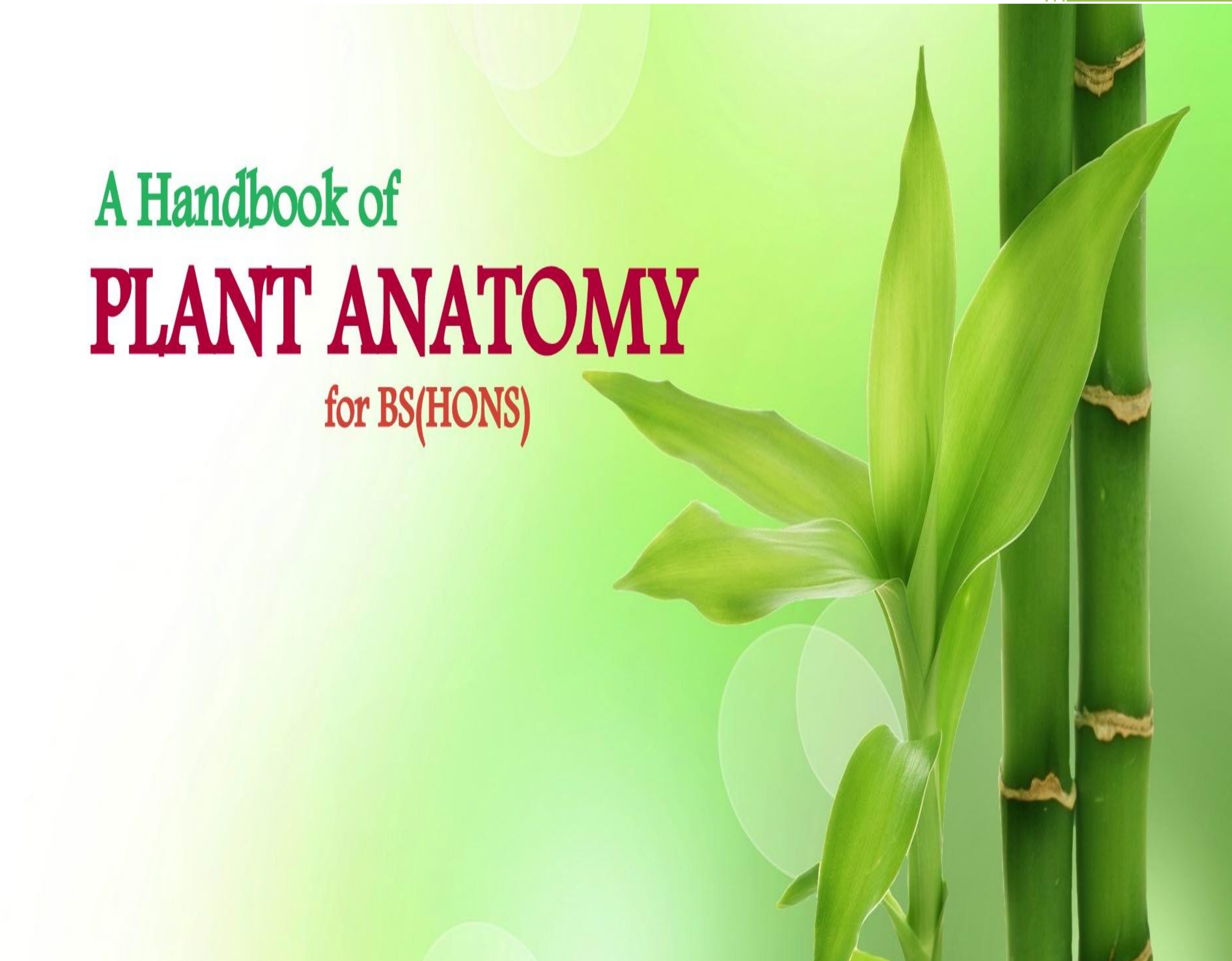

A Handbook of

PLANT ANATOMY

for BS(HONS)

LCWU

LAHORE COLLEGE FOR WOMEN UNIVERSITY

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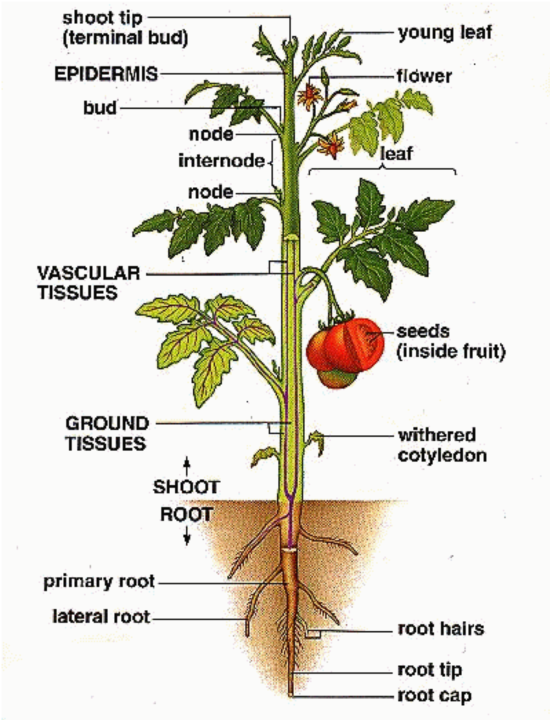


Labeled diagram of a primary plant body showing root and shoot systems

1. Plant body (Primary Plant Body)

1.1. The Root System

- Underground (usually).
- Anchors the plant in the soil.
- Absorbs & conducts water and nutrients.
- Food storage

1.2. The Shoot System

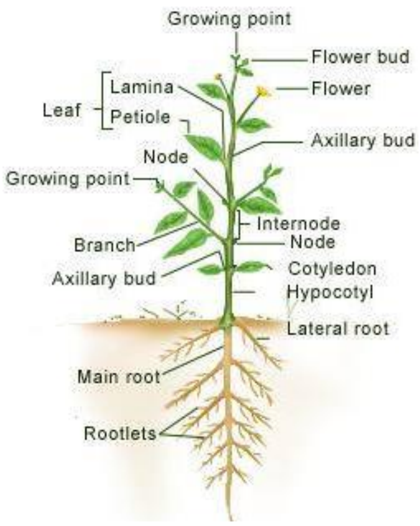
- Above ground (usually).
- Elevates the plant above the soil.
- Many other functions including:
  - photosynthesis
  - reproduction & dispersal
  - food and water conduction

1.3. Organization of Plant body- Cells, Tissues, Organs, Organ Systems

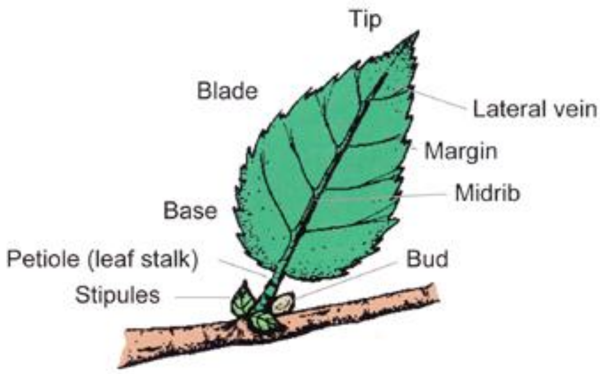
- Cells;
  - *Example:* Parenchyma, Sclerenchyma, vessel elements etc.
- Cells are organized together to form **tissues;**
  - *Example:* xylem, phloem etc.
- Tissues are organized together to form **organs**;
  - *Example:* Leaves, stamens etc.
- Organs are organized together to form **organ systems;**
  - *Example:* Flowers, shoots etc.

