IV. Structure of Leaf

(I) Bifacial leaf and isolateral leaf

Bifacial leaf: In general, the upper surface of the leaf (ventral surface or adaxial surface) is dark green, and the lower surface (back surface or abaxial surface) is light green because different light receiving conditions of the two surfaces of a blade and different internal structures result in large differentiation of mesophyll tissues and formation of palisade tissues and spongy tissues.

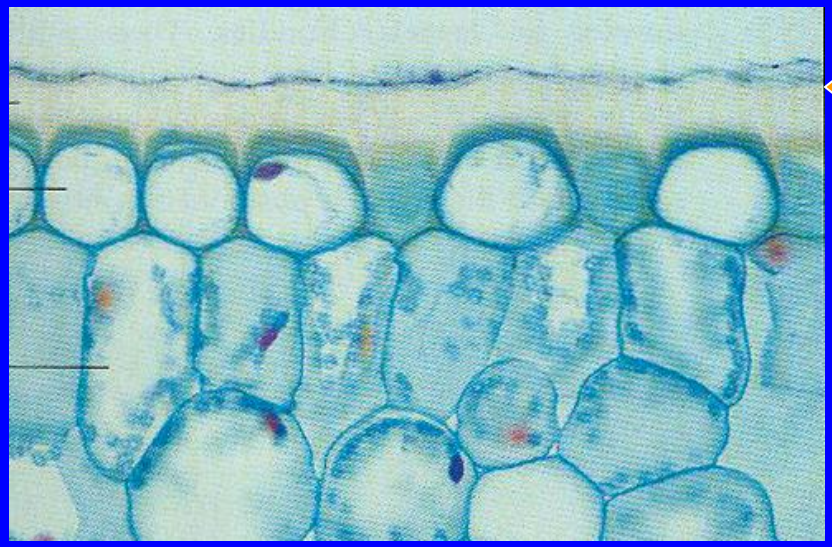
Isolateral leaf: The two surfaces of each leaf of some plants don't have a large difference in light receiving condition and their internal structures are similar, resulting in unremarkable tissue differentiation of mesophyll.

(II) General structure of angiosperm leaf

1. Epidermis

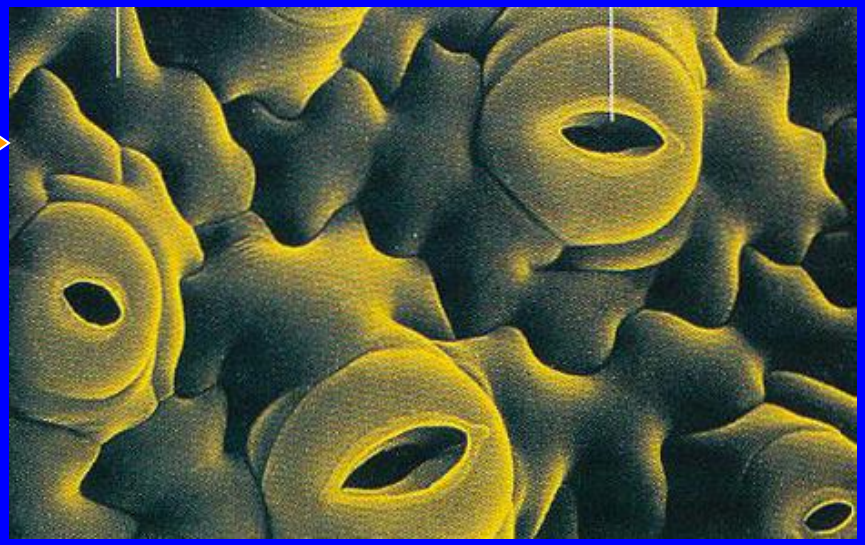
① General characteristics

In general, epidermis consists of upper epidermis and lower epidermis. There is a layer of living cells. Multiple epidermises exist in some cases. The flat cut surface reveals flat cells in a regular or irregular shape, and uneven and crisscross radial wall; the transverse section is rectangular or square, and the external wall is thick and has cuticle, wax layer in some cases. It does not contain chloroplast, but has stomata or stomatal complex. Generally speaking, the leaves in the upper part of a plant have more stomata than the lower part does, leaf apex and midrib have more stomata than leaf margins do, lower epidermis has more stomata than upper epidermis does, the locations with sufficient sunlight have more stomata than the dark and humid locations do, and submerged leaves usually don't have stomata. There are also water stomata on the epidermis of leaf apex or margins.



Light micrograph of a section through the upper surface of kaffir lily leaf.

SEM of a leaf surface, showing epidermal cells and stomata.



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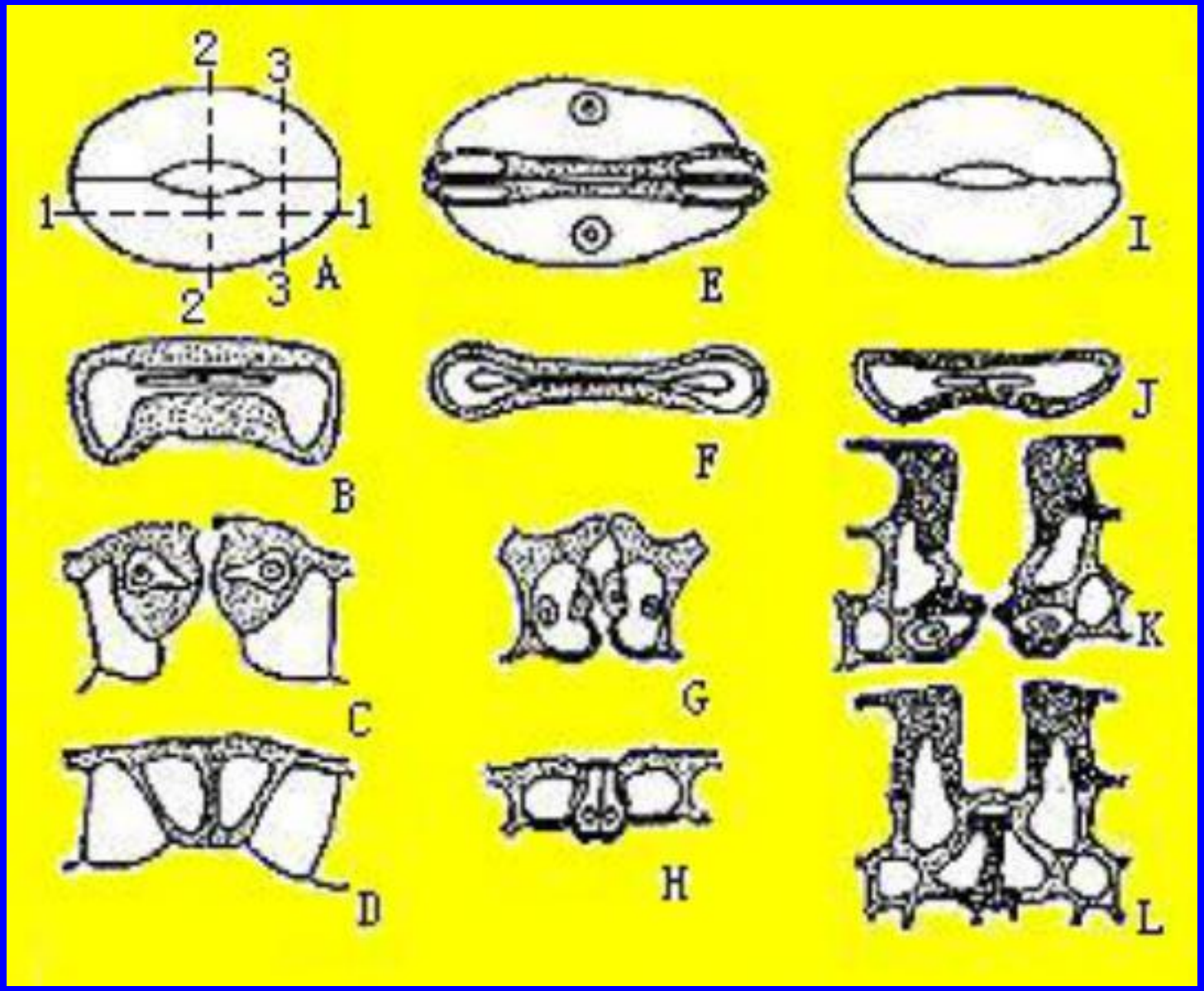

② Types of stomata

Anomocytic: Without subsidiary cells, a few cells in a same size and shape as epidermis encircle a guard cell irregularly, such as watermelon and *vicia faba*.

Unequal: Three subsidiary cells in different sizes encircle a guard cell and one of them is smaller than the other two, such as red-spotted stonecrop.

Paracytic: One or a few subsidiary cells accompany each guard cell on the side face and their long axes are parallel with the long axes of stomata, such as *radix rubiae*.

Diacytic: Each stoma is encircled with two subsidiary cells. Their common wall forms a right angle with the long axis of the stoma, such as *Dianthus caryophyllus* and *Mentha haplocalyx*

