I. Diffèrent types of plant tissue

A tissue is a collection of cells of the same type, with the same embryological origin, the same general structure and the same physiological function.

These tissues form the plant's various organs (roots, stems, flowers, etc.). They are formed from meristems. The basic structural framework of plants is composed of different types of tissues. Based upon the capacity to divide, the plant tissues can be classified into two main types namely **permanent tissues** and **meristematic tissues.** In contrast to permanent tissues, the cells of meristematic tissues **don't lose their capacity to divide**. They don't differentiate to gain a permanent shape, size, or function; rather, they remain relatively small, immature, and cytoplasmically dense with high respiration rates.

Permanent tissue

The tissue which have lost their power of division are called as permanet tissue but at the time of need they can revive their power of division.A

*Simple tissues: A simple tissue comprises just one cell type.

*Compound tissues: A complex tissue contains several cell types in an intimate mixture.

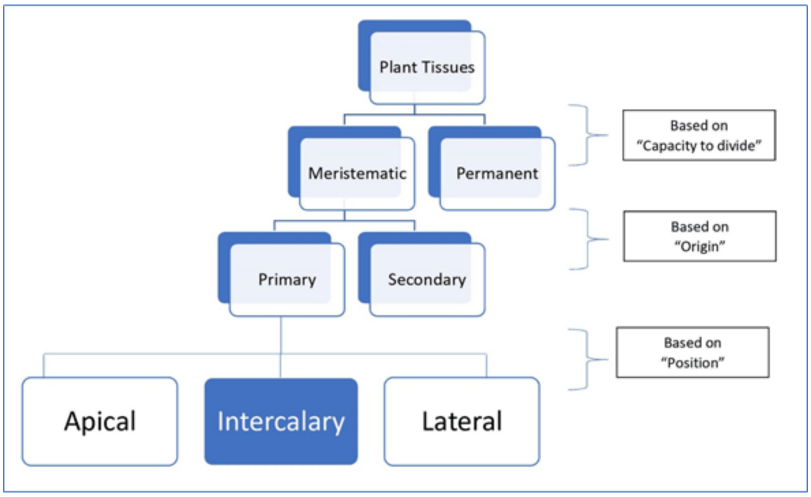

Figure 1: Different plant tissues. *In the above diagram, the intercalary meristem is depicted as a primary meristem and can be distinguished from the other primary meristems by their location. While the apical meristem is located at the apex and the lateral meristem at the girth, the intercalary meristem is found in the internodes. Source: Akanksha Saxena of Biology Online.* https://www.biologyonline.com/dictionary/intercalary-meristem

1. Meristems tissue

A meristem or meristematic tissue consists of a group of self-perpetuating cells that retain their capability of division, i.e., these cells are capable of continuous division and contribute to the growth of a plant body.

Meristems contribute to both primary (taller/longer) and secondary (wider) growth: Primary growth is controlled by root apical meristems or shoot apical meristems. Secondary growth is controlled by the two lateral meristems, called the vascular cambium and the cork cambium. Not all plants exhibit secondary growth.

1.1.Primary meristems

Primary meristems appear first during embryogenesis (the formation of the embryo), located at the apex of stems (cauline meristems) and roots (root meristems), and at the base of leaves laterally (axillary meristem), these functioning primary meristems will give rise to different tissues. These are referred to as primary tissues, to distinguish them from secondary tissues, which appear in some plants at a later stage. They are typically responsible for the lengthy growth of plants, and the tissues derived from them undergo slight thickening in the absence of secondary meristems. Their cells are characterized by:

➢ Small and isodiametric, perfectly joined.

➢ A chromatin-rich central nucleus occupying a large part of the cell volume (high nucleocytoplasmic ratio).

Organelles with little structure, undifferentiated plastids (proplasts),

➢ Numerous small vacuoles Thin walls (primary walls).

➢ Numerous mitochondria.

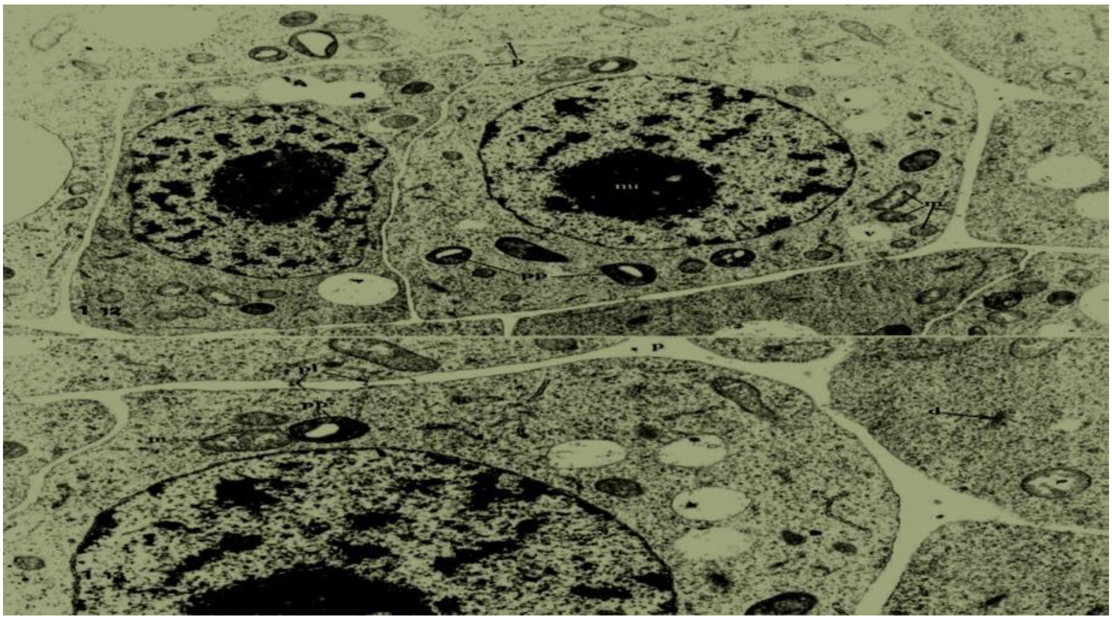

FIGURE 2: Characteristics of meristematic cells ("Pea root apical meristem cells (X 2000) (m = mitochondria, n = nucleus, nu = nucleolus, p = wall, pp = proplast, v = vacuole). Jean-Claude Roland et *al.,* 2008.

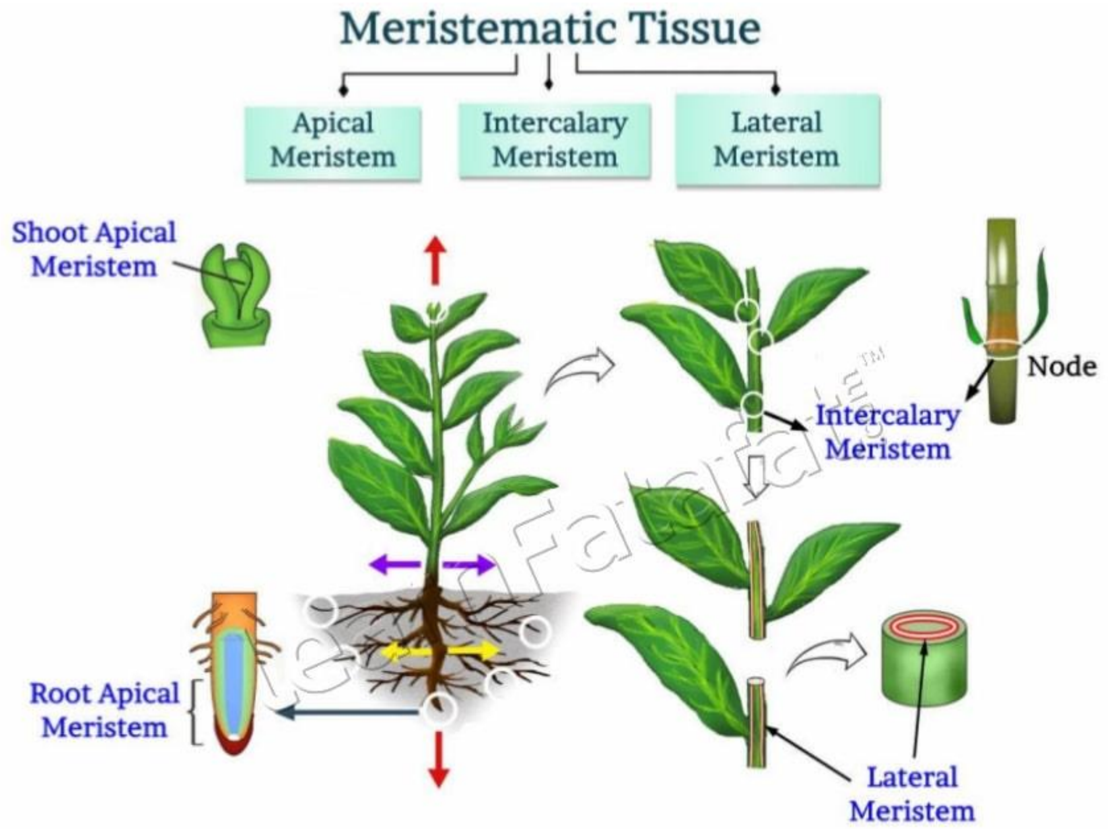

Figure 3: localisation meristematic tissue. https://learnfatafat.com/meristematic-tissue/

1.1.1. Apical meristem

1.1.1.1. The cauline meristem (Shoot apical meristem)

The cauline meristem (stem meristem) is responsible for building up the aerial part of the plant, from which cells appear that multiply and differentiate to produce stems, leaves, axillary buds and floral buds, making it both histogenic and organogenic. In a completely repetitive and indefinite way, until the death of the plant.

