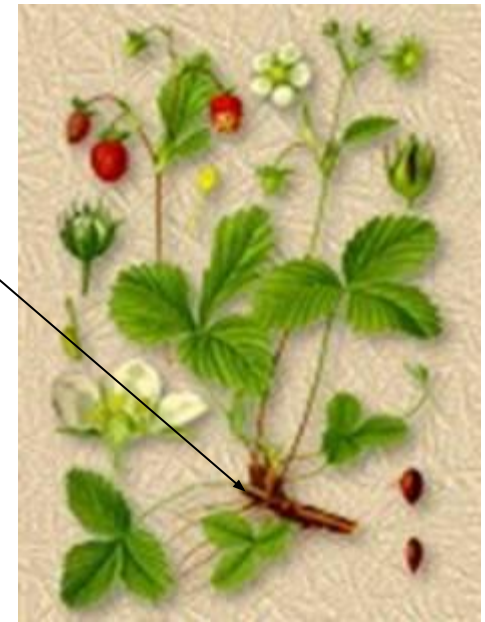
### Monocot:





# Arrangement leaves on the stem

- **Alternate** — leaf attachments are singular at nodes, and leaves alternate direction, to a greater or lesser degree, along the stem.
- **Opposite** — leaf attachments are paired at each node; **decussate** if, as typical, each successive pair is rotated 90° progressing along the stem; or **distichous** if not rotated, but two-ranked (in the same geometric flat-plane).
- **Whorled** — three or more leaves attach at each point or node on the stem. As with opposite leaves, successive whorls may or may not be decussate, rotated by half the angle between the leaves in the whorl (i.e., successive whorls of three rotated 60°, whorls of four rotated 45°, etc). Opposite leaves may appear whorled near the tip of the stem.
- **Rosulate** — leaves form a rosette



## BILBERRY LEAF (*Myrtilli folium*)

USES: Bilberry leaf has been used for diabetes, stomach problems, arthritis, blood circulation problems, and heart problems.

Red raspberry leaf is used for gastrointestinal (GI) tract disorders, including [diarrhea](#) Red raspberry leaf is used for gastrointestinal (GI) tract disorders, including diarrhea; for [respiratory system](#) Red raspberry leaf is used for gastrointestinal (GI) tract disorders, including diarrhea; for respiratory system disorders, including [flu](#) Red raspberry leaf is used for gastrointestinal (GI) tract disorders, including diarrhea; for respiratory system disorders, including flu and [swine flu](#) Red raspberry leaf is used for



**Khat** (*Catha edulis*; "edible kat") is a flowering plant native to the Horn of Africa and the Arabian Peninsula. The leaf and stem are used as a recreational drug and as medicine.

As a recreational drug, the leaves and stem are chewed by people in East Africa and the Arabian countries to elevate mood (as a euphoriant).

As a medicine, khat leaf is used for [depression](#)As a medicine, khat leaf is used

for depression, [fatigue](#)As a medicine, khat leaf is used for depression, fatigue, [obesity](#)As a

medicine, khat leaf is used for depression, fatigue, obesity, [stomach](#)As a

medicine, khat leaf is used for depression, fatigue, obesity, stomach ulcers, and male [infertility](#). It is also used to lower the

Senna has been used in alternative medicine as a laxative and an aid to treat constipation







Salvia officinalis



Mentha piperita



Plantago lanceolata



Urtica dioica