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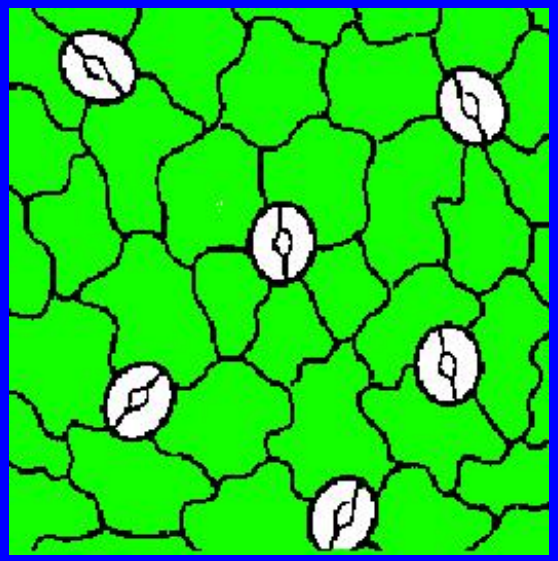
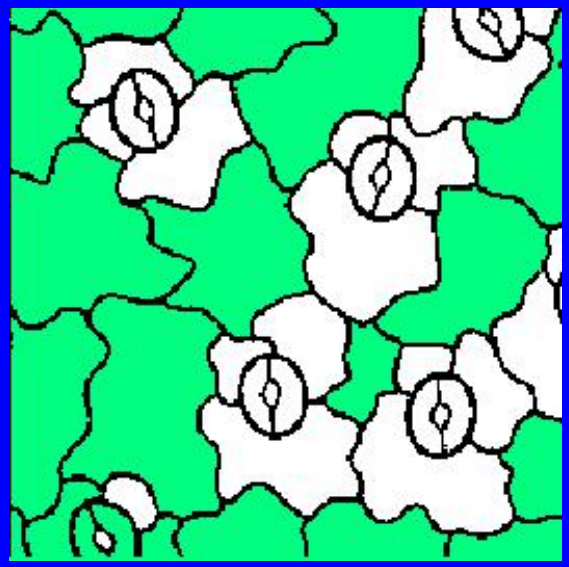
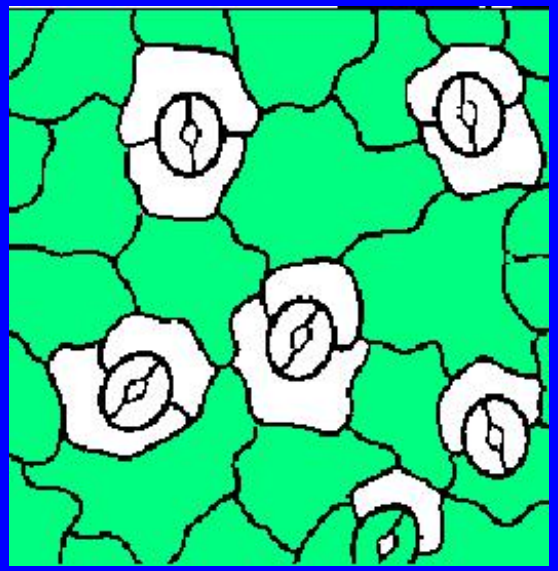


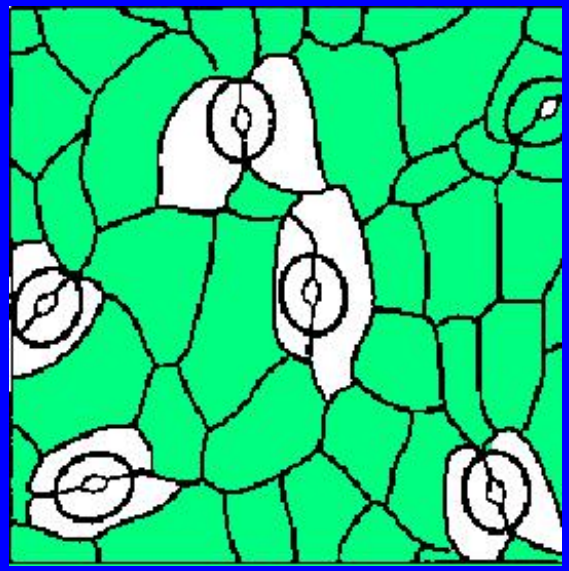
Anomyocytic



Unequal



Paracytic



Diacytic

2. Mesophyll

It is a generic term of the green tissues between upper and lower epidermises, consists of parenchyma cells and contains rich chloroplast.

Palisade tissue: Refer to the orderly arranged green tissue near upper epidermis. The cells are in a shape of long cylinder and their long axes are vertical to the leaf surface and in a shape of fence and contain more chloroplast.

Spongy tissue: Refer to the green tissue near lower epidermis. It is in an irregular shape, arranged untidily and loose, has many spores, looking like sponge and contains less chloroplast.

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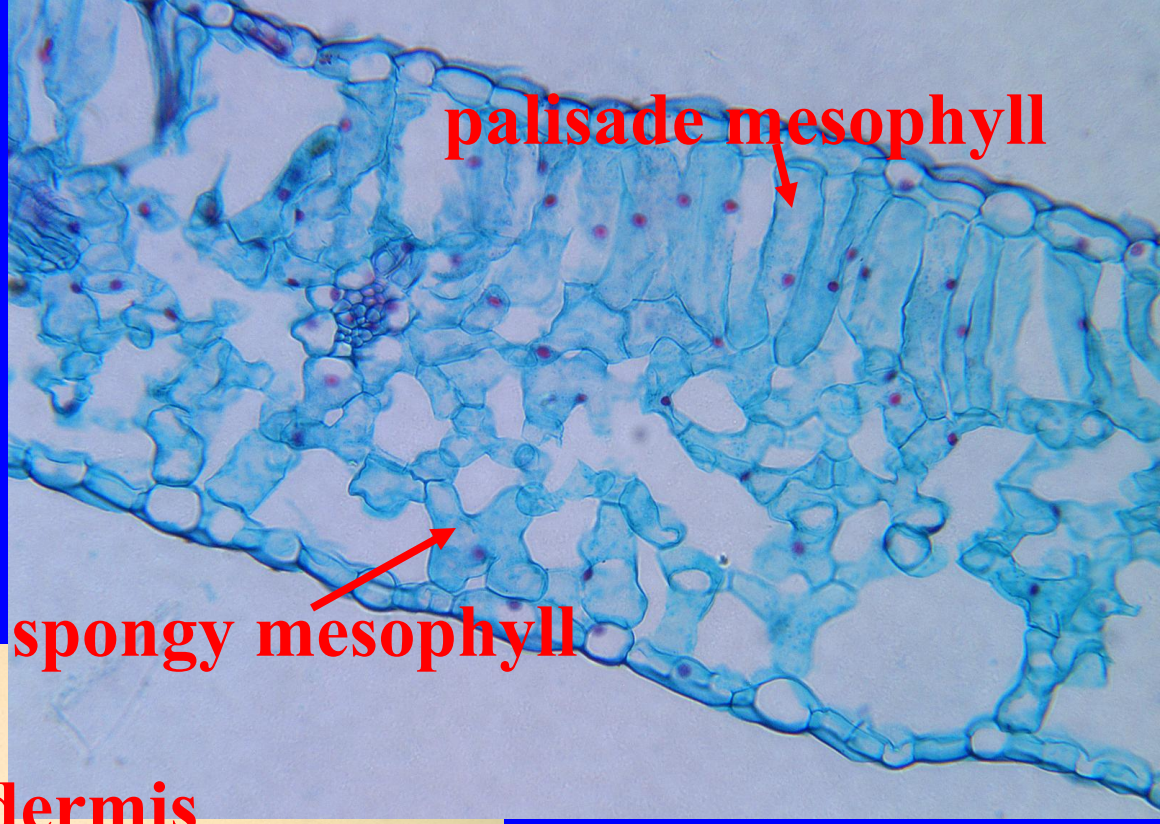
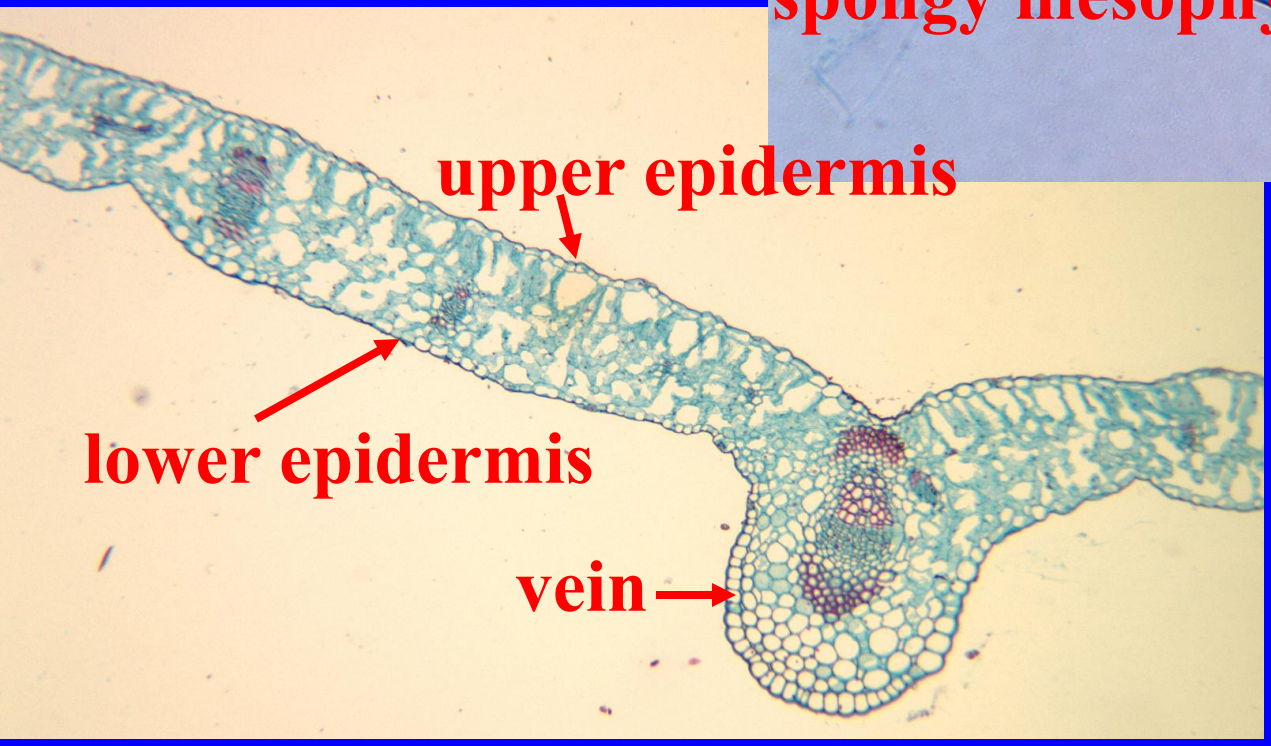
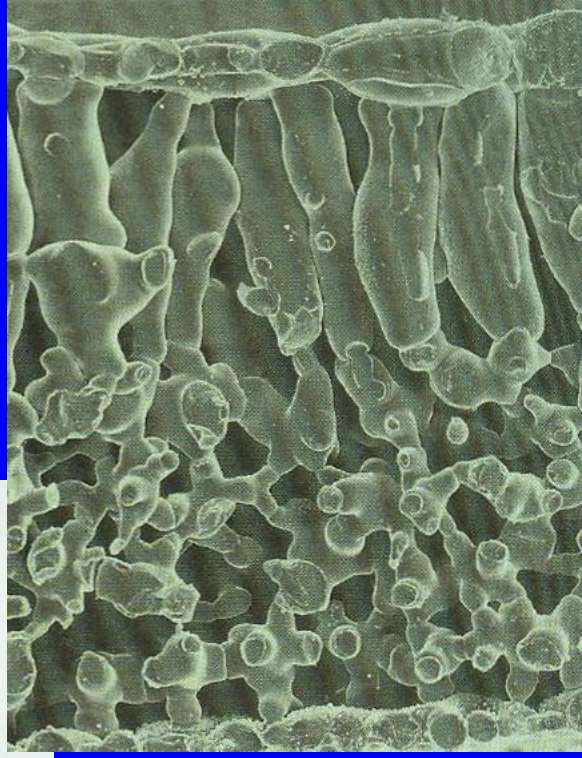
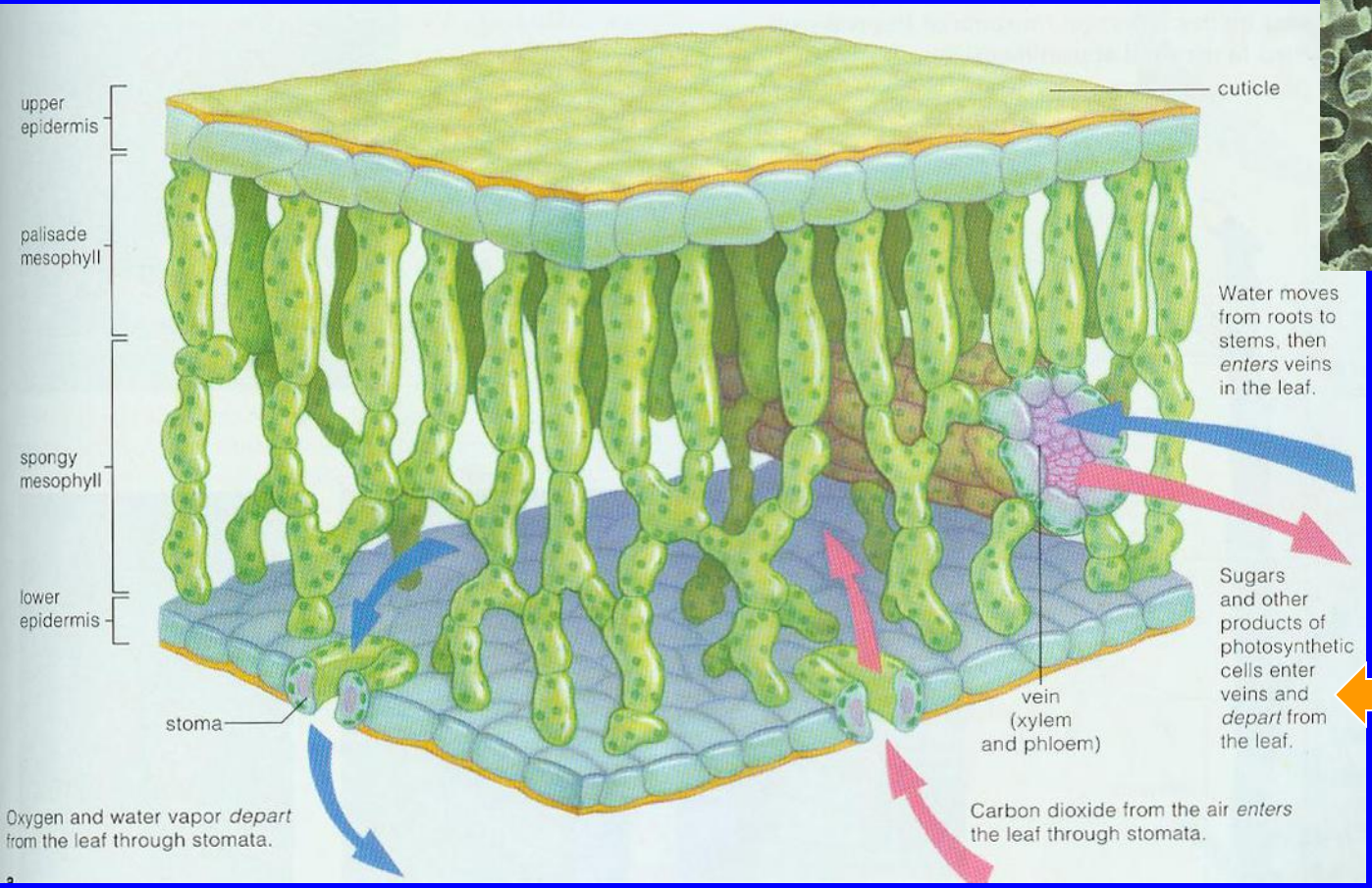