The cauline meristem does not consist of a simple stack of cells, but of several zones with no clear boundaries. In Angiosperms, this meristem forms a dome 0.5 to 3 mm in diameter, made up of small cells.

The central section of the cauline meristem reveals the existence of three regions:

1-**An axial zone, Za,** with two superficial layers, the tunicas T1 and T2 and the corpus C. The superficial layer, tunica (T1), all around the meristem, is distinguished by its strictly anticlinal divisions (partitions perpendicular to the surface), and is the origin of the epidermis. The T2 tunica initiates leaves by partitioning, while the underlying C corpus beneath it forms the central tissues of the stem and leaves. Mitosis occurs in all directions in this layer.

2 A lateral zone, ZL, surrounds this axial zone, the part on the right corresponding to the appearance of a leaf, ZLF. Periclinal divisions, dp, can be distinguished (the partitions are parallel to the surface).

2. **A medullary meristem, Mm**, with infrequent mitoses, forming stacked rows of cells at the origin of the central medulla, M.

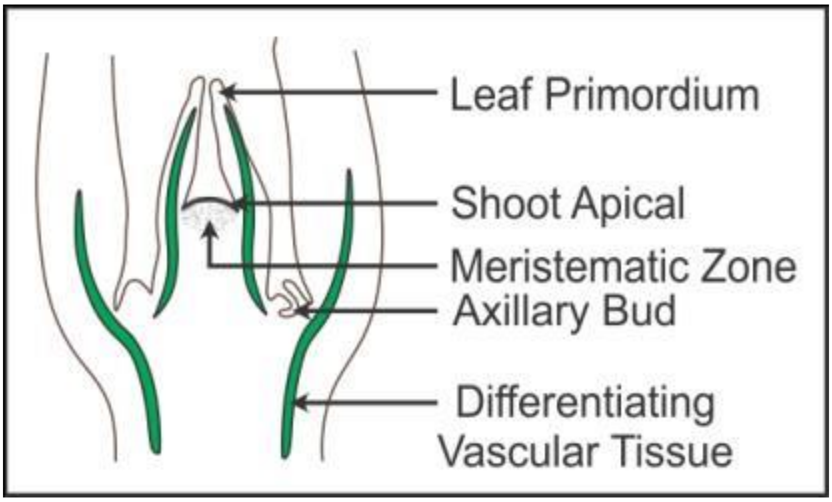

Figure 4: The cauline meristem

https://www.topperlearning.com/answer/draw-well-labelled-diagrams-of-a-shoot-apical-meristem-b-root-apical-meristem/z3o5z8vtt

- **Transformation of the apical meristem into the floral meristem**

Under the action of processes that may be linked to two light-sensitive proteins, a phytochrome and a cryptochrome, the stem meristem transforms either into a floral meristem, giving rise to a single flower, or into an inflorescence meristem, which in turn produces floral meristems. This change is accompanied by exceptional modifications.

A system with indefinite growth, such as the apical meristem, becomes definite, since once floral morphogenesis is complete, the meristem ceases all activity and disappears when the flowers or fruit fall.

These transformations correspond to a slowdown in the activity of the lateral zone (ZL), which nevertheless gives rise to the sepals, the first floral parts to appear, while the corpus proliferates abundantly, i setting up what will become the floral receptacle. The tunica T2 will be the source of reproductive floral parts, hence its name of sporogenic promeristem.

1.1.1.2. The root meristem

The apical root meristem is also formed during embryogenesis. It elaborates root tissues and the root cap: it is solely histogenic. It does not produce lateral organs and is therefore not organogenic.

Lateral roots form endogenously, some distance from the apex, from the pericycle (the cell base between the bark and the stele). The pericycle initiates root branching. The structure and function of the branches are identical to those of the root's apical meristem.

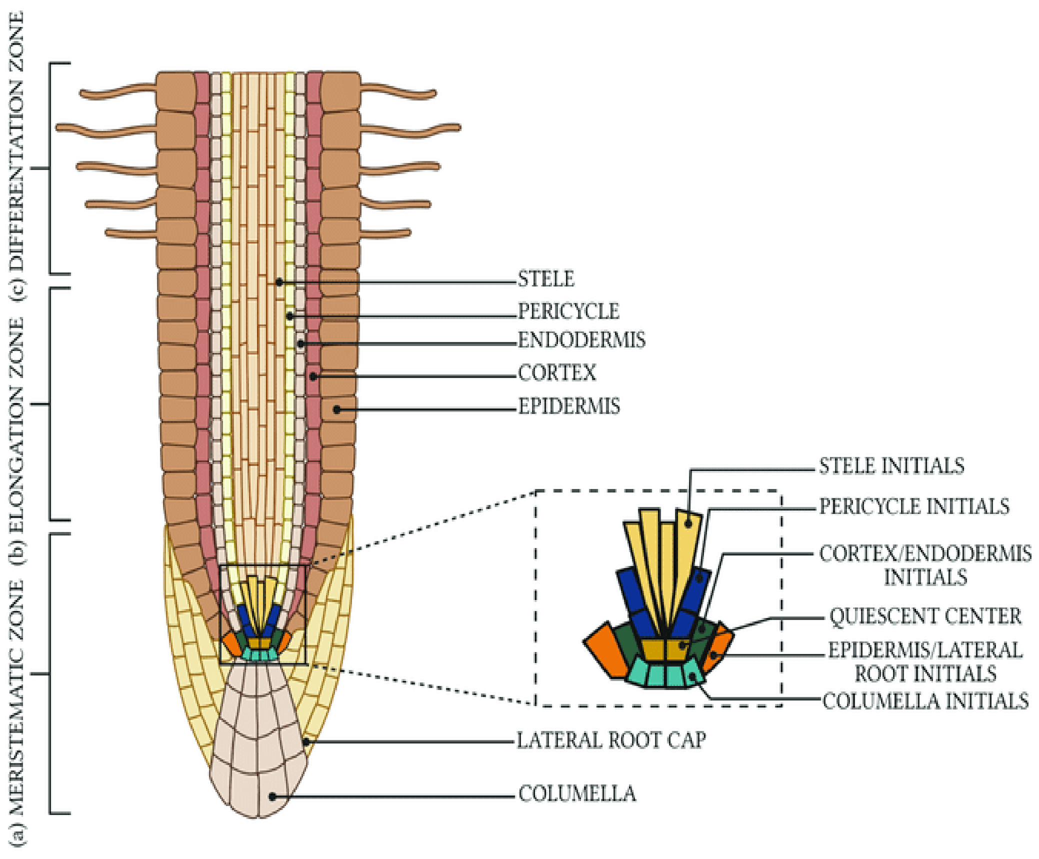

Figure 5: The root meristem.

https://www.researchgate.net/figure/Organization-of-plant-root-meristem-There-are-three-distinct-developmental-zones-a_fig1_356716506

1.1.2. primary tissues

1.1.2.1. Protective tissues

Protective tissues protect the plant. They consist of parenchymatous cells that are modified to protect the plant from physical damage and desiccation.

① L'épiderme

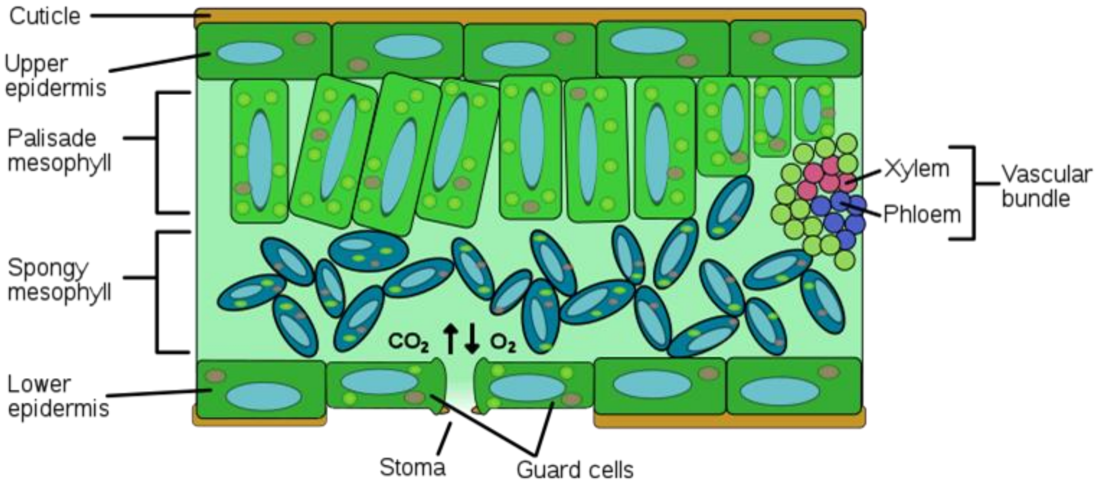

Figure 6 : Leaf anatomy. https://www.yaclass.in/p/science-cbse/class-9/tissues-4999/plant-tissues-4816/re-6ae954bd-26a9-48f9-98c0-93c239b0c39f