1.4. Root

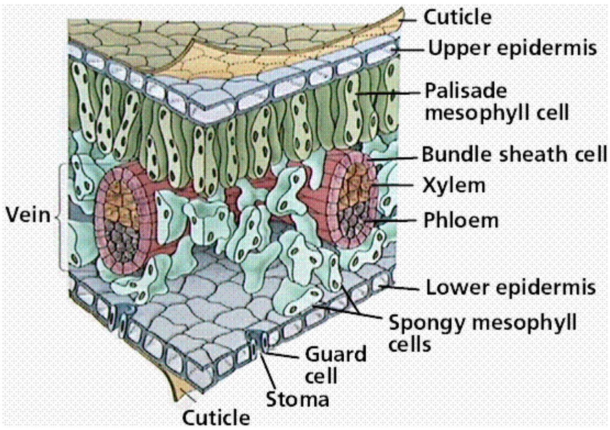
The primary body consists of a central cylinder of vascular tissue; the **stele**; surrounded by large storage parenchyma cells; the **cortex**; on the outside of which lies a protective layer of cells; the **epidermis.** The root epidermis of some plants is covered by a thin and waxy **cuticle**.



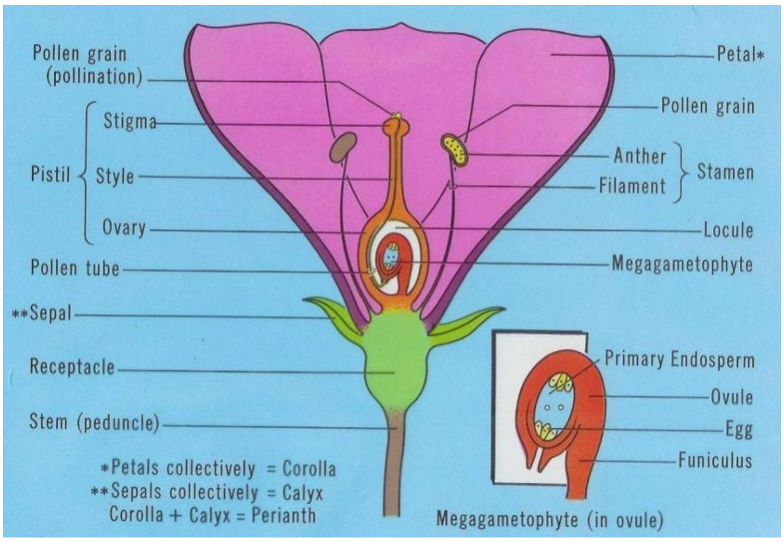
Labeled diagram of a primary plant body showing root and shoot systems



Labeled diagram of a plant body showing a leaf parts



Labeled diagram of internal structure of a leaf



Labeled diagram of T.S. of a flower showing its parts

1.5.Stem

The aboveground, conspicuous part of flowering plants constitutes the shoot system, which is composed of erect stems on which leaves, flowers, and buds are attached.

- Leaves are attached to the stem at regions called **nodes**.
- The section of stem between nodes is an **internode** and
- The upper angle between the stem and the leaf at the node is called the **leaf axil**.

Terminal buds are present at the tips of the main stem and branches and contain the apical meristem tissues. The shoot originates in the embryo at the end opposite the root and develops a complex shoot apex.

1.6.Leaf

Leaves may be arranged as one **(alternate)**, two **(opposite)**, and three or more **(whorled)**.

- If a single blade is attached to a petiole the leaf is **simple.**
- If the blade is divided into two or more individual parts, the leaf is **compound** and may be **pinnate** or **palmate** depending upon the **leaflets** arrangement.

Leaves arise in the shoot apex of stems in cells immediately below the **protoderm**.

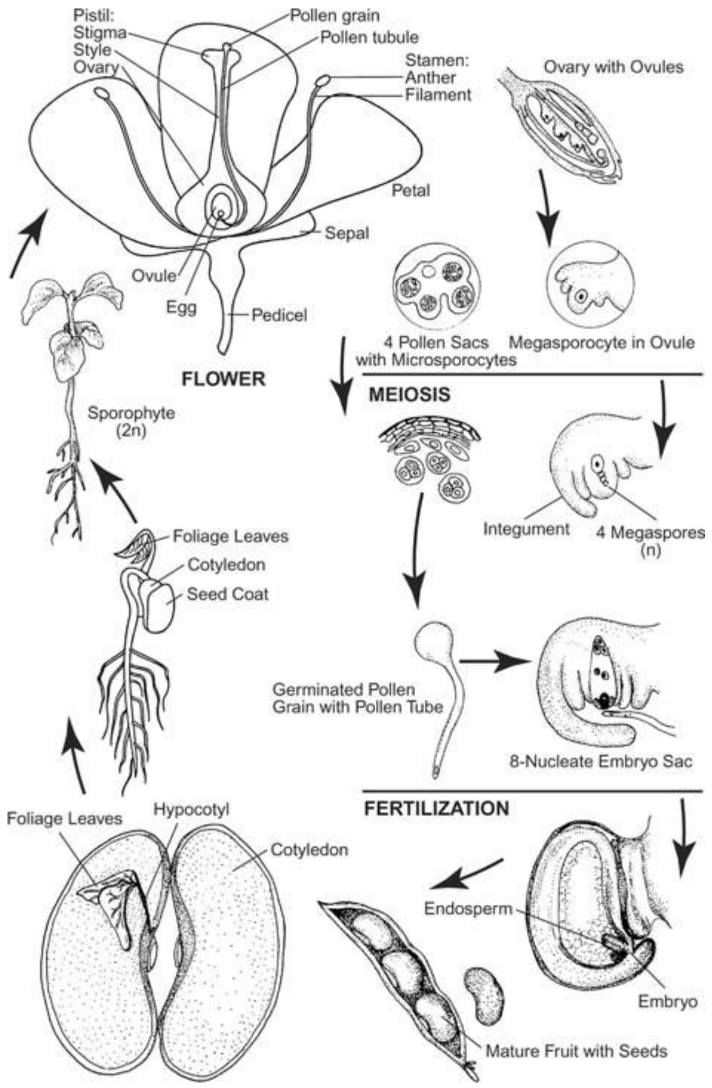
The standard leaf has three tissue regions:

- Epidermis
- Mesophyll
- Veins (Vascular tissue)

1.7.Flower

Flowers arise from apical meristems. The floral primordia develop into four different kinds of specialized leaves that are borne in whorls at the tip of the stem.

- The first formed outer whorl; the **calyx** (**sepals**); they are often green.



Labeled diagram showing life cycle of angiospermic embryo development

- The **petals** of the next whorl; the **corolla**; are frequently brightly colored.
- Together the calyx and the corolla are called the **perianth**.
- The next two whorls; **androecium** and **gynoecium**; are composed of highly modified reproductive structures that have lost their leaf like appearance.
- The androecium is composed of **stamens** and
- The gynoecium consists of **carpels**.