This micrograph especially shows the palisade and spongy mesophyll cells.

This micrograph shows the tissue layers of a leaf from the kidney bean plant.





Generalized diagram of leaf internal structure.

3. Leaf vein

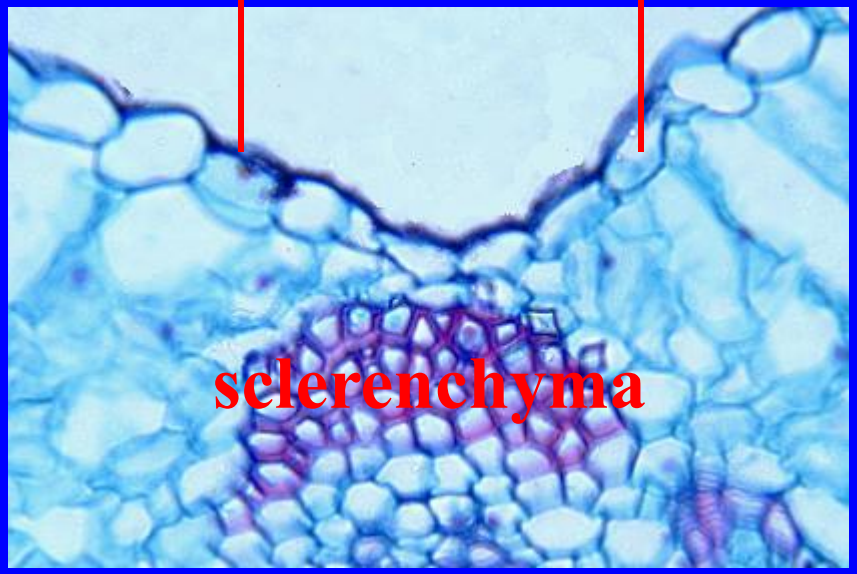
① The internal structure varies with the size of leaf veins. For example, midrib is composed of vascular bundles and mechanical tissues and connected to the vascular bundles in the stem via petiole;

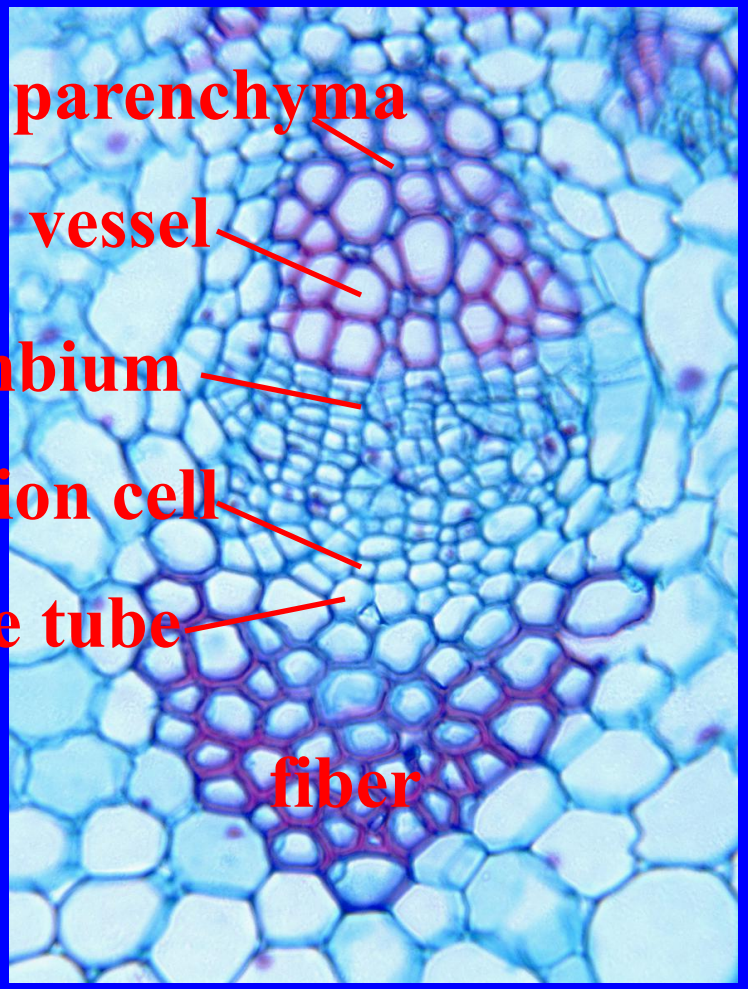
② In blades, xylem is in the upper part, phloem is in the lower part and vascular bundles are wrapped with bundle sheaths composed of parenchyma cells;

③ In midribs and large leaf veins, vascular bundles often are highly developed and have cambia and their movement is limited and in a short time;

④ A considerable amount of mechanical tissues are under and over the vascular bundles. The mechanical tissues under vascular bundles are more developed;