Primary tissue consisting of a layer of living cells arranged side by side, generally without chloroplasts. This tissue covers the aerial organs and provides protection against desiccation and external aggression of all kinds (parasites, etc.). In leaves, the epidermis is interrupted at the level of the stomata. Stomata are responsible for gas exchange with the atmosphere, and their density is usually highest in the epidermis below the underside of the leaf. Occasionally, epidermal cells can modify themselves to form single or multicellular meristems, simple or branched, forming either protective or secretory hairs or trichomes. The number, shape and relative arrangement of these elements vary according to environmental conditions and have a specific character. In some places, the outer wall of these cells is thickened and made impermeable by a deposit of waxes and cutin, forming the cuticle, which forms a protective film on the surface. The epidermis is derived from a layer of meristematic cells, the protoderm, which covers the developing organs and in which mitosis takes place perpendicular to the surface (anticlinal mitosis).

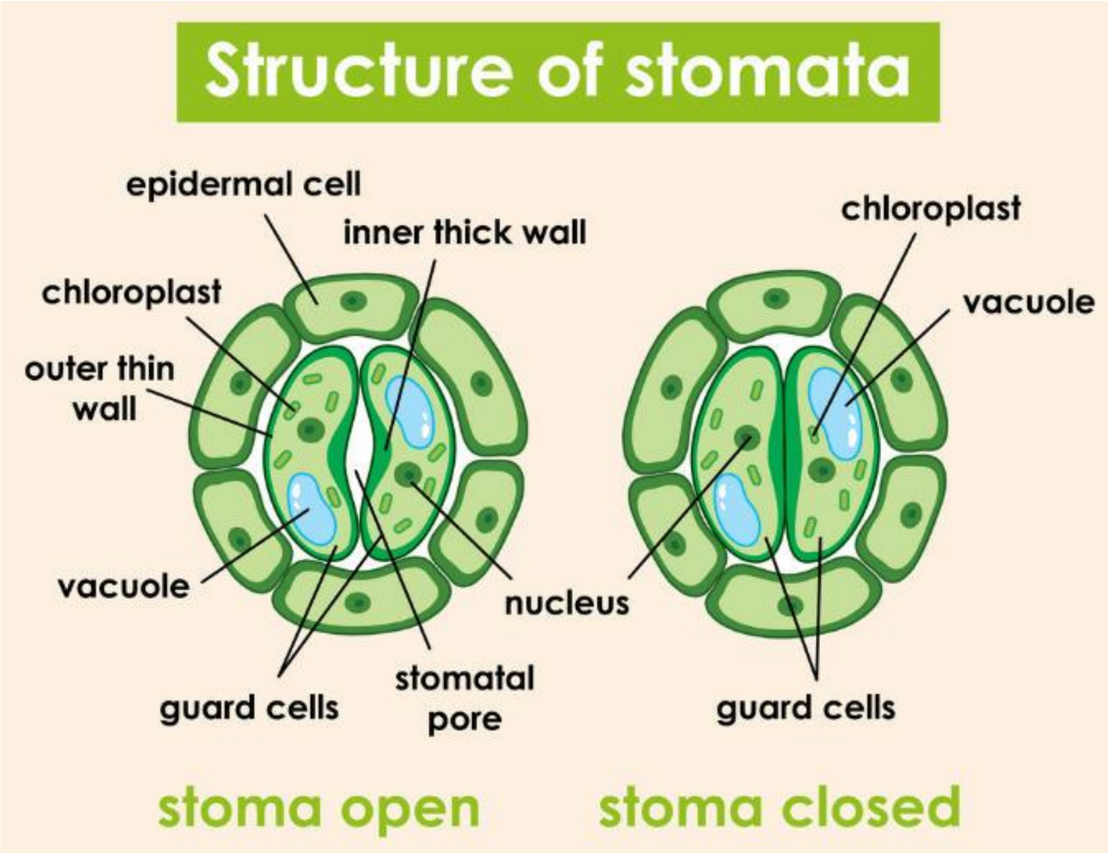

Figure 7: Stomatal structure in plants.

https://www.careerpower.in/school/biology/stomata

Functions of stomata:

1. Stomata is enclosed by two kidney-shaped guarding cells that are necessary for gaseous exchange in the leaf.

2. Stomata also facilitates transpiration, a process by which loss of excess water in the form of water vapour through leaves' surface.

② The rhizoderm or piliferous base

A rhizoderm (sometimes simply called root epidermis) is found at the periphery of root organs. It is unistrate, lacking cuticle and stomata. However, it contains locally differentiated cells. Some of these cells are very elongated and very permeable, hypertrophic, and thus take the form of a hair, known as the absorbing hair (the whole of which forms the piliferous base). The piliferous base is present in young roots at the level of the absorbing region, increasing the surface area for exchange with the underground environment. Above the piliferous zone, the rhizoderm is replaced by the underlying layer of parenchymatous cells, which undergo suberization (i.e., become rigid and impermeable, rendering them incapable of absorption) and differentiate into the suberous layer. These structures limit dehydration and provide mechanical protection underground. These tissues should not be confused with the suber, a secondary tissue.

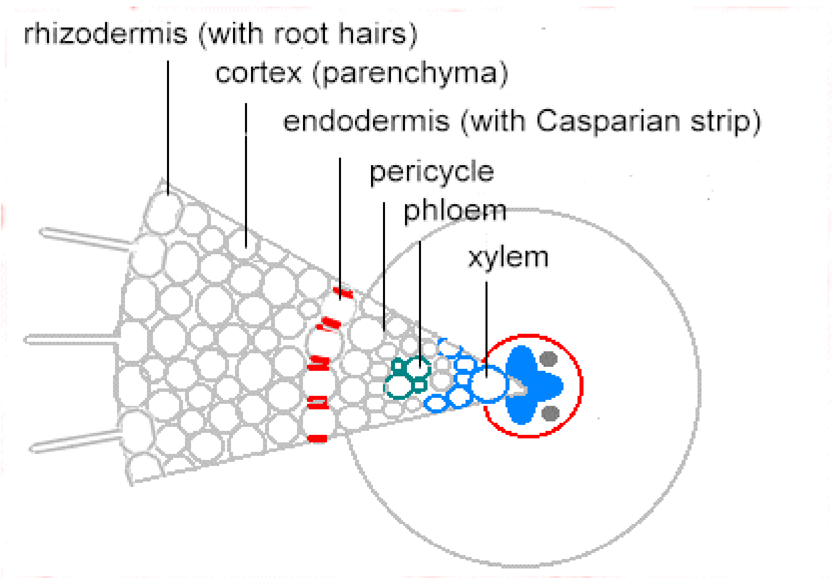

Figure 8 : The rhizoderm or piliferous base. © Michael Knee.https://www1.biologie.uni-hamburg.de/b-online/e05/05b.htm

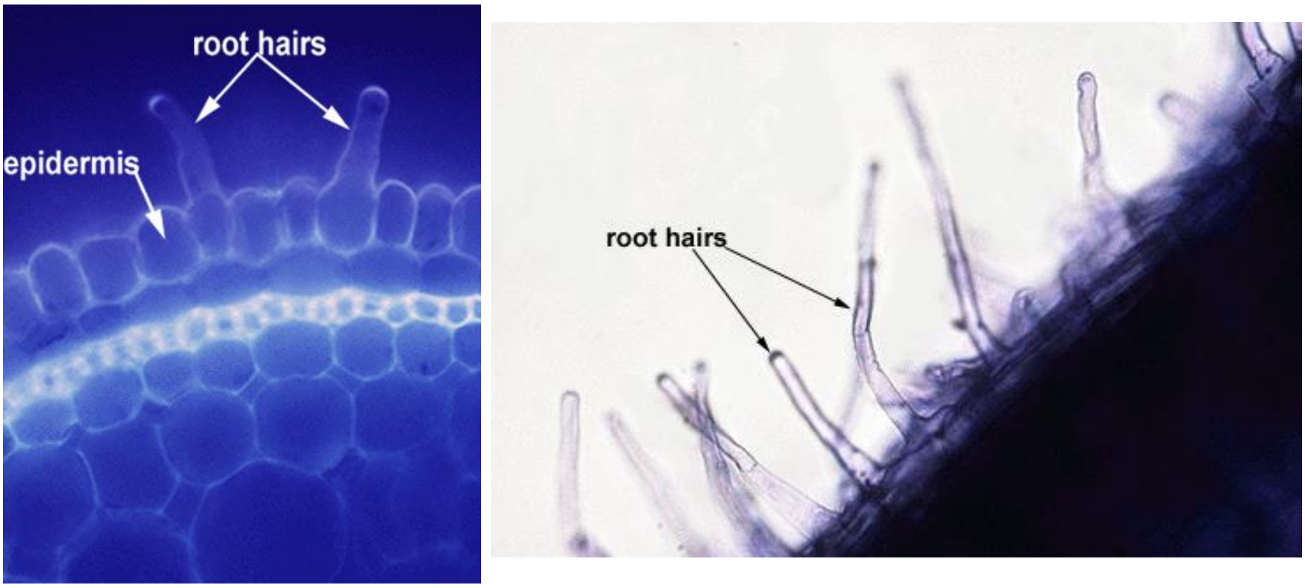

Figure n 9: root hairs. © Thomas L. Rost 1997. https://www1.biologie.uni-hamburg.de/b-online/e05/05b.htm