1.8.Fruits &seeds

Seeds develop from ovules in the ovary, and at maturity consist of an **embryo** and a reserve food supply surrounded by a protective covering; the **seed coat**.

Fruits are ripened ovaries containing seeds with sometimes additional flower or inflorescence tissues associated with them. Only angiosperms produce flowers and fruits.

1.9.Life cycle of embryo development

Like other plants, angiosperms alternate a sporophytic generation with a gametophytic one, a sporic meiosis. The **microgametophyte** consists of only three cells and is the germinated pollen grain. The **megagametophyte** is the mature embryo sac, a seven-celled structure in the ovule surrounded by, and dependent upon, sporophyte tissue.

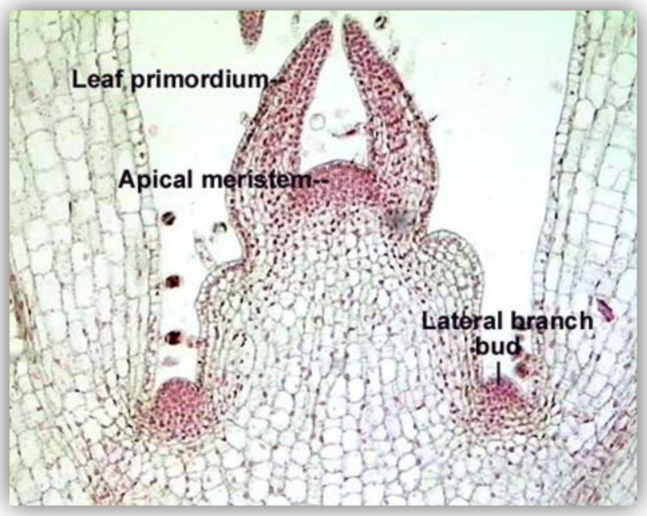


Diagram showing shoot apex containing apical meristem

2. Meristems

A tissue composed of immature, not well differentiated cells, which has capacity of division, is known as **meristematic tissue**.

There are two types of meristems according to their origin:

- Primary meristem
- Secondary meristem

2.1.Primary meristem

It is the meristem that is present right from the **embryonic stage** and continues to be active throughout the life of a plant. It is responsible for **primary growth** in the plant body. It gives rise to the primary permanent tissues of the plant body. Primary meristem includes:

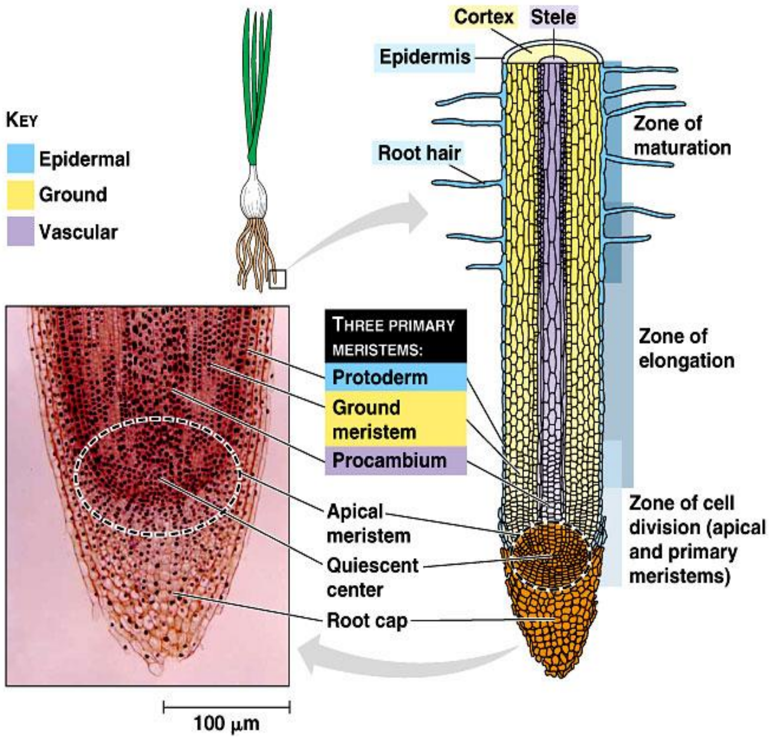
- ➢ Apical meristem
- ➢ Sub-apical meristem
- ➢ Intercalary meristem

2.1.1. Apical meristem

- ➢ It is the meristem present at the tip of the stem, commonly called as shoot apex.
- ➢ Due to the activity of apical meristem, the plant body keeps increasing in its length.
- ➢ Development is exogenous.
- ➢ Growth of shoot is not uniform due to the presence of node and internodes.
- ➢ Shoot apex is differentiated into regions and zones.

2.1.1.1. Reason of Identification

- ❖ Presence of leaf primordial and presence of lateral branches
- ❖ Dome shaped apex



Labeled diagram of L.S. of Root apex of *Allium sepa* showing primary meristematic tissues

2.1.2. Sub-apical meristem

- It is the meristem present at the tip of the root, commonly called as root apex.
- The position of root apex is sub-apical / sub-terminal due to the presence of root cap.
- Development of root apex is **endogenous.**
- Development of root apex is uniform due to the absence of nodes and internodes.
- There is the region of elongation that growth in length occurs.
- Above this elongation zone lies the region of maturation, where the primary tissues of the root mature, completing the process of cell differentiation that actually begins in the upper portion of the meristematic region.
- Sub-Apical meristems are **composed** of the following:

❖ **Promeristem**

This is a one cell, or a number of cells, which; by cell division (mitosis); gives rise to the histogens or regions of active cell division and tissue formation.

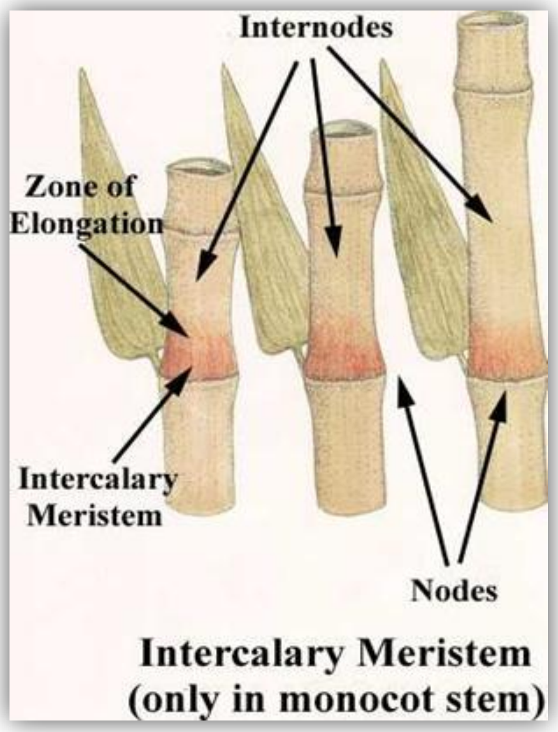
❖ **Histogens**

These arise from the promeristem and divide repeatedly to form the primary permanent tissue. Different histogens, which give rise to different permanent tissues, can be distinguished, namely:

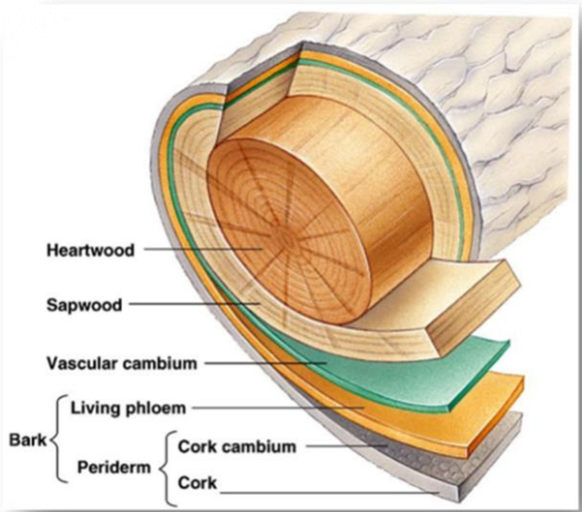
- **Protoderm**; from which the epidermis differentiates,
- **Ground meristem**; which give rise to the cortex,
- **Procambium;** from which the pericycle and first vascular bundles develop,
- **Calyptrogen**; (which is found only in roots) from which the root cap (**calyptra**) differentiates.

2.1.2.1. Reason of Identification

❖ Presence of root cap and root hairs.



Labeled Diagram of Sugar cane (*Saccharum officinale*)
showing intercalary meristem



Labeled diagram of T.S. of Wood showing secondary meristems

2.1.3. Intercalary meristem

- It contributes towards the increase in length as it brings about elongation of the internodal regions.
- It is the meristem that occurs between permanent tissues.
- It is present at the base of nodes, internodes, leaves etc.
- It is also responsible for the formation of branches at the nodal regions.
- Intercalary meristems may contain no initials.
- These are mature cells.
- This prevents it from being a structurally weak part of the organ.
- The primary function of an intercalary meristem is to facilitate longitudinal growth of a plant organ.
- Cell divisions in this tissue push the stem upward. Grasses and other monocots have intercalary.
- Nodes mature first.
- In this, internode matures basipetally.

2.1.3.1. Reason of Identification

- Presence between the permanent tissues.
- It contains no initials.

2.2. Secondary meristem

That meristem which develops from the cells which first differentiate and function as mature tissues and then resume meristematic activity. It is responsible for secondary growth in the plant body.

Secondary meristem includes lateral meristem.

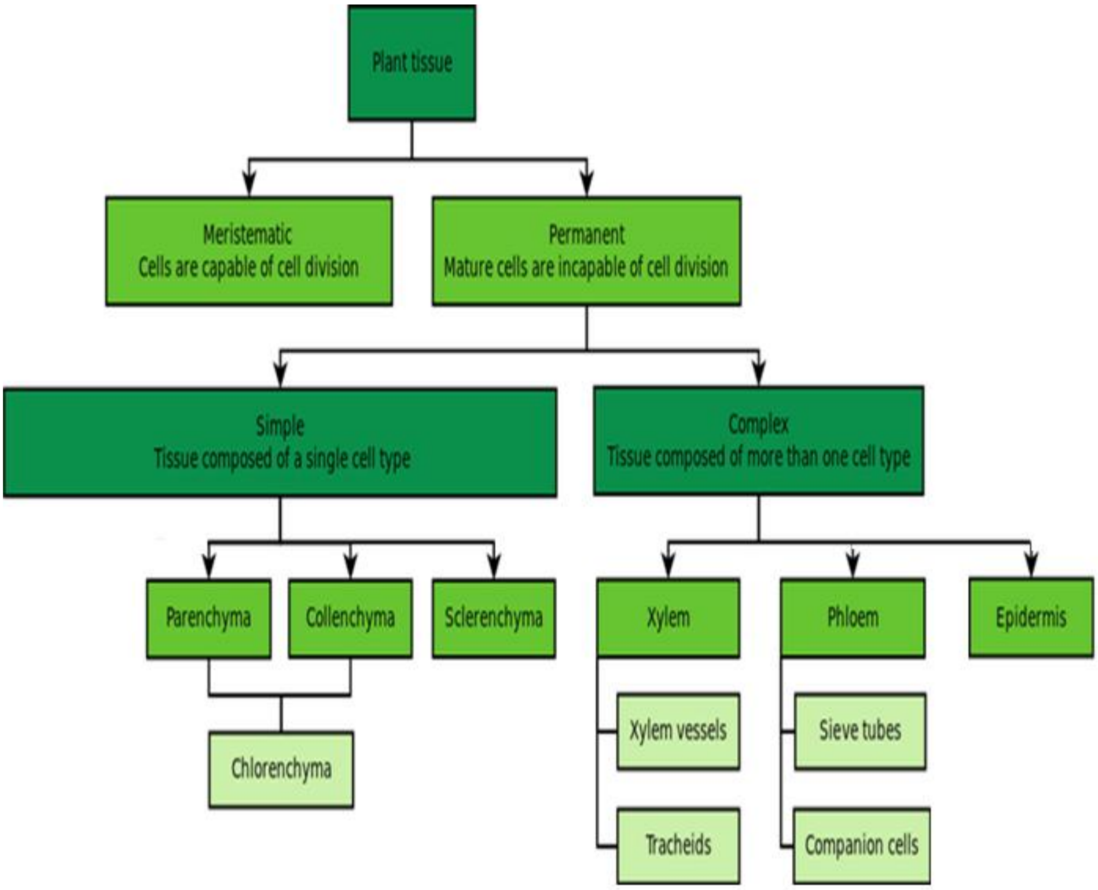
2.2.1. Lateral meristem

- It is the meristem that occurs laterally, parallel to the long axis of plant body.
- It lies under the bark of the plant in the form of cork cambium.

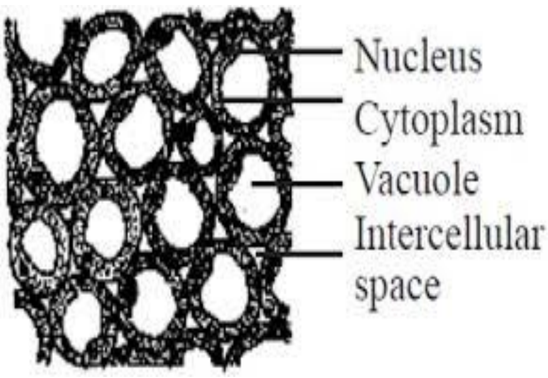
- It is responsible for an increase in the girth or width of the plant body as it brings about the formation of secondary permanent tissues.
- Vascular cambia are found in dicots and gymnosperms; but not in monocots, which usually lack secondary growth.
- Vascular cambium arises from the primary meristem, **procambium** that remains undifferentiated between the primary xylem and primary phloem.
- It is composed of elongated cells.
- The meristematic cells of the vascular cambium are highly vacuolated and It contains dense cytoplasm.
- This meristem consists of a narrow zone of cells that form new secondary xylem (wood) and secondary phloem (secondary vascular tissues).
- Another lateral meristem is the cork cambium, which produces cork, part of the bark.