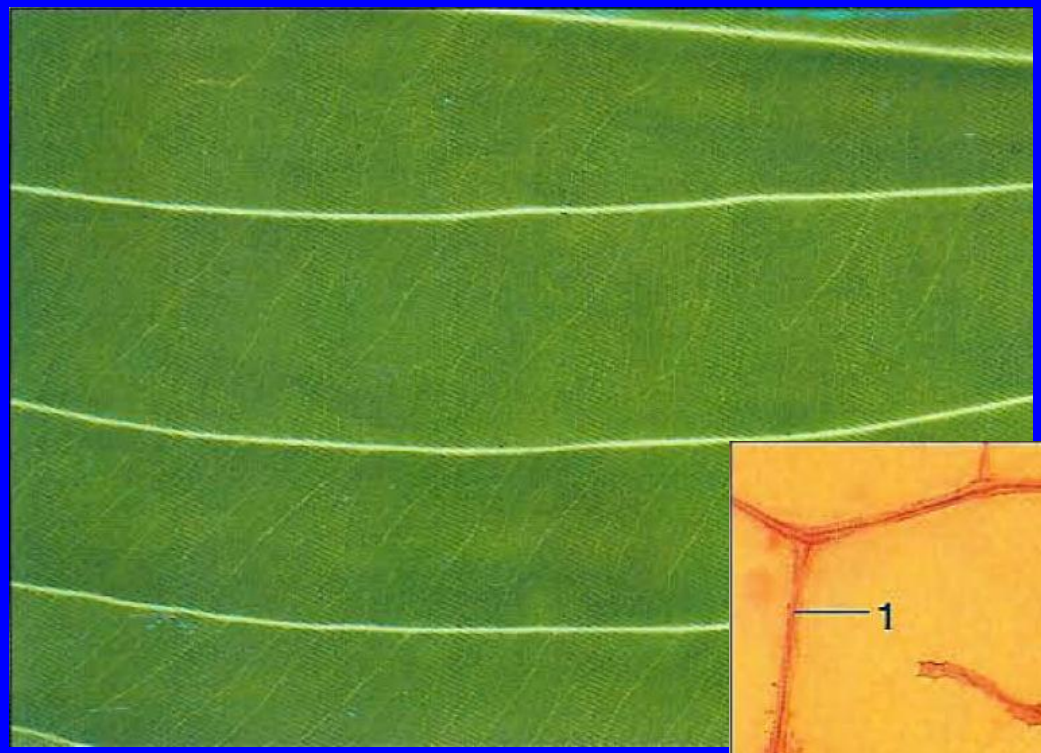
⑤ Simplification trend of vein structure: Disappearance of cambia; reduction of mechanical tissues; structural simplification of xylem and phloem: At the vein end, xylem has a spiral tracheid only, phloem has only short and narrow sieve elements and enlarged companion cells, and even there are only xylem molcules.





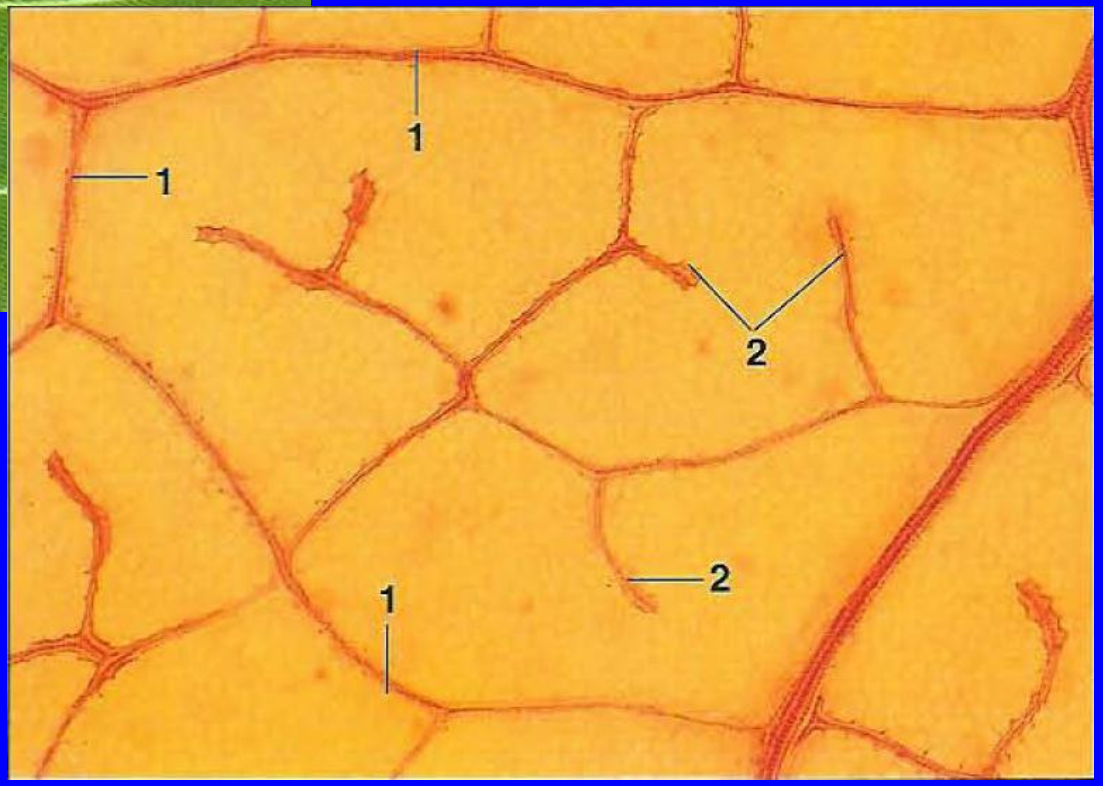
Transverse section through a main vein of a bean leaf showing the fine structure of a bundle and upper epidermis.

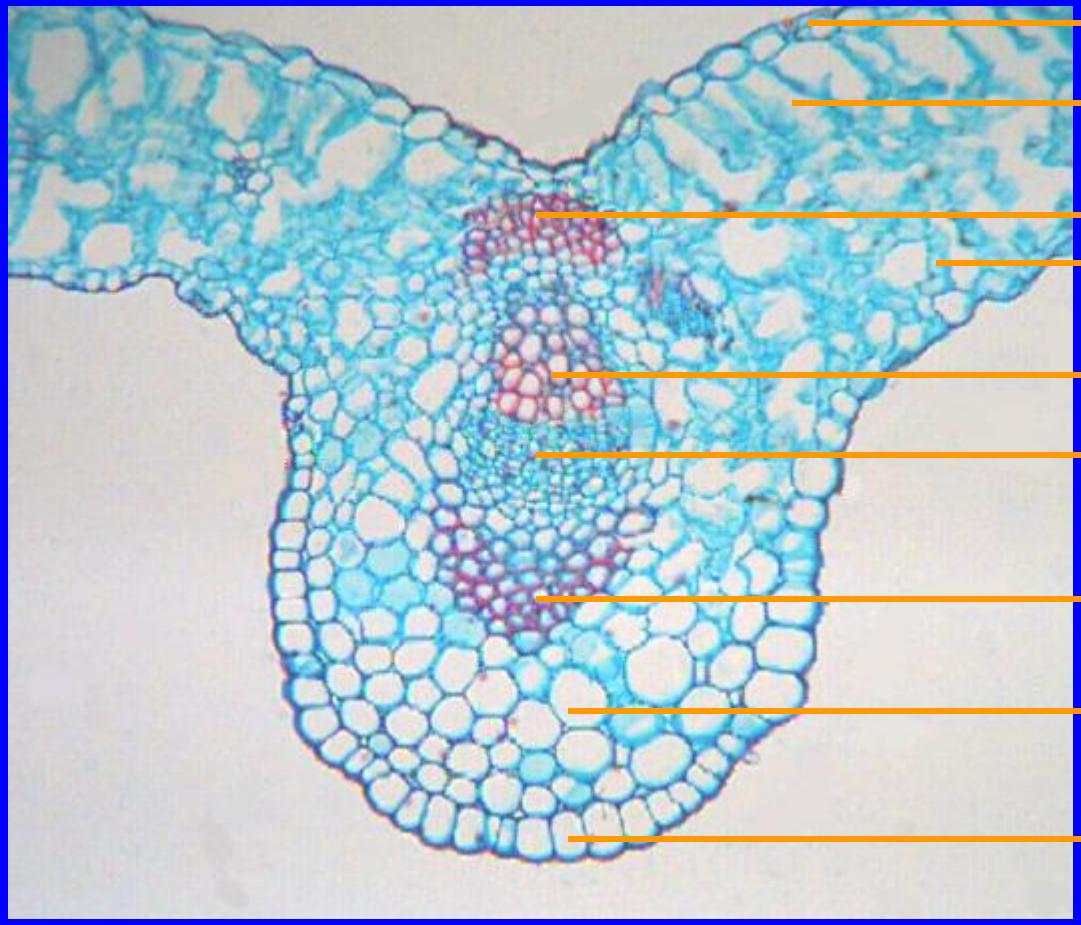
Chapter IV Vegetative Organs of Seed Plants - the Leaf



Leaf of the monocotyledon *Hosta* showing its venation. The main parallel longitudinal veins are connected by abundant, obliquely transverse, branched commisures.

Cleared dicotyledonous leaf showing the xylem and reticulate venation. Note the demarcation of areoles in the mesophyll which are enclosed by veinlets (1) whose branches end blindly (2).





Light micrograph of transverse section through the main vein of a bean leaf.

4. Structure of petiole

Petiole consists of epidermis, basic tissues and vascular bundles.

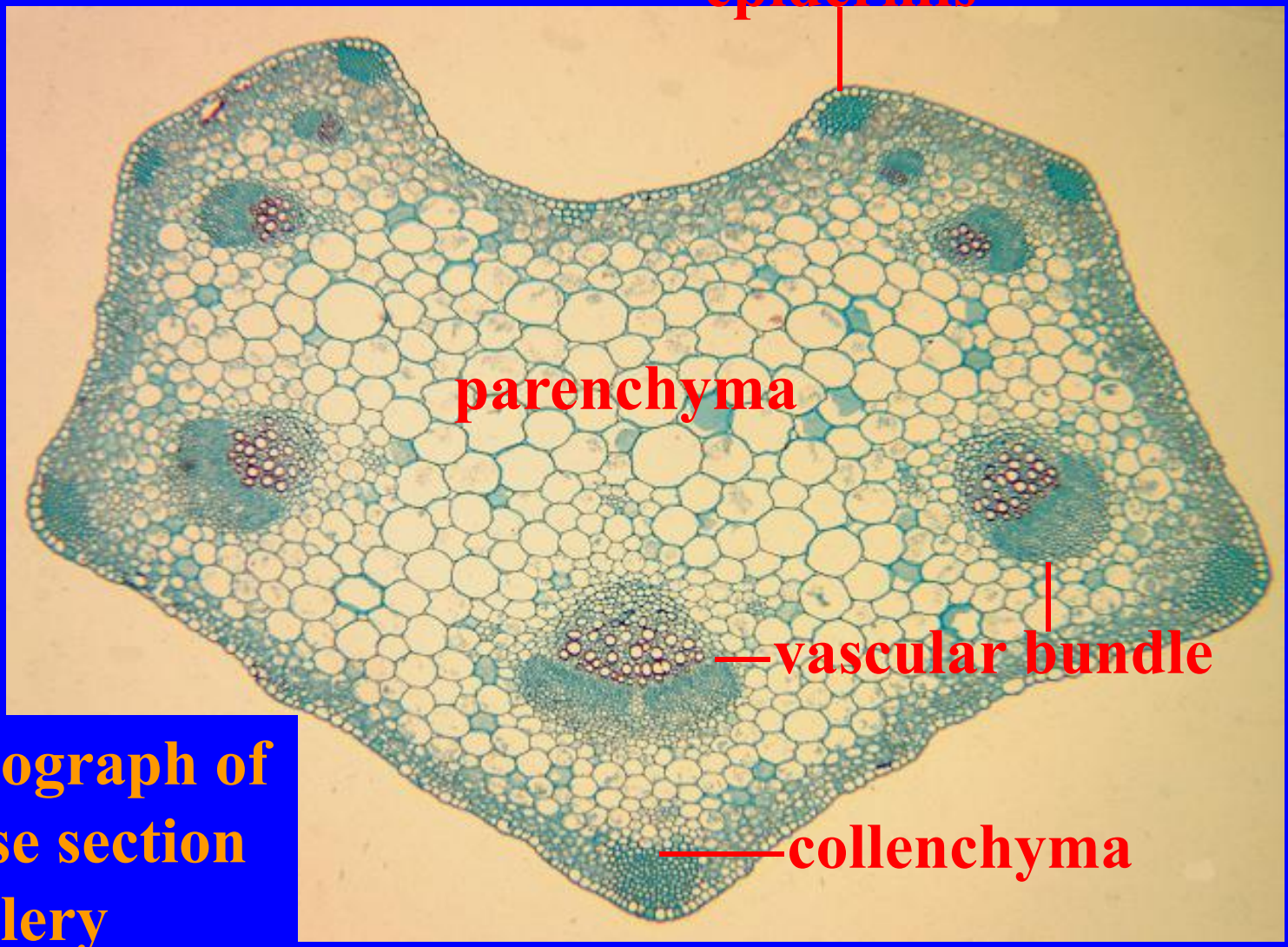
The transverse section is often crescent, round or triangular. The outermost layer is epidermis.