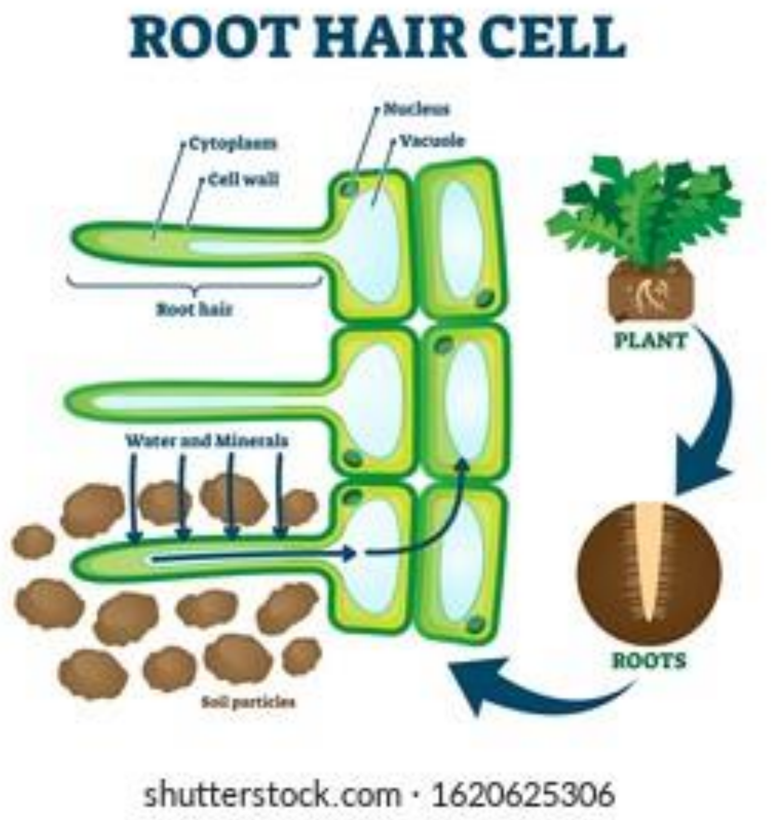

Figure 10: plant-absorbing hair .

https://www. https://www.shutterstock.com/fr/search/root-hair-cell

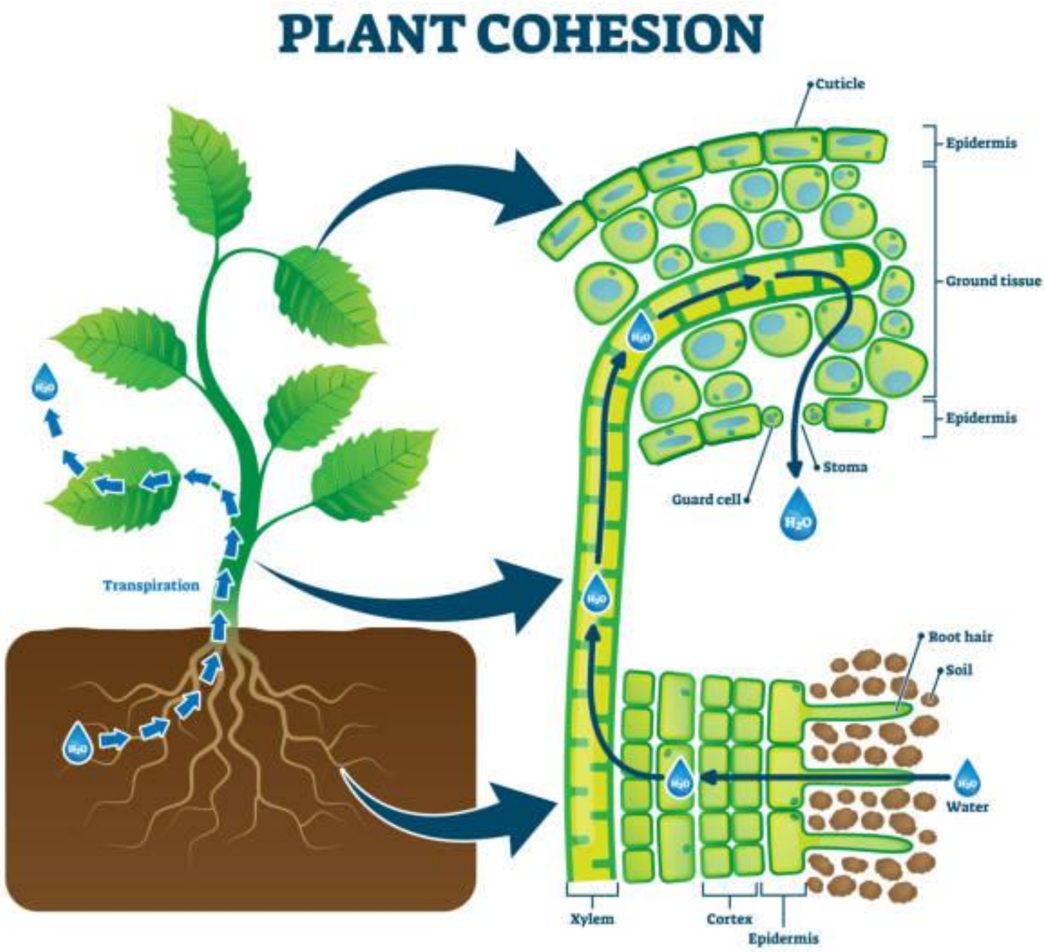

Figure 11: plant cohesion. https://www.istockphoto.com/photos/plant-cuticle

③ Endoderm

This is a special monolayer covering tissue with a protective function for vascular tissue. Unlike the epidermis, it is the deepest layer of the cortex surrounding the pericycle. pericycle at the root level. Because of its location and cellular characteristics, it plays a fundamental role in of water and mineral salts to the absorption zone of young roots. The outer and inner tangential walls of these cells are cellulose, while the others are reinforced by deposits of suberin or even lignin, known as the Caspari frame. The Caspari frame is completely impermeable. The Caspari frame thus prevents the apoplastic transport of water and mineral salts. mineral salts through the apoplasmic (permissive) pathway, thereby forcing the symplasmic (restrictive) pathway. (restrictive) route. This characteristic allows it to play its role as a filter.

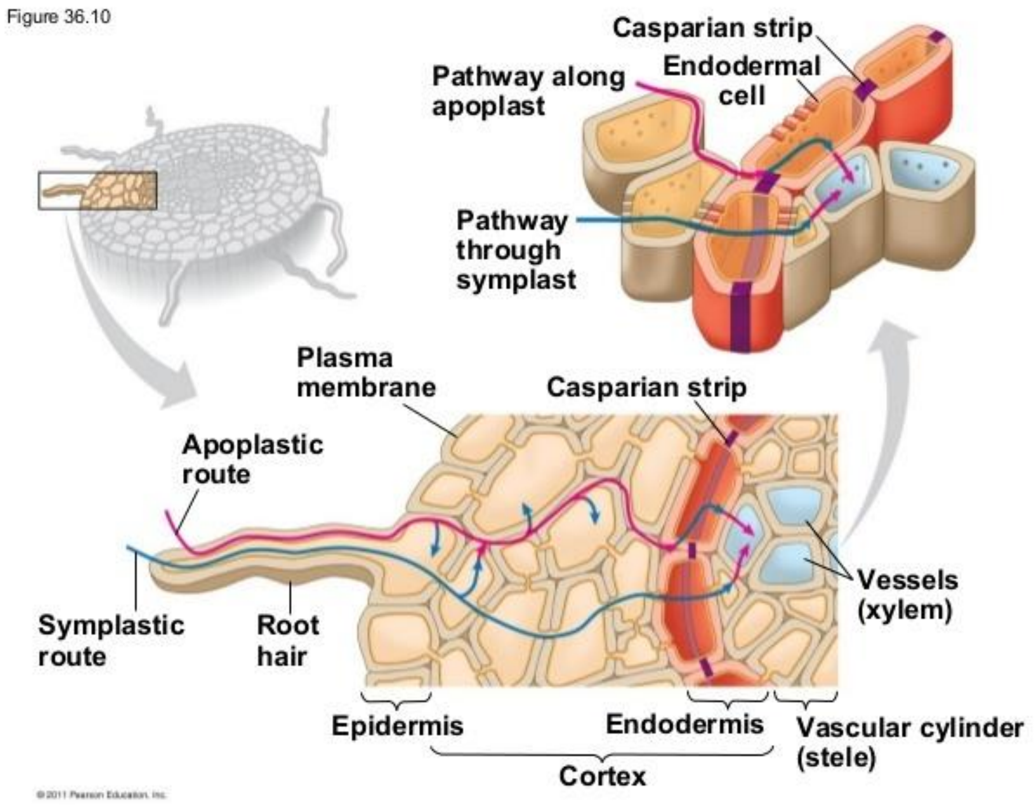

Figure 12: Root endodermis. *Water and mineral salts can move between the rhizodermis and cortex cells, but must pass through the endodermis cells because of the Caspari frame. (b) The Caspari frame forces water and dissolved minerals from the soil to pass through the endodermis cells instead of between them.* https://www.quora.com/What-essential-role-does-the-root-endodermis-play-during-mineral-absorption-in-plants

1.1.2.2. Basic tissues

These make up the majority of young plants. These tissues fill the space between the covering tissues and the conducting tissues. These are the parenchyma and the sclerenchyma and collenchyma.