2.2.1.1. Reason of Identification:

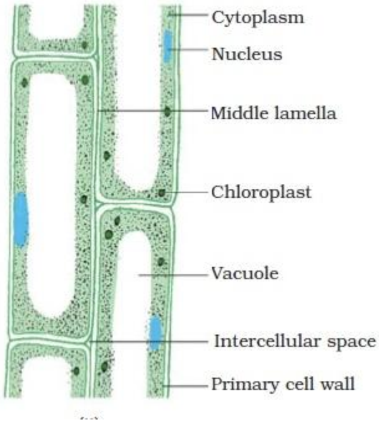
- Present laterally, parallel to the long axis of plant.
- Responsible to increase the diameter of plant.



Graphical chart showing types of plant tissues



T.S of Parenchyma tissue



L.S. of Parenchyma tissue

3. Permanent Tissues

3.1.Simple Permanent Tissues

These tissues are called simple because they are composed of similar types of cells which have common origin and function. They are classified into:

- Parenchyma
- Collenchyma
- Sclerenchyma

3.1.1. Parenchyma

Parenchyma *(para* – **beside** and *chyma* – **in filling, loose, unpacked***)* is the bulk of a substance. In plants it consists of relatively unspecialized cells with thin cell walls that are usually loosely packed so that large spaces between cells (intercellular spaces) are found in this tissue. They are live cells. This tissue provides support to plants and also stores food.

3.1.1.1. Shape

These cells are usually spherical or oval, polyhedral and lobed cells in shape. Sometimes the cells may be elongated. Very rarely the cells become irregular in shape.

3.1.1.2. Distribution

It is the main tissue in the plant body, occurring in almost all regions. It is particularly abundant in the root, nectaries, salt gland, vascular parenchyma and stem..

3.1.1.3. Arrangement

They are usually loosely arranged with prominent intercellular spaces. In certain regions like epidermis, the cells become compactly arranged and hence, intercellular spaces are absent.

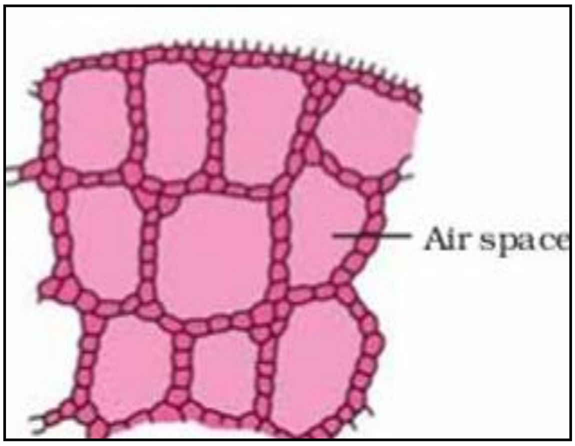


Diagram showing Aerenchyma tissues

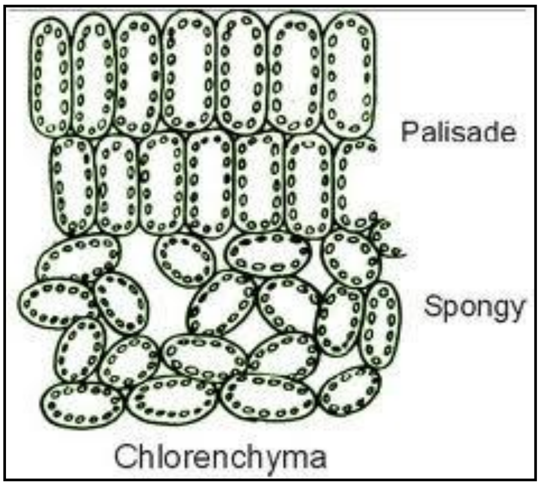


Diagram showing chlorenchyma tissues

3.1.1.4. Composition

Every cell has a thin cell wall represented by the primary wall. It is composed of only cellulose. Every cell has a large vacuole surrounding which a large amount of granular cytoplasm is present.

A prominent nucleus is seen situated just above the vacuole. The various cell organelles are found in a highly functional state. The vacuole encloses either storage products or secretory products. Parenchyma is commonly described as a simple, living, and storage tissues.

3.1.1.5. Types of Parenchyma

In the different regions of the plant body, parenchyma cells are involved in different functions. On this basis, following types of parenchyma can be recognized.

- **Chlorenchyma**

It is the parenchyma in which the cells contain large number of chloroplasts. Chlorenchyma takes part in photosynthesis. It occurs in the leaves and other green parts of the plant body.

- **Prosenchyma**

It is a type of parenchyma where cells are elongated with tapering ends.

- **Aerenchyma**

It is the parenchyma in which the cells enclose large intercellular spaces that are filled with air. Aerenchyma helps in buoyancy and respiration. It is characteristically found in aquatic floating plants.

- **Vascular parenchyma**

It is the parenchyma, which is found associated with the vascular tissues xylem and phloem. Accordingly, it is distinguished into xylem parenchyma and phloem parenchyma.

- **Medullary parenchyma**

It is the parenchyma, which is found radially arranged in between the vascular bundles in the stem. It is meant for storage of reserve food.

- **Conjunctive parenchyma**

It is the parenchyma, which occurs in the root system. It is specially meant for storage of water.

- **Armed parenchyma**

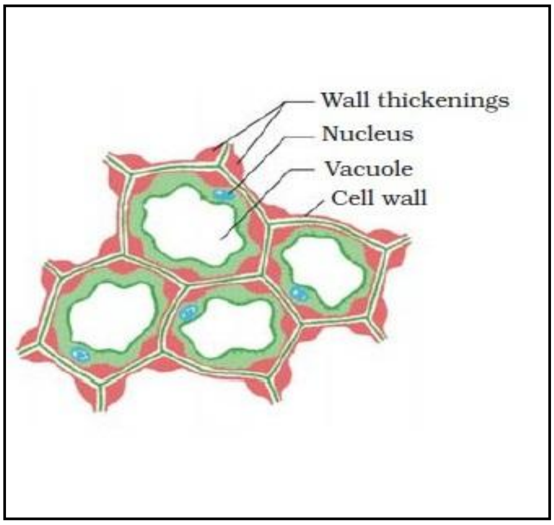
It is the parenchyma, which is found in the epidermis of leaves in some gymnosperms. The cells have many spiny projections. It is defensive in function.

3.1.1.6. Functions of Parenchyma

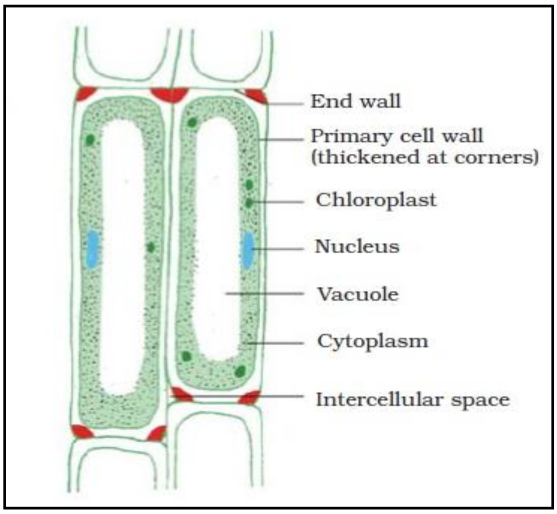
- Parenchyma is mainly involved in functions like storage and respiration. It also takes part in other functions like photosynthesis, absorption, and secretion and protection division.
- The most important function of the parenchyma cells of roots and stem is the storage of food (e.g. starch) and water.
- The intercellular air spaces permit gaseous exchange.
- Armed parenchyma is defensive in function.
- Vascular parenchyma is associated with translocation of food and water.
- Medullary parenchyma Aerenchyma helps in buoyancy and respiration.
- Medullary parenchyma meant for storage of reserve food.
- Conjunctive parenchyma storage of water.
- Chlorenchyma associated with photosynthesis because it contains large number of chloroplasts.