The basic tissues often have multiple layers of collenchyma in the outer part and parenchyma in the inner part.

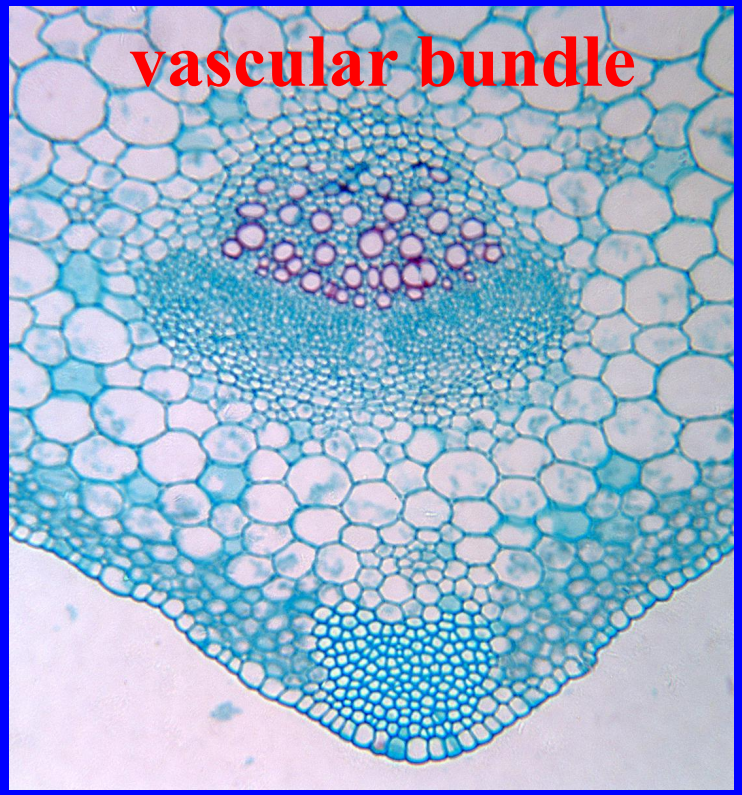
Vascular bundles are arranged in an arc, circular or parallel shape; xylem is above them and phloem is below them; the outside of each vascular bundle is often encircled with sclerenchymatous cells; in petioles of dicotyledonous plants, there are cambia, but the movement is in a short period.

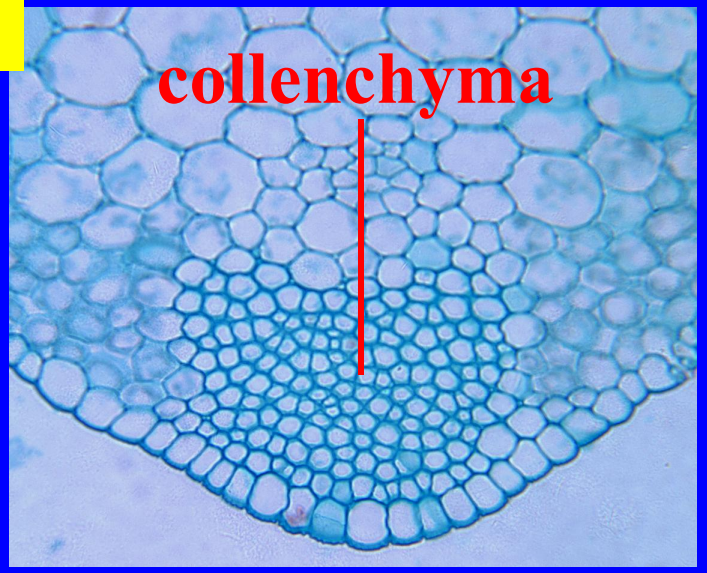
5. Structure of stipule

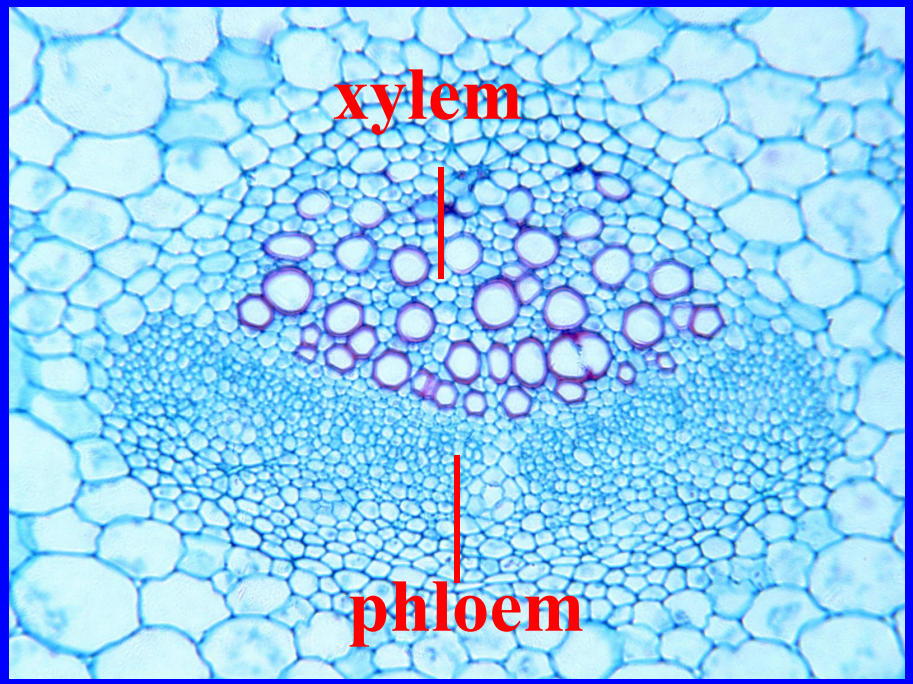
If the appearance of stipule is leaf like, its structure is similar to blade structure in general.



Light micrograph of a transverse section through celery petiole.







Part of a transverse section showing the location of vascular bundle and collenchyma in a celery petiole.

(III) Leaf features of monocotyledons

1. Epidermis

① Cell shape is regular and long and short cells are arranged alternately on lines.

Long cells: They are in a shape of rectangular cylinder, the major diameter is consistent with the direction of the longitudinal axis of leaf, and the wall is not only cutinized but also filled with silicious substances.

Short cells:

Silicified cells: It is often filled with a single silica nodule that is hard and may prick fingers.

Suberized cells: They are cells with a suberized cell wall and often contain organic matters.

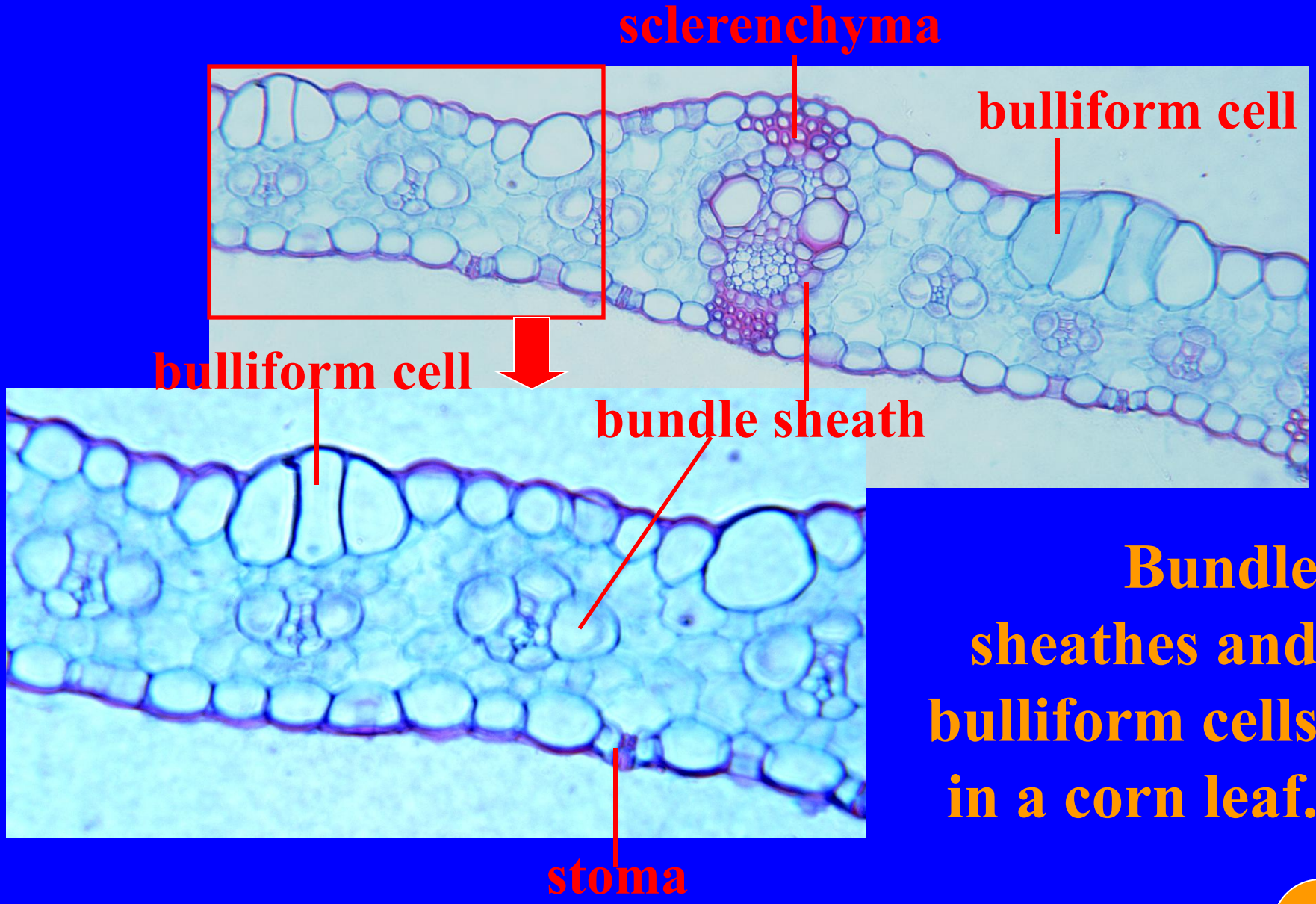
Chapter IV Vegetative Organs of Seed Plants - the Leaf