① Filling Tissue (Parenchyma)

Parenchyma is a filling tissue composed of poorly differentiated living cells, often with a single large vacuole and a thin, flexible, purely pectocellulosic primary wall; no secondary wall.

Parenchyma tissues are the most voluminous in the plant and are found in the cortical and medullary regions (pith) of stems and roots, the mesophyll of leaves, and the pulp of fruits.

A/Chlorophyll parenchyma or chlorenchyma

Chloroplasts are found only in aerial organs. In leaves (often highly chlorophyllous; called mesophyll). In monocotyledonous leaves it is homogeneous, whereas in dicotyledonous leaves it is generally heterogeneous, consisting of :

- **Chlorophyllous palisade parenchyma**, the site of photosynthesis. The cells that make up this parenchyma contain numerous chloroplasts. It is generally located on the upper surface of the leaf, surrounded by the epidermis and traversed by the veins.
- **The lacunar chlorophyll parenchyma,** generally found on the lower surface of the leaf, is rich in aerial lacunae, with a reduced number of chloroplasts, and participates in gas exchange through the stomata.

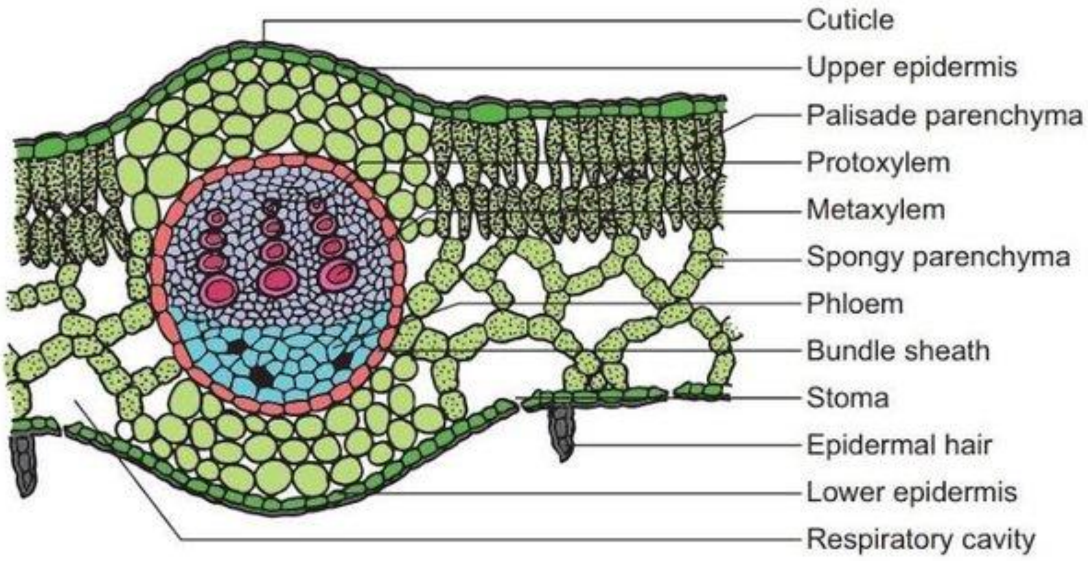

Figure 13: parenshyma tissus in laef. https://www.quora.com/Why-is-parenchyma-cells-present-in-soft-parts-of-plants

Mesophyll tissue is a modified type of parenchyma only. It contains chloroplasts and performs the function of photosynthesis. It is seen in all green leaves. In angiosperms it is made up of two types of cells -

- **Palisade parenchyma -** Its cells are rod shaped and arranged parallel to each other. They do not enclose intercellular spaces mostly.
- **Spongy parenchyma-** these cells are oval, circular or irregularly shaped and enclose intercellular spaces for gaseous exchange during photosynthesis.

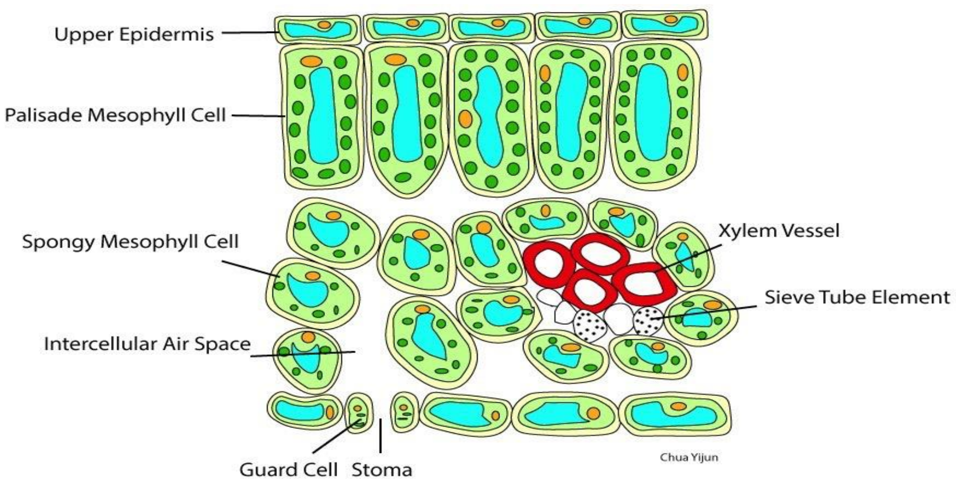

Figure 14: laef parenchyma. Parvinder Kaur. https://www.quora.com/Why-is-parenchyma-cells-present-in-soft-parts-of-plants

In **dicot** leaves both of these tissues are present. But in **monocot** leaves only spongy parenchyma cells are found.

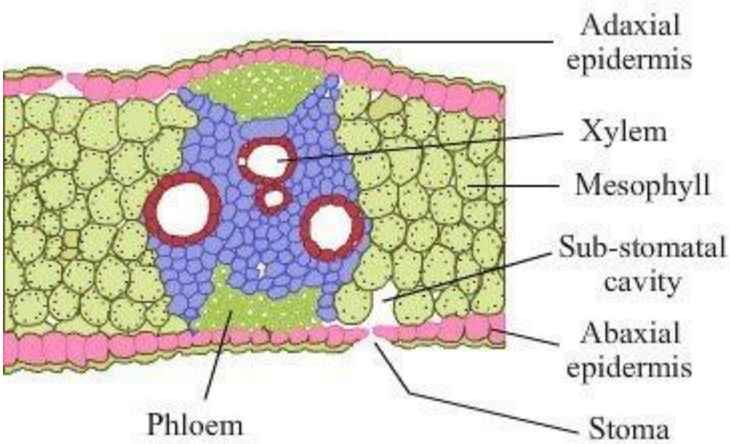

Figure 15: monocot laef parenchyma (mesophyll). Parvinder Kaur. https://www.quora.com/Why-is-parenchyma-cells-present-in-soft-parts-of-plants

B/ Storage parenchyma

The cells in this tissue synthesize and stores a number of substances. Although these substances can be solid, like starch grains and crystallized proteins, they are mostly found in solution, such as lipids, proteins, and others. Usually they are stored in vacuoles, which are the compartment specialized in storing molecules. In the cytoplasm, some moleculares are also stored like carbohydrates and nitrogenated substances. Some parenchymatic cells store only one type of substance, but a mix of different substances can also be found in the same cell.

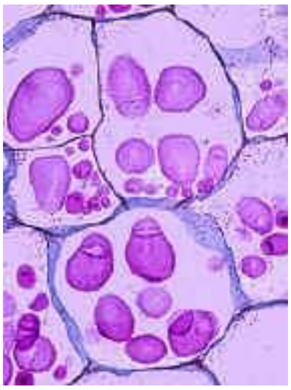

Figure 16: Storage parenchyma. https://eima86.tripod.com/id4.html

The mos frequent stored molecule is starch. Stored proteins are a good source of nitrogen, which is very important for the plant, and the destiny of these proteins is usually degradation.