3.1.2. Collenchyma

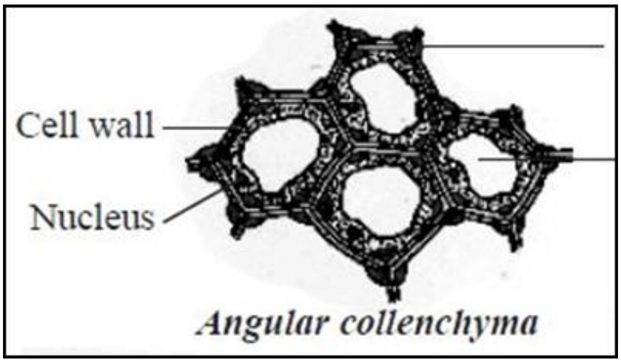
Collenchyma is Greek word, where *collen* means **gum** and *chyma* means **infusion**. It is a living tissue of primary body like Parenchyma It is a type of simple permanent tissue, which is mainly meant for providing mechanical support to the shoot system of a plant. Collenchyma is completely absent in the root.



T.S of Angular Collenchyma tissue



L.S of Angular Collenchyma tissue



T.S. of Angular Collenchyma

Cells are thin-walled but possess thickening of cellulose and pectin substances at the corners where number of cells join together.

3.1.2.1. Shape

It is composed of elongated cells that are compactly arranged. Sometimes, the cells may enclose small intercellular spaces. In a section, the collenchyma cells appear polygonal, spherical or oval in shape.

3.1.2.2. Distribution

It occurs chiefly in hypodermis of stems and leaves. It is absent in monocots and in roots.

3.1.2.3. Arrangement

The cells are compactly arranged and have very little inter-cellular spaces.

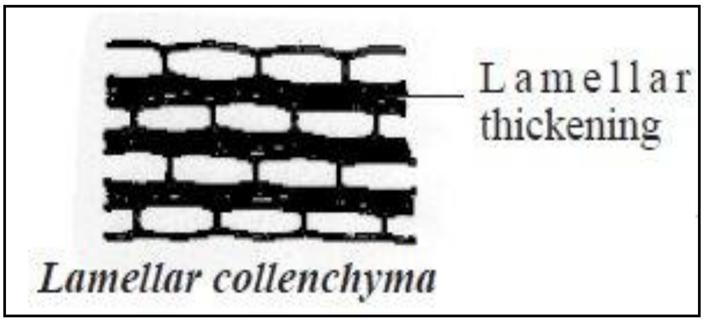
3.1.2.4. Composition

The cells are characterized by the presence of a cell wall, which is unevenly thick. The cell wall is composed of a primary wall made up of cellulose and at certain places. It is deposited with a secondary wall made up of **hemicellulose** or **pectin**. Every cell has a large, prominent vacuole filled with certain secretory products. Surrounding the vacuole, a granular cytoplasm is present. A nucleus is usually found situated just above the vacuole. The cell organelles are usually found in a functional state. Collenchyma is commonly described as a simple, living, mechanical tissue.

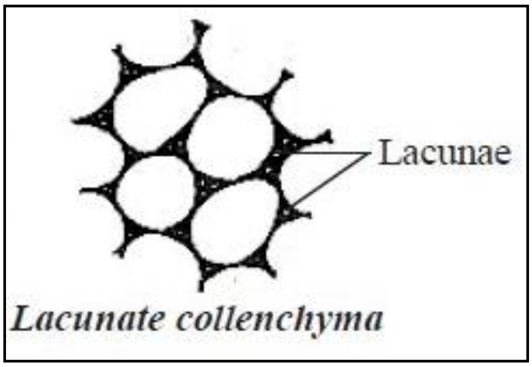
3.1.2.5. Types of Collenchyma Tissue

- **Angular collenchyma**

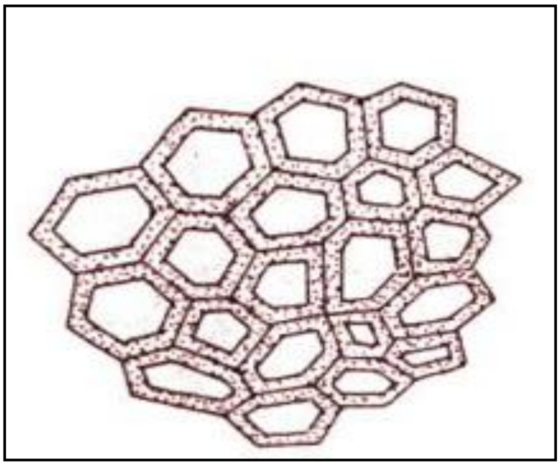
Thickening of cell wall is longitudinal in the angles of cells. In cross section these thickening are seen to be in those places where three or more cells meet **.e.g.** in petiole of *Vitis* and in the stems of *Solanum tuberosum*.



T.S. of Lamellar Collenchyma



T.S. of Lacunar Collenchyma



T.S. of Sclerenchymatous tissue

- **Lamellar collenchyma**

Collenchyma in which, thickening takes place on the tangential walls of the cells **.e.g.** cortex of stem in *Sambucus nigra* etc.

- **Lacunar collenchyma**

Collenchyma in which, thickening appear in those parts of cells wall which face intercellular spaces **.e.g.** petioles of species of Compositae family; *Salvia* and *Malva* etc.

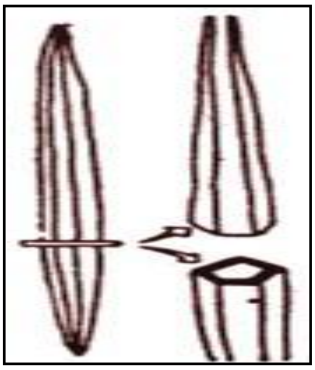
3.1.2.6. Functions

- It provides mechanical strength to the petiole leaves and stem of young dicot plants.
- Collenchyma confers flexibility to various parts of the plant like petiole and stem, allowing for easy bending without breakage.
- It allows for growth and elongation of plant organs.
- Collenchyma present in leaves also prevents them from tearing.
- The living cells of collenchyma store food.
- Collenchyma when containing chlorophyll performs the function of photosynthesis.
- Collenchymatous tissue acts as a supporting tissue in stems of young plants.
- It provides mechanical support, elasticity, and tensile strength to the plant body
- It is present in the margin of leaves and resists tearing effect of the wind.

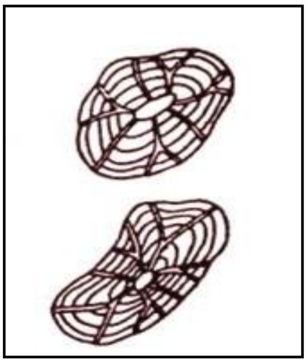
3.1.3. Sclerenchyma

Sclerenchyma is Greek word where *Sclerene* means **hard** and *chyma* means **infusion**. This tissue consists of thick-walled, dead cells. These cells have hard and extremely thick secondary walls due to uniform distribution of lignin.