A portion of a monocot leaf showing the parallel veins.

Stomata in a surface view of a cleared leaf blade of the monocotyledon of *Zea mays*.

② Stomata: Stomata are arranged longitudinally. The guard cells look like dumbbells with a narrow middle part and sclerenchyma and the two ends are expanded into balls with parenchyma; there is a subsidiary cell outside each guard cell. It is different from the shape of epidermis cell and even its content is different, too, but it is still derived from the epidermis cells on the lateral side of stomata.

③ Bulliform cells: At many locations of upper epidermis, som special large water-containing cells can be seen. They have large vacuoles and no or little chlorophyll, the radial wall is thin and the exterior wall is thick. They are called bulliform cells. They are often located between two vascular bundles and arranged on a number of longitudinal lines on a leaf and in a shape of fan in transverse section. Generally, they are believed to have a relation with blade stretching and curling



Bundle sheathes and bulliform cells in a corn leaf.

2. Mesophyll

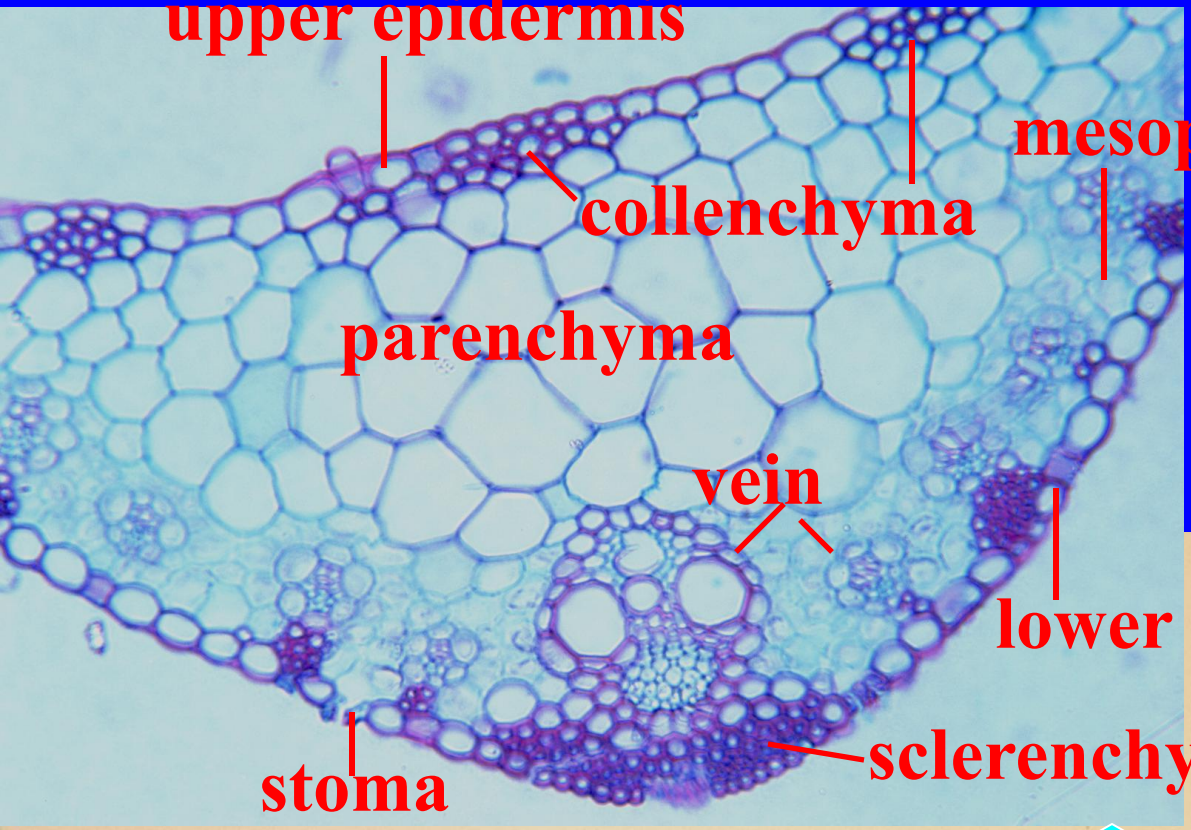
There isn't differentiation between palisade tissues and spongy tissues, intercellular space is small and the intercellular spaces inside stomata are large and form substomatic cavities.

3. Leaf vein

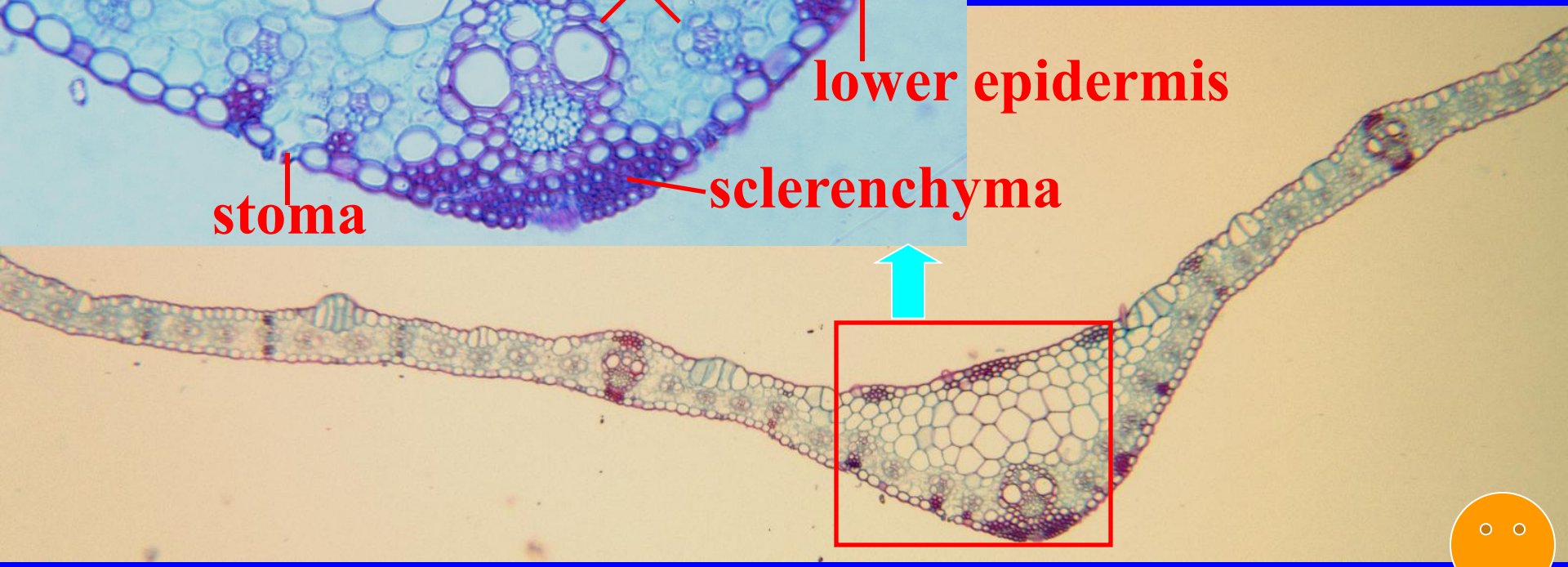
Vascular bundles are closed collateral and arranged in parallel. Sclerenchyma exists between larger vascular bundle and upper/lower epidermis. Outside a vascular bundle, often there is one or two layers of cells to form a vascular bundle sheath:

Vascular bundle sheath of single-layer cells: The cells are large and regularly arranged and contain chloroplast, which is larger than that inside mesophyll cells, and no or only a little grana, and they have strong ability to accumulate starch, such as corn, sugar cane and sorghum, which are "C_4 plants".

Vascular bundle sheath of double-layer cells: The cells in the outer layer are parenchyma and large and contain chloroplast , which is smaller than that inside mesophyll cells; the inner layer is sclerenchyma and the cells are small and almost don't contain chloroplast, such as paddy, wheat and barley, which are "C_3 plants".



Transverse section through the main vein of a corn leaf.