- **Aquiferous parenchyma**. Although all parenchymatic cells store some amount of water, those of the aquiferous parenchyma are specialized in this function. They are large cells, with a thin cell wall and a very large vacuole where water is stored. In the cytoplasm or in the vacuole, there is a mucilaginous substance that increase the capacity of absorption and retention of water. Aquifereous parenchyma is present in plants that live in dry environments, known as xerophyte plants. Plant underground organs that store nutrients are not specialized in the storing of water, although those cells that contain starch granules or other substances are capable of storing large amount of water.

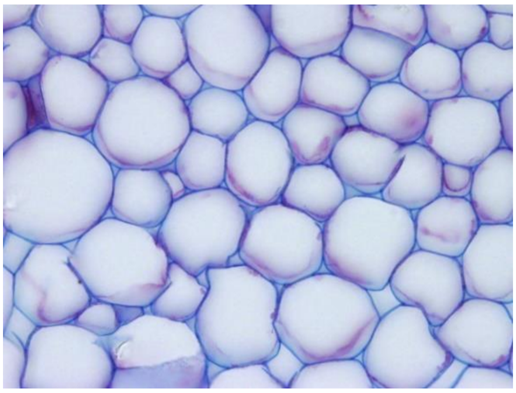

Figure 17: Aquifereous parenchyma. https://mmegias.webs.uvigo.es/02-english/1-vegetal/v-imagenes-grandes/parenquima_acuifero.php

- **Aeriferous parenchyma (aerenchyma).** There are large interconnected empty intercellular spaces, where gases can diffuse and aerate the root.

  Aeriferous parenchyma or aerenchyma contains large intercelular empty spaces, larger than in other plant tissues. This tissue is well-developed in plants living in wet or aquatic environments (these plants are known as hydrophytes), although it can be also found in non aquatic plants under stress. Both, stem and root can develope aerenchyma. In the roots, two ways of aerenchyma formation have been observed: **schizogeny** and **lysogeny**. **Schizogeny** is a process that occurs by cell differentiation during the development of the organ. **Lysogeny** is a consequence of the stress and the intercellular cavities are produced by cell death. Lysogenic aerenchyma is found in wheat, rice, corn and barley.

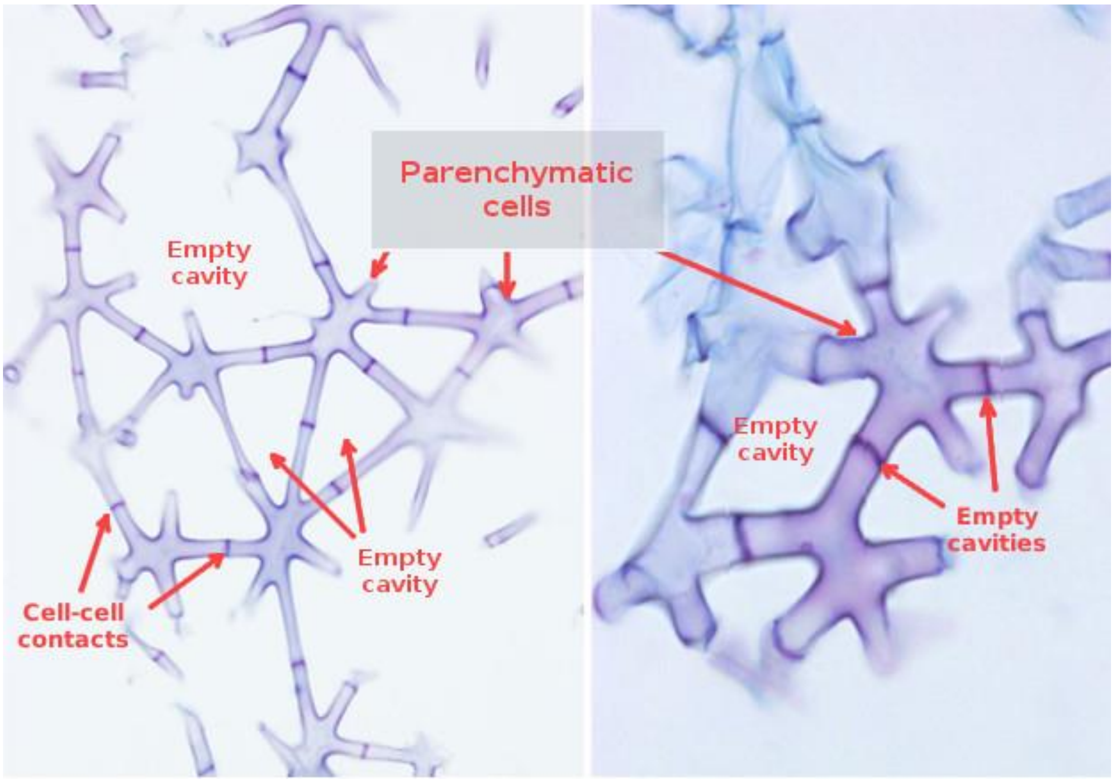

Figure 18: Aeriferous parenchyma. https://mmegias.webs.uvigo.es/02-english/1-vegetal/v-imagenes-grandes/imagenes/parenquima-aerifero-todo.jpg

2. 1.1.2.2 Supporting or Mechanical Tissues (Collenchyma and Sclerenchyma)

Supporting tissues reinforce tissue structures. They are composed of thick-walled cells with thick walls that give them a certain rigidity, especially in herbaceous plants. Collenchyma and sclerenchyma. These tissues are derived from the parenchyma.

① Collenchyma

This is a primary tissue found under the epidermis in the form of tufts or crowns, located in the periphery of the aerial parts of young growing organs (stem and petiole), consisting of living cells with a thick secondary pectocellulose wall (several layers of cellulose). Some collenchyma allow for relative flexibility and may even undergo some cell elongation if the wall is not too thick.

Different types of collenchyma

Collenchyma according to the degree of wall thickening:

a- **annular collenchyma**, with uniform cellulose deposition in the wall.

b- **angular collenchyma**, where cellulose thickening is concentrated in the corners of the wall.

c- tangential or lamellar collenchyma, in which only the tangential walls, i.e. those that are parallel to the outer surface. This type of collenchyma is found in the bark of stems.

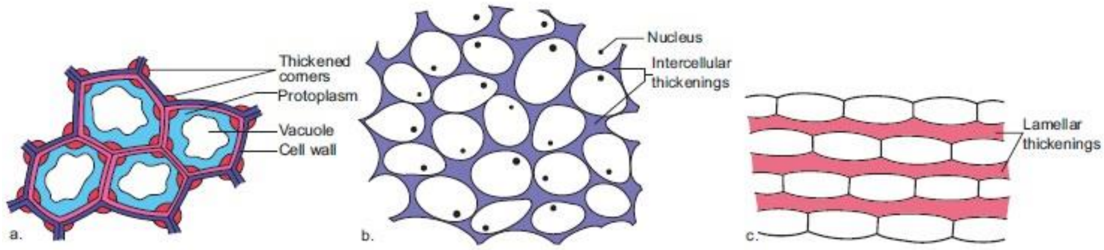

Figure 9.6: Types of Collenchyma a) Angular collenchyma, b) Lacunar collenchyma, c) Lamellar collenchyma

https://img.brainkart.com/imagebk34/b5xQIhY.jpg

② Sclerenchyma

The sclerenchyma is dead cell and lacks protoplasm. The cells are long or short, narrow thick walled and lignified secondary walls. The cell walls of these cells are uniformly and strongly thickened. The sclerenchymatous cells are of two types: Sclereids and Fibres.

A. Sclereids (Stone Cells)

Sclereids are dead cells, usually these are isodiametric but some are elongated too. The cell wall is very thick due to lignification. Lumen is very much reduced. The pits may simple or branched. Sclereids are mechanical in function. They give hard texture to the seed coats, endosperms etc., Sclereids are classified into the following types.

- **Types of Sclereids**

1. Branchysclereids or Stone cells:

Isodiametric sclereids, with hard cell wall. It is found in bark, pith cortex, hard endosperm and fleshy portion of some fruits. Example: - Pulp of Pyrus.

2. Macrosclereids:

Elongated and rod shaped cells, found in the outer seed coat of leguminous plants. Example: Crotalaria and Pisum sativum.

3. Osteosclereids (Bone cells):

Rod shaped with dilated ends. They occur in leaves and seed coats. Example: seed coat of Pisum and Hakea

4. Astrosclereids:

Star cells with lobes or arms diverging form a central body. They occur in petioles and leaves. Example: Tea, Nymphae and Trochodendron.

5. Trichosclereids:

Hair like thin walled sclereids. Numerous small angular crystals are embedded in the wall of these sclereids, present in stems and leaves of hydrophytes. Example: Nymphaea leaf and Aerial roots of Monstera.