Mature sclerenchyma cells are dead and have secondary cell walls thickened with cellulose and usually impregnated with lignin.



Sclerenchyma Fibers



Sclereid cells

3.1.3.1. Shape

They appear as hexagonal net in transverse section.

3.1.3.2. Distribution

Sclerenchymatous cells mainly occur in hypodermis, pericycle, secondary xylem and phloem. They also occur in endocarp of almond and coconut. It is made of pectin, lignin, and protein.

3.1.3.3. Arrangement

Sclerenchymatous cells are closely packed without inter-cellular spaces between them.

3.1.3.4. Composition

These cells have hard and extremely thick secondary walls due to uniform distribution of lignin. Lignin deposition is so thick that the cell walls become strong, rigid and impermeable to water. Mature sclerenchyma cells are dead and have secondary cell walls thickened with cellulose and usually impregnated with lignin. In contrast to collenchyma, which is pliable, sclerenchyma is elastic. The cell cavity or lumen is very small or it may disappear completely.

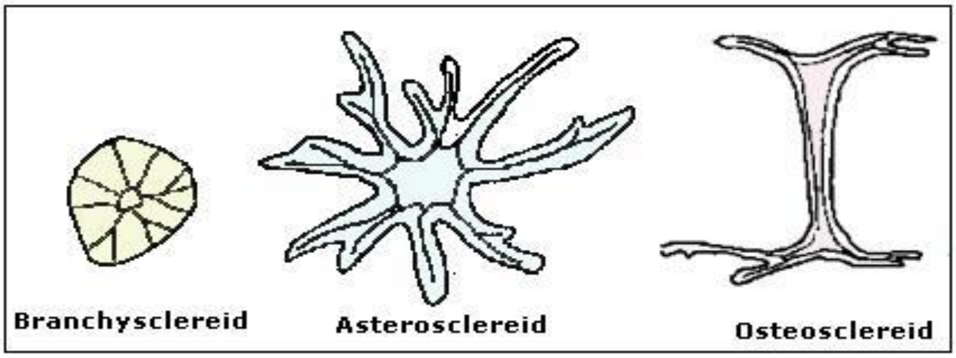
3.1.3.5. Types of Sclerenchyma Cell

There are two types of sclerenchyma cells.

- Sclereid cells
- Fibers

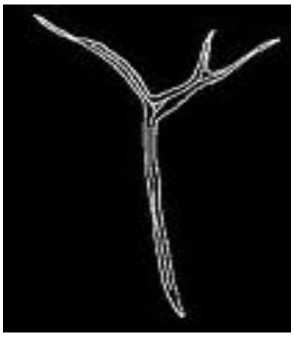
3.1.3.5.1. Sclereid cells

The cells are irregular in shape. The cell walls are thick, hard and lignified which makes the lumen very small. Simple pits (canals) are found in the thickened cell walls and link adjacent cells. These are commonly found in fruit and seeds. These are extremely variable in shape and are present in various tissues of the plant such as the periderm, cortex, pith, xylem, and phloem.



Shapes of Sclereid cells

Macrosclereid



Trichosclereid

3.1.3.5.2. Fibers

The cells are needle-shaped with pointed tips, thick walls and rather small lumen. Secondary cell walls, impregnated with, are formed. Simple pits are also present. Fibers are abundant in the vascular tissue of angiosperms, **i.e**. flowering plants. They can be found almost anywhere in the plant body, including the stem, the roots, and the vascular bundles in leaves.

3.1.3.6. Types of Sclerenchyma tissue on the basis of shape

- **Branchy Sclereid**

Branchy sclereid or stone cells which are more or less isodiametric in form such sclereid are usually found in phloem, cortex and bark of stem and flesh of fruits as pear.

- **Asterosclereids**

These are variously branched and often star shaped such sclereid cells are found in leaves.

- **Osteosclereids**

These are bone shaped or spoon shaped sclereid cells, the ends of which are enlarged lobed and sometimes even somewhat branched such sclereid cells are found in seed coat and also in the leaves of certain dicotyledons.

- **Macrosclereid**

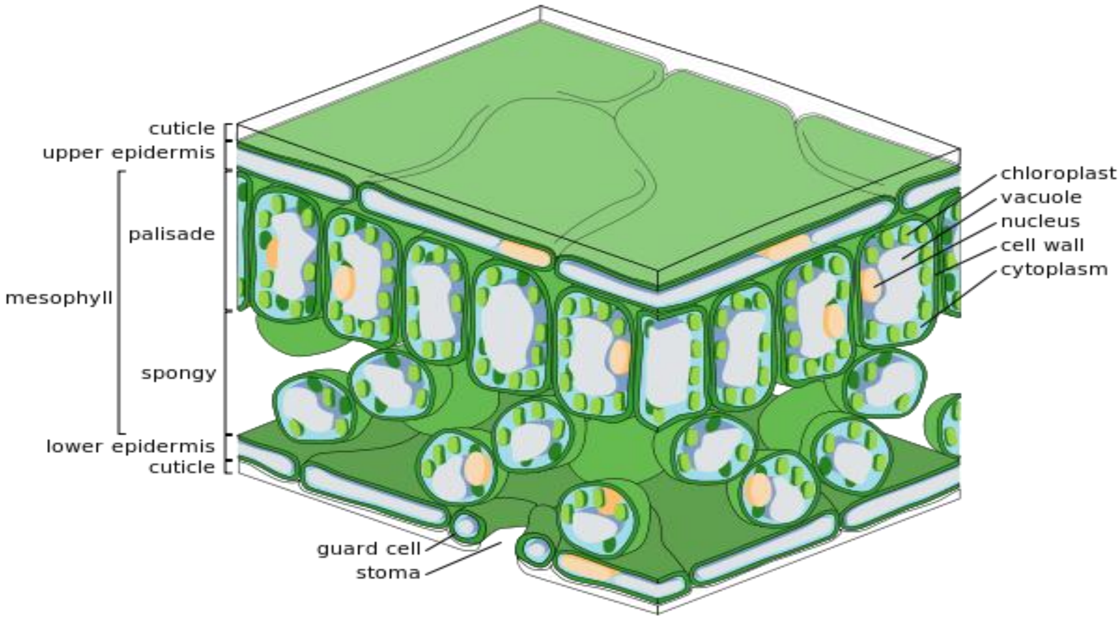
These are rod shaped sclereid cells, such sclereid cells are often form continuous layer in the testa of seed **.e.g.** in members of leguminosae family.

- **Trichosclereid**

These are very elongated somewhat hair like and regularly one branched sclereid cells.

3.1.3.7. Functions

- Sclerenchyma is an important supporting tissue in plants.



3D diagram of Leaf Epidermis

- Sclereids are responsible for the hardness of date seeds and the shell of walnut.
- Fibers probably play a role in the transport of water in the plant.
- Starch granules are stored in the young, living fibers.
- The main function of Sclerenchymatous tissues is to give support to the plant sclerenchyma.
- They also occur in leaves and fruits and constitute the hard shell of nuts and the outer hard coat of many seeds.