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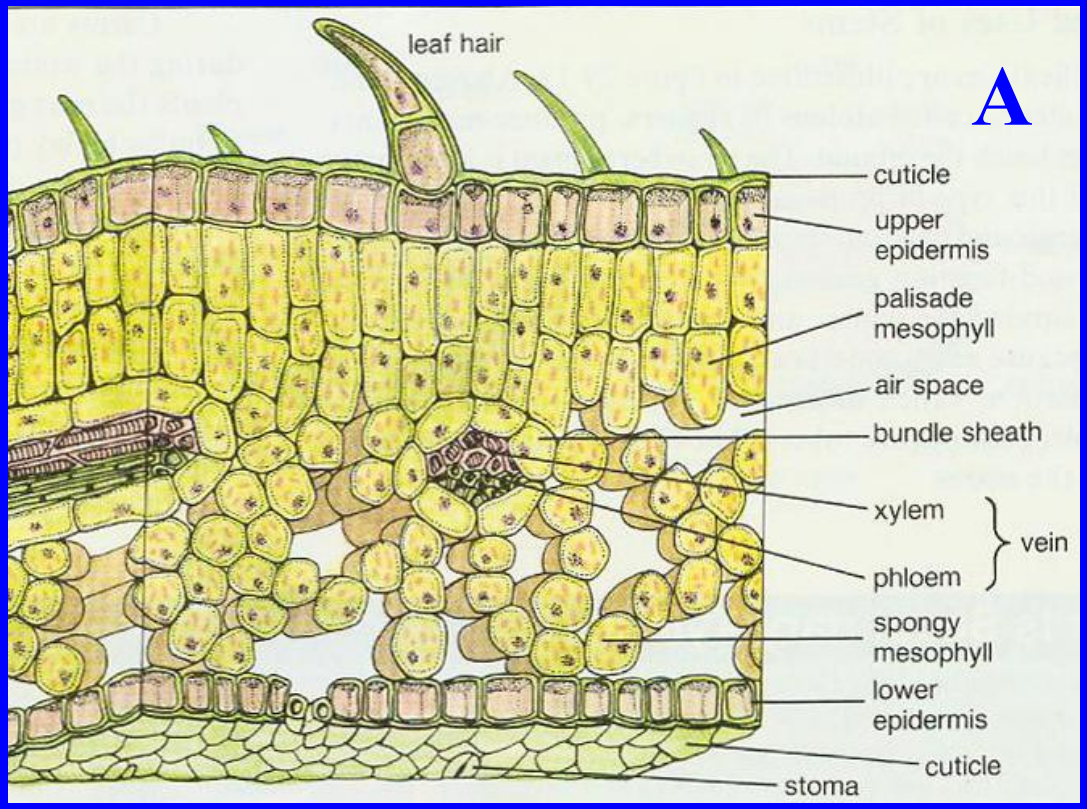
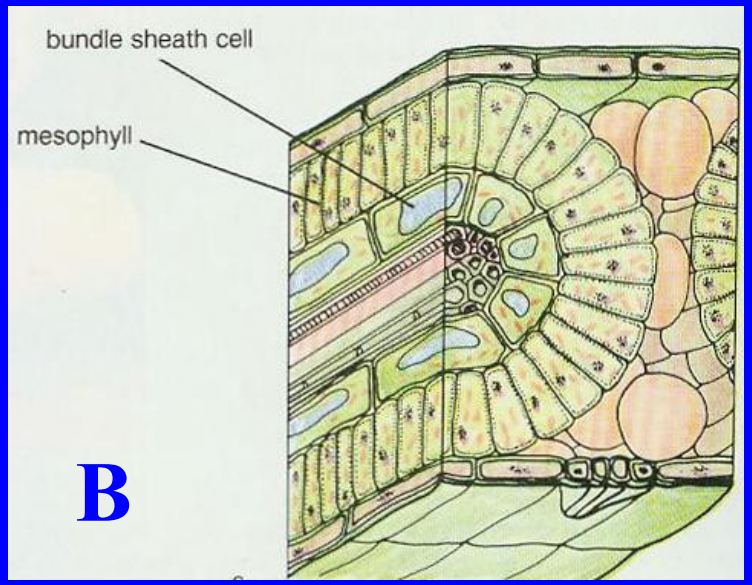




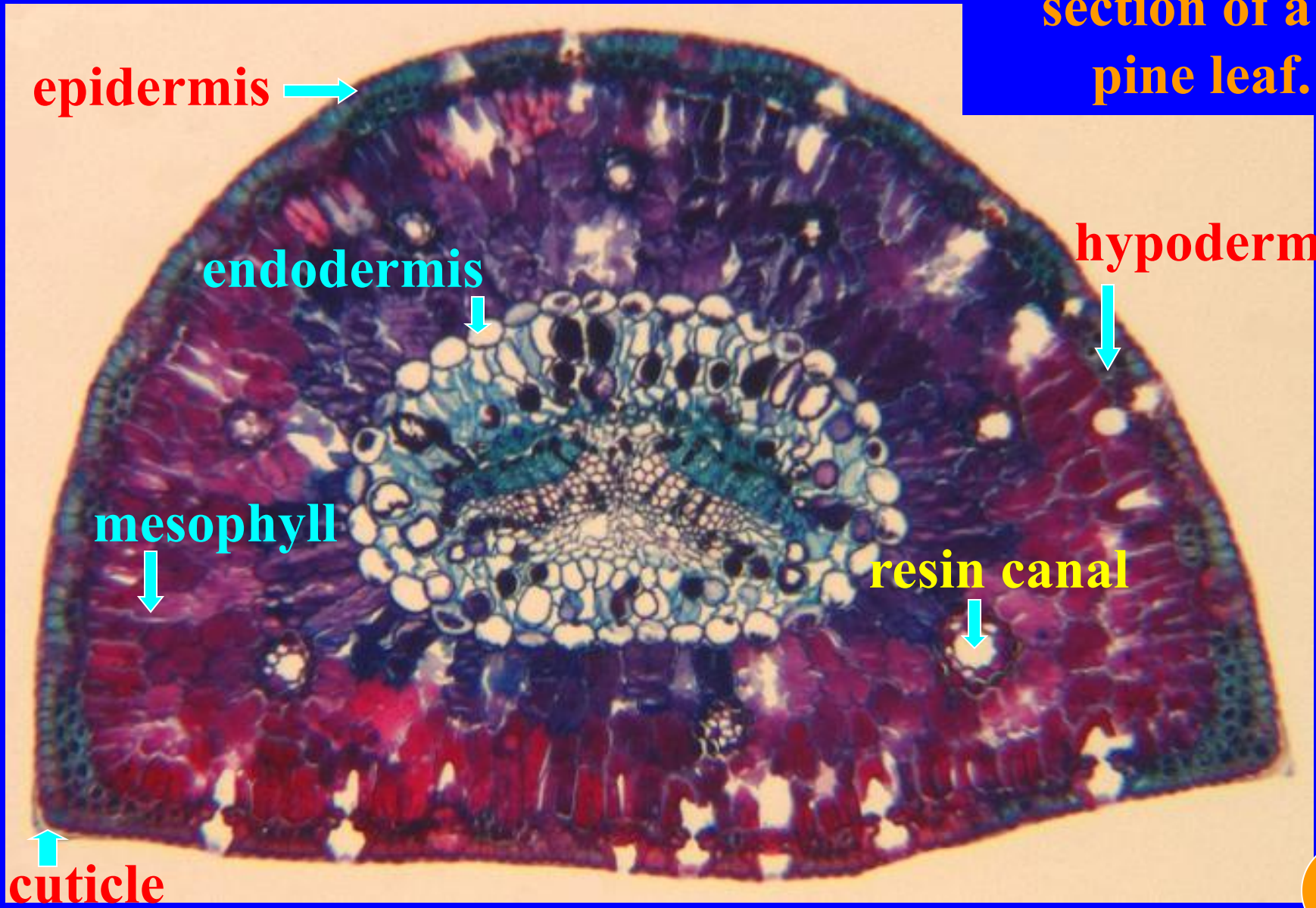
Drawing of a leaf from a C_3 plant (A), and a leaf vein from a C_4 plant (B).

Chapter IV Vegetative Organs of Seed Plants - the Leaf

(IV) Features of pine needle structure

1. Evergreen, needle-like leaves, occurring on short branches, in a xerophytic form, reducing transpiration area;
2. The cell wall of epidermis is thick, the cuticle is developed, and under epidermis is hypodermis, which is composed of a multiple layers of sclerenchyma, and stomata are invaginated;
3. The walls of mesophyll cells are invaginated into folds. Chloroplast is distribueted along folds to enlarge photosynthesis area;
4. Inside leaf, there are a number of resin canals;
5. Inside mesophyll, there is obvious endodermis;
6. Two bundles of vascular tissues are at the center of the leaf.

Transverse section of a pine leaf.