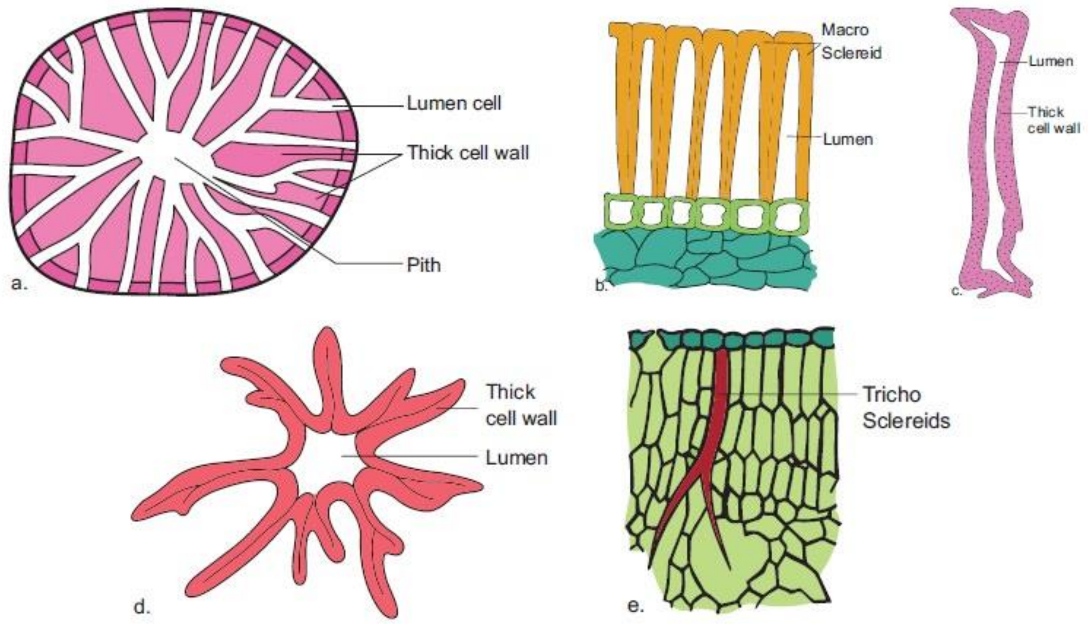

Figure 9.7: Types of Sclereids a) Brachysclereids, b) MacroSclereids, c) Osteosclereids, d) Astrosclereids, e) Trichosclereids

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B. Fibres

Fibres are very much elongated sclerenchyma cells with pointed tips. Fibres are dead cells and have lignified walls with narrow lumen. They have simple pits. They provide mechanical strength and protect them from the strong wind. It is also called supporting tissues. Fibres have a great commercial value in cottage and textile industries.

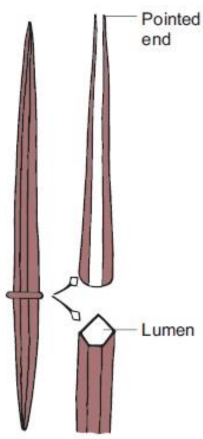


Figure 9.9 T.S of fibre

https://img.brainkart.com/imagebk34/rwBmXle.jpg

2. 1.1.3. Conducting tissues

All vascular plants have conductive tissues that ensure the conduction of sap (raw sap for the xylem and refined sap for the phloem). Conducting tissue cells are grouped into structural units that form long columns. There are 2 types of conducting vessels: phloem and xylem, which are closely related ontogenetically, anatomically, and physiologically; they form the vascular system that ensures correlations between the different parts of the plant.

Vessel: a tube that distributes sap to the different parts of a plant.

Phloem: a group of thin, elongated, interconnected vessels.

Primary **xylem** and primary **phloem** are the two primary conducting tissues in herbaceous plants. They are grouped in bundles (criblovascular bundles).

In woody plants, there is a zone of poorly differentiated, actively dividing cells between the primary xylem and the primary phloem. This generative zone, known as the ligule-ligneous cambium, produces cells that differentiate to form the secondary conducting tissues that are the secondary xylem (wood, hence the term ligule) and the secondary phloem (or ligule).

A/ The xylem

The xylem is responsible for the circulation of mineral sap, or raw sap, and is composed of very elongated dead cells with walls thickened by lignin deposits, interrupted in places to allow raw sap to pass through. The xylem has two types of sap-conducting cells:

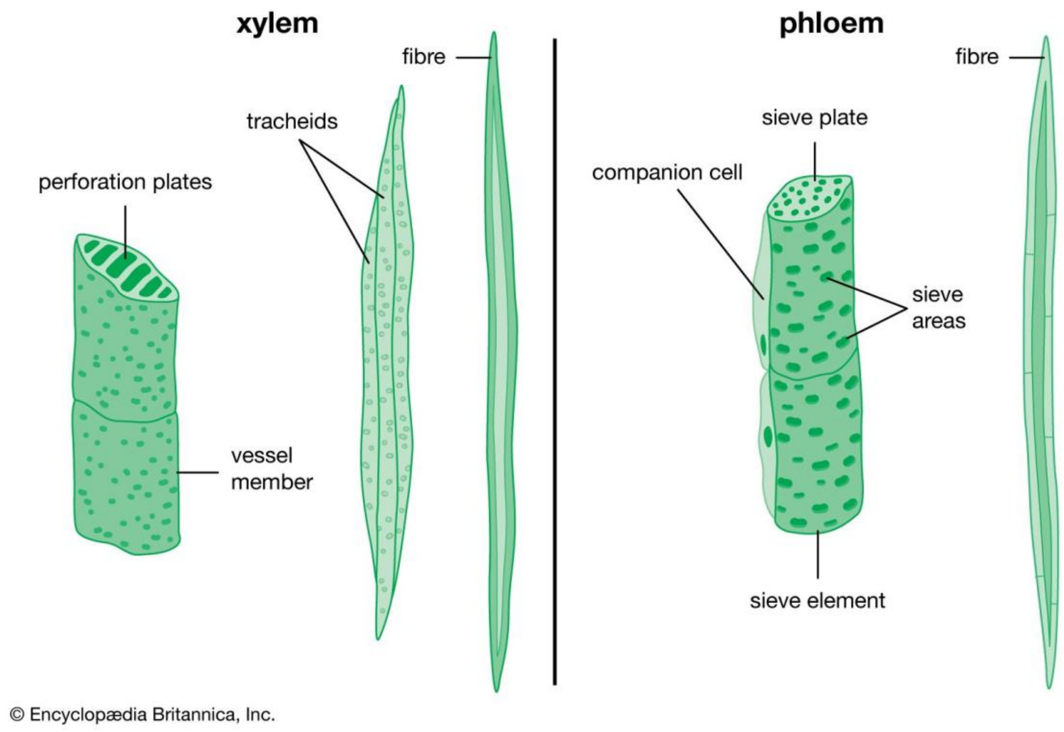
1. Tracheids, made up of dead cells whose transverse walls have disappeared, are relatively short, laid end to end and parallel to each other. The sap circulation is essentially vertical.

2. Tracheids are composed of elongated parallel cells. The ends are beveled and the cells are less rich in lignin. In tracheids, the transverse wall persists, causing a chicane-like flow.

B/ Phloem

The phloem allows the sap to move by means of sieve cells. Angiosperm sieve cells have companion cells. Both cells originate from the same mother cell that has undergone unequal mitosis. The products of this division have a radically different evolution: while the larger daughter cell becomes considerably hydrated and transforms into a sieve element (sieve tubes), the smaller one remains very dense and retains pronounced meristematic characteristics (companion cells).

1. **Sieve tubes**, living cells without nuclei, elongated in the longitudinal direction, arranged end to end, with thick pectocellulose walls. The transverse walls are interspersed with pores called sieves, which allow the sap to pass through.
2. **Companion cells are fine**, living cells with nuclei that are associated with each sieve cell. The unsieved cellulose walls help control sap flow in the sieve tubes.



Figures 19: phloem and xylem cells. https://cdn.britannica.com/02/5602-050-24031F4A/Cells-phloem-xylem.jpg

2.1.1.4. Secretory tissues

These are very different tissues in plants, specialized in the synthesis (secretion) of certain substances: heterosides, alkaloids, latex, essences. These tissues can accumulate the synthesized products in their cells or release them from the cells into the cavities of the organs, in which case the secreted products are excreted. There are two categories of secretory tissues

- **External secretory tissues:** epidermis and secretory hairs.

- **Internal secretory tissues:** isolated secretory cells, secretory pouches and ducts, laticifers, etc.

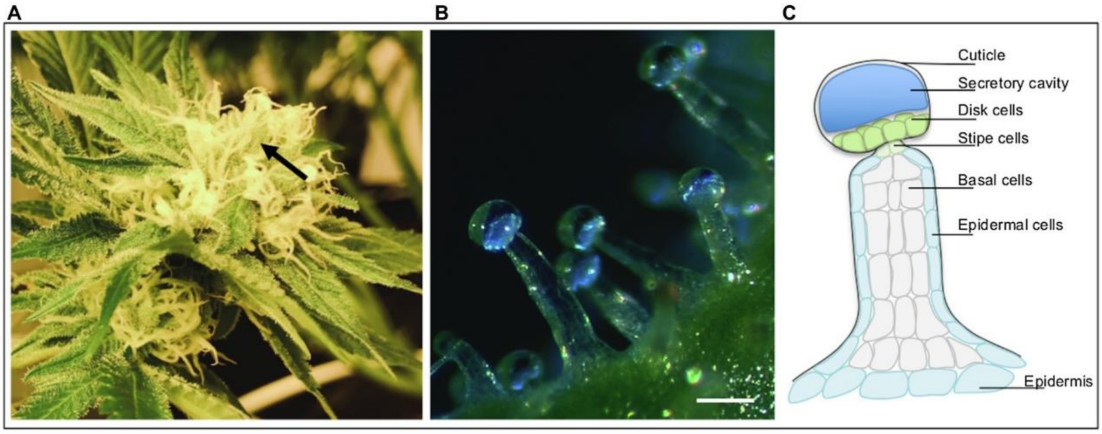


Figure 20: glandular hairs on the surface of an epidermis (External secretory tissues) https://www.frontiersin.org/files/Articles/721986/fpls-12-721986-HTML/image_m/fpls-12-721986-g001.jpg

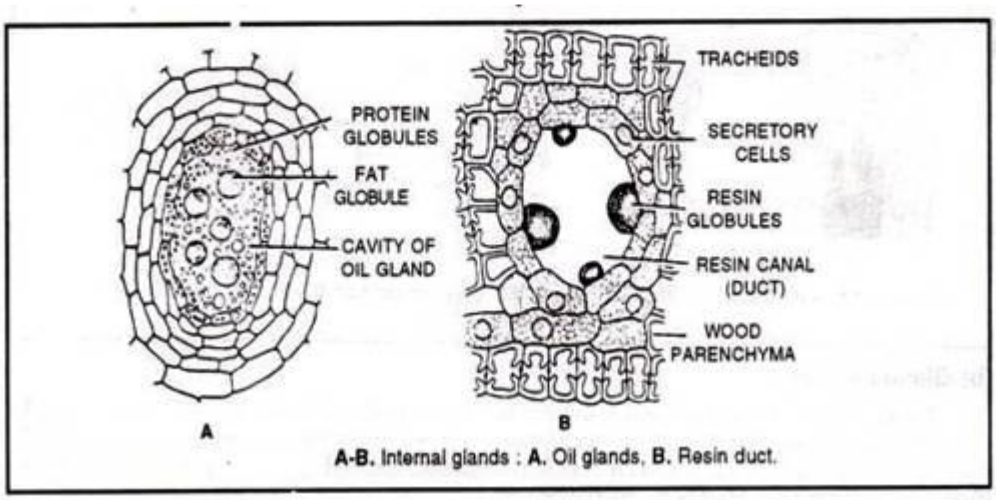


Figure 21: https://qsstudy.com/wp-content/uploads/2017/09/Secretory-tissue-1.jpg

2.2. Secondary (lateral) meristems (cambium and phellogen)

In dicotyledonous angiosperms, when the primary growth comes to an end, it can be followed by a completely different growth. This is due to the function of secondary meristems or generative zones, which are responsible for the growth in thickness of the organs. These structures are made up of cells that differ from those of the primary meristem in shape (rectangular) and cellular content: a central vacuole and a nucleus that occupies a lateral position. There are two secondary meristems responsible for the growth in thickness.

- **Cambium or liberoligneous generatrix.**
- **Phellogen or suberophellodermal generative base.**

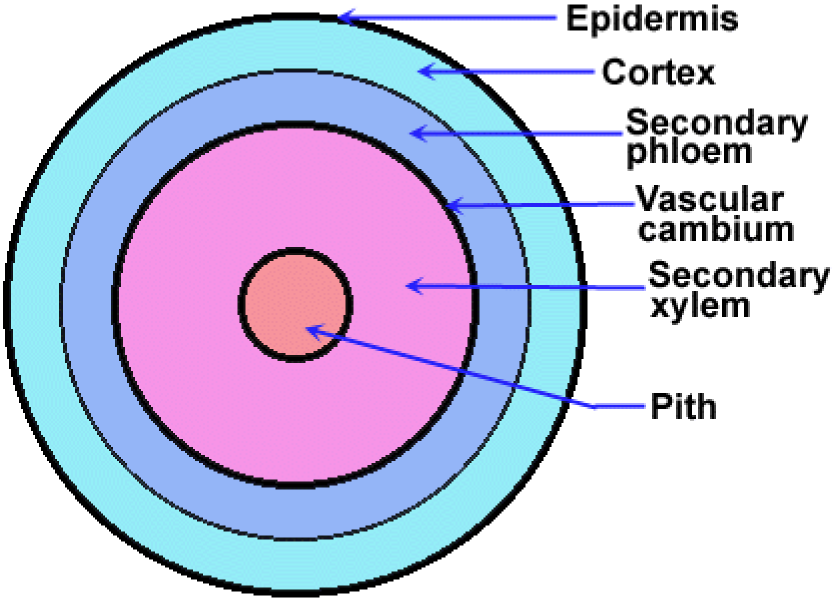


Figure 22: location of secondary tissues.

https://labs.plb.ucdavis.edu/rost/tomato/Stems/secstem05.gif

2.2.1. Secondary tissues

2.2.1.1 Cambium or liberoligneous generative layer

Initially located between the primary xylem and the primary phloem in the form of a cylinder made up of a single layer of cells, sometimes called the "cambial ring", it can be identified between these two tissues by its basically rectangular cells arranged in regular rows with a thin cellulose wall. These are apparently undifferentiated living cells (thin walls, large nuclei, but less fragmented vacuoles than in primary meristems) responsible for the production of secondary xylem or wood (inwards) and secondary phloem or liber (outwards). A complete ring is formed by the fusion of two types of cell zones: interfascicular cambial cells and intrafascicular cambial cells. This fusion forms the cambium ring.

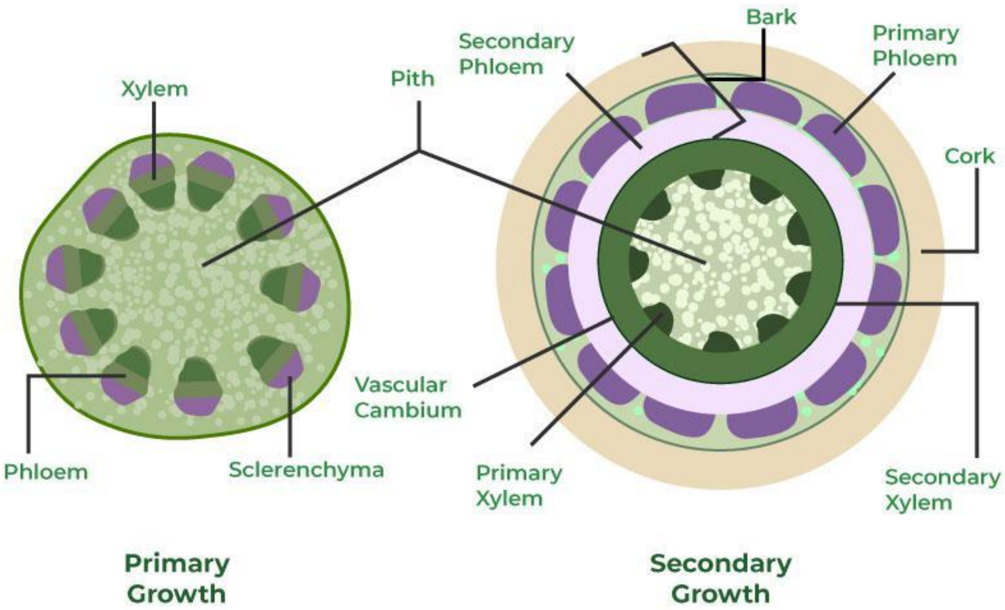


Figure 23: primary grawth and secondary grawth. https://media.geeksforgeeks.org/wp-content/uploads/20220825115840/PrimaryandsecondsryGrowth.jpg

2.2.1. Secondary tissues

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2.2.1.2. Phellogen or suberophellodermal generative base.

The phellogen or suberophellodermal generative base is the birthplace of the secondary tissues that will replace the epidermal tissues of primary growth. The phellogen develops in 2 parts: the suber on the outside and the phelloderm on the inside. The whole of the phelloderm, cortex and suberophellodermal layer is called the periderm; it corresponds to the "bark" of trees in the usual sense. The outer part of the periderm, which exfoliates and cracks, is called the rhytidome. Locally, the periderm generally shows ovoid zones where the cortex is thinner and the cells are less connected, allowing gas exchange between the atmosphere and the deeper tissues: these are the lenticels.

2.2.1.2.1 Protective tissues (suber or cork, phelloderma)

A/ Suber

The suber (or cork) is the second replacement tissue for the epidermal cells; it can also replace the piliferous base. In fact, the suber appears in organs undergoing thick growth, more precisely in the subperiophellodermal layer. Its formation requires the suberification of its constituent cells (the cellulose is impregnated with suberin, which leads to their death).

B/ The phelloderm

Consists of a few layers of aligned square cells with a cellulose wall. This tissue is often quite small.