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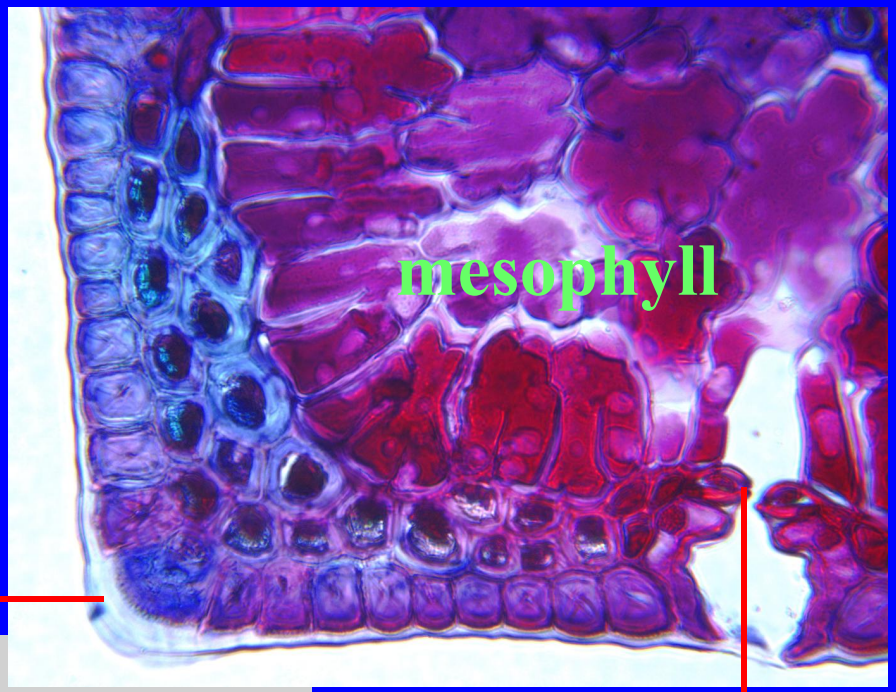
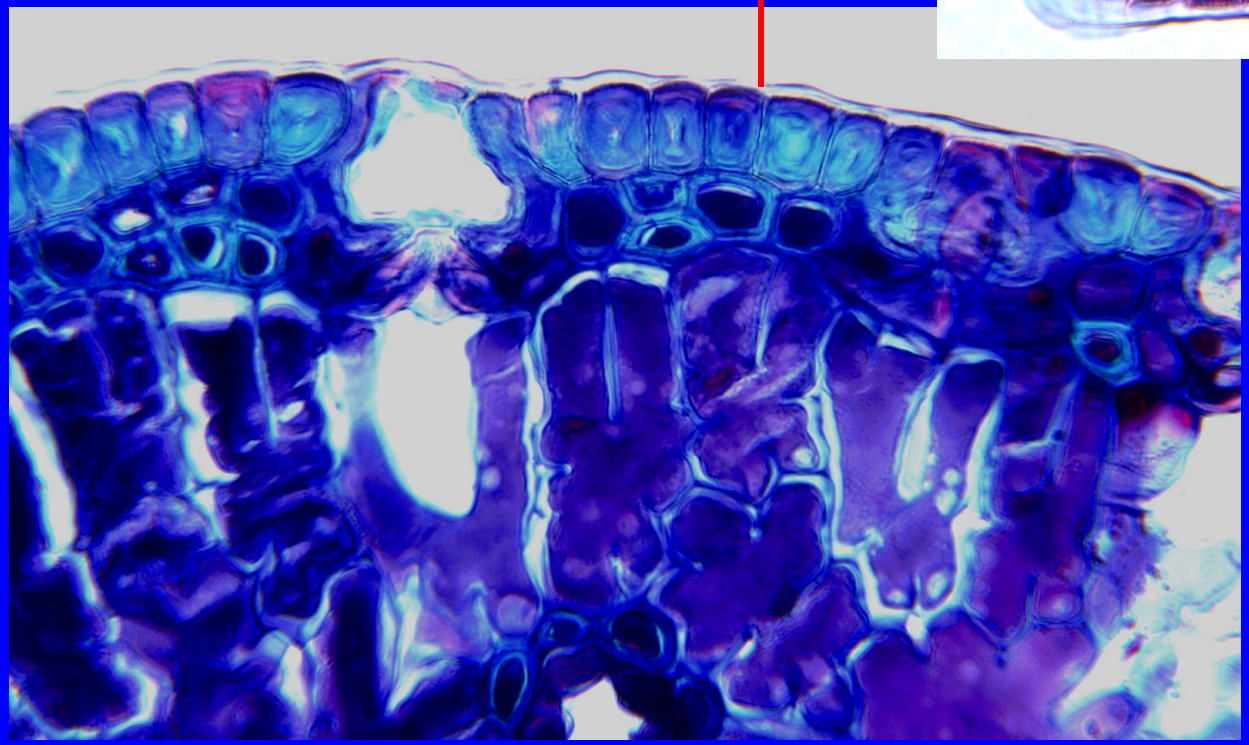
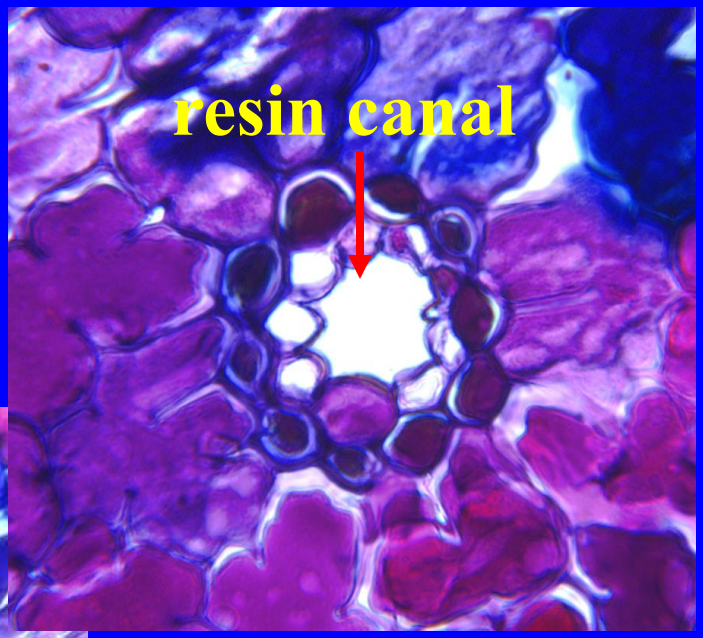
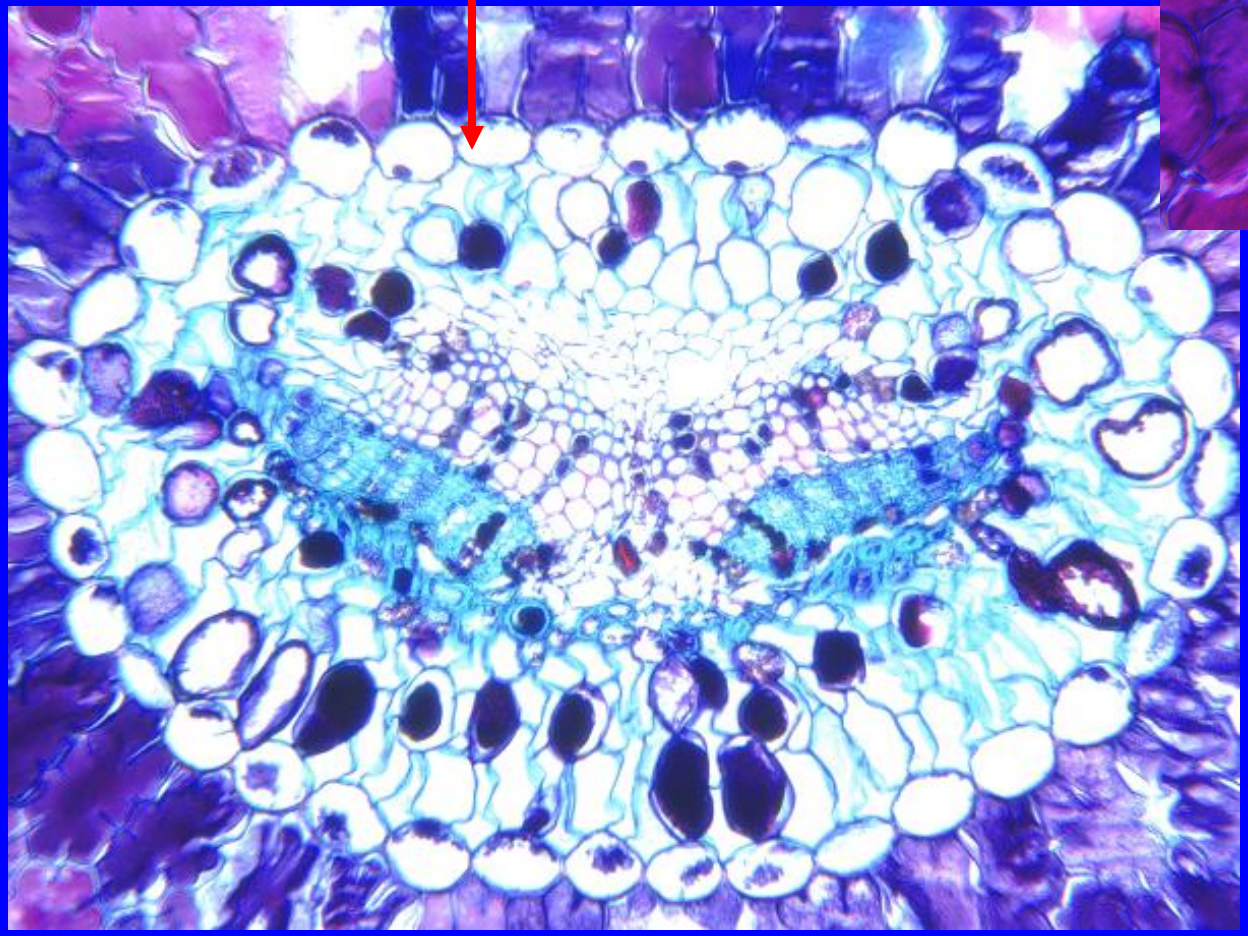
Fine morphology of epidermis, mesophyll, and stoma cells in a pine leaf.







endodermis



Endodermis, resin canal, and vascular bundles in a pine leaf.

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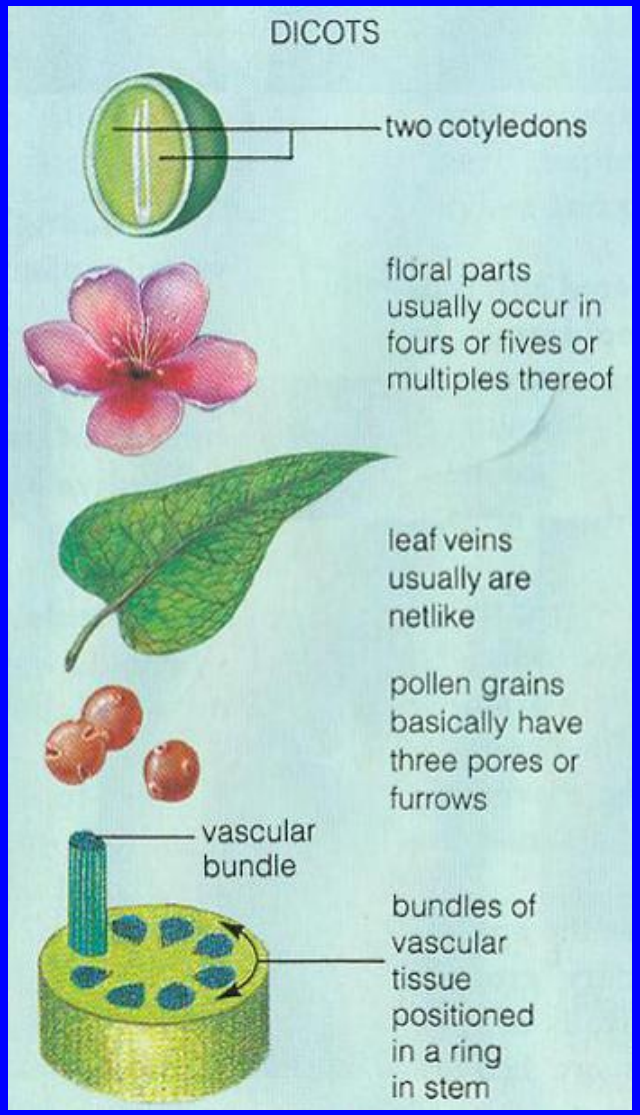

Comparison of the main features that distinguish dicots from monocots.