3.2. Complex Permanent Tissues

3.2.1. To study different types of cells of epidermis

- **Material and chemicals**

Stems and leaves of *Helianthus annus*, needles, safety blade, forceps, slides, cover slips, saffranine, dropper, water, microscope, etc.

- **Method**

  - Scrap the surface of the stem or leaf with safety blade and needles.
  - Now collect this scrapped material with forceps very carefully, preventing the crushing of the delicate epidermal layer.
  - Place it on the glass slide and stain with saffranine.
  - After staining, mount in glycerin after spreading the material almost into individual cells.
  - Then observe different types of epidermal cells and draw them.

- **Observations**

Different types of normal and specialized epidermal cells are observed showing distinct characteristics and structures.

3.2.2. Epidermis

Epidermis is a single-layered group of cells that covers plants' leaves, flowers, roots and stems. It forms a boundary between the plant and the external environment.

It is the outermost cell layer of the primary plant body. The epidermis is main component of the dermal tissue system of leaves, and also stems, roots, flowers, fruits, and seeds; it is usually transparent.

The cells of the epidermis are structurally and functionally variable. Most plants have an epidermis that is a single cell layer thick. Some plants like *Ficuselastica* and *Peperomia* have an epidermis with multiple cell layers.

Epidermal cells are tightly linked to each other and provide mechanical strength and protection to the plant.

The walls of the epidermal cells of the above ground parts of plants contain cutin, and are covered with a cuticle.

The cuticle reduces water loss to the atmosphere; it is sometimes covered with wax in smooth sheets, granules, plates, tubes or filaments.

3.2.2.1. Types of Epidermal Cells

There are two basic types of epidermal cells:

- Normal cells
- Specialized cells

3.2.2.1.1. Normal Cells

The normal epidermis cells, i.e. the least specialized cells constitute the largest group of dermal cells. They seem either polygonal or elongated in top view. Their walls are often wavy or sinuate.

- **Elongated epidermis cells**

They can be found at organs or parts of organs that are elongated themselves; like stems, leaf petioles, leaf veins or leaves of monocots. The epidermises of the leaf's upper- and undersurface may have different structures. Wide varieties of different cell shapes may even exist in species of a single family, e. g. in the Crassulaceae family.

- **Single layered** or **multi layered epidermal cells**

The epidermis is more often not built only from a single cell layer, though multi-layered, water-storing epidermises that evolved from initially single-layered tissues by periclinal division have been shown among the species of several families (Moraceae: most of Ficus-species, Piperaceae: Peperonia, Begoniaceae, Malvaceae and others).

- **Cuticle producing cells**

Epidermis cells secrete a cuticle that covers all epidermal surfaces like an uninterrupted film. It may either be smooth or structured by bulges, rods, filaments, folds, or furrows.

3.2.2.1.2. Specialized Epidermal Cells

Specialized epidermal cells include various types of cells which perform distinguishing functions:

- **Guard cells**

Stomata are produced by the guard cells that are laid out within the epidermis in regular intervals. They act as gateways for the passage of water n gases as in transpiration.

- **Trichomes**

Epidermal attachments of various shape, structure and function are called trichomes. They protect and support the leaf and produce glands in the form of scales. They are basically epidermal appendages.

- **Idioblasts**

Cells in a tissue that differ in size, form or contents from cells of the tissue (or the cells containing tannins, oils, crystals and other substances like silica cells or cork cells etc.)

Structure of Stomata

➢ **Bulliform cells**

In some plants i.e. (monocot leaves) elongated bubble like cells mostly help in the storage of water.

➢ **Mayosin cells**

They are sac like, tilled with enzymes for their certain roles and mostly found in family Cruciferae.

3.2.2.1.3. Stomata

To Study Different Types of Stomata:

- **Material**

Leaves, slides, cover slips, microscope, water, forceps etc

- **Method**

  - ➢ Tear the leaf suddenly and with force with lower epidermis upwards.
  - ➢ A thin membranous lower epidermis gets separated near the broken edges. Pull this into a strip with forceps or fingers. Then, add water and observe.

- **Definition**

The continuity of epidermis is interrupted by minute openings/ pores, each of which is limited by two specialized cells called the **guard cells**. The guard cells together with the opening between them constitute the **stoma**.

- **Stomatal apparatus/stomatal complex**

Subsidiary /accessory cells constitute two or more cells bordering the guard cells. The stoma together with the subsidiary cells if present termed as **stomatal apparatus** or **stomatal complex.**

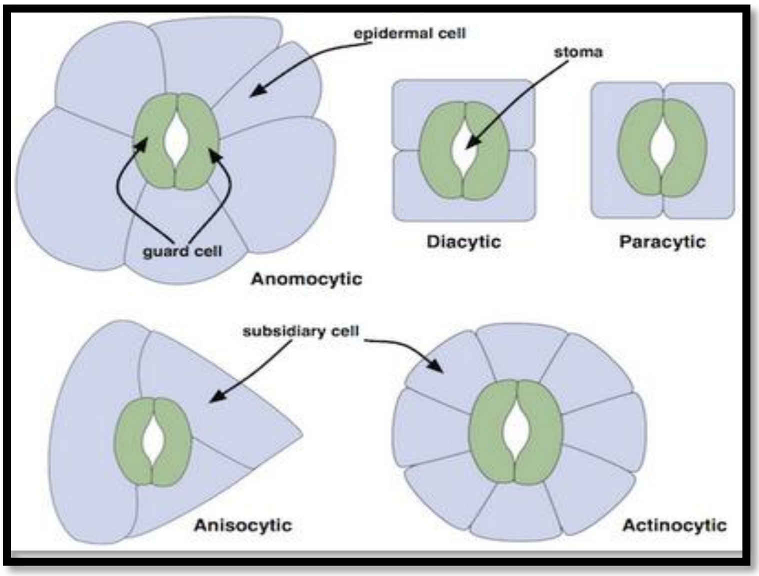


Diagram showing types of stomata present in Dicots

- **In Dicots and Monocots**

In dicot leaves with reticulate venation the stomata are distributed in *no particular order*. In monocots leaves with parallel venation the stomata are distributed *in parallel rows.*

- **Level of Stomata**

The guard cells of the stomata may exist at three different levels:

- Normal
- Raised
- Sunken

- **Shape of Guard cells**

- Dumb bell shaped
- Kidney shaped
- Elongated

- **Types of Stomata in Dicots**

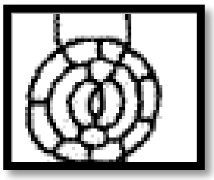
These types are on the basis of arrangement and number of subsidiary cells neighboring the guard cells.

- **Anomocytic type (irregular-celled type)**

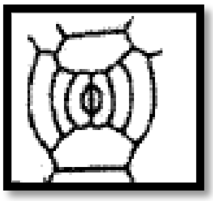
In this type the guard cells are surrounded by a certain number of cells that do not differ in size and shape from other epidermal cells .e.g. *Ranunculus*

- **Anisocytic type (unequal-celled type)**

In this type the guard cells are surrounded by three unequally sized subsidiary cells .e.g. *Hibiscus rosa-sinensis*, *Brassica campestris*.



Type of Stomata present in Family Graminae



In monocots, type of stomata where they are not associated with subsidiary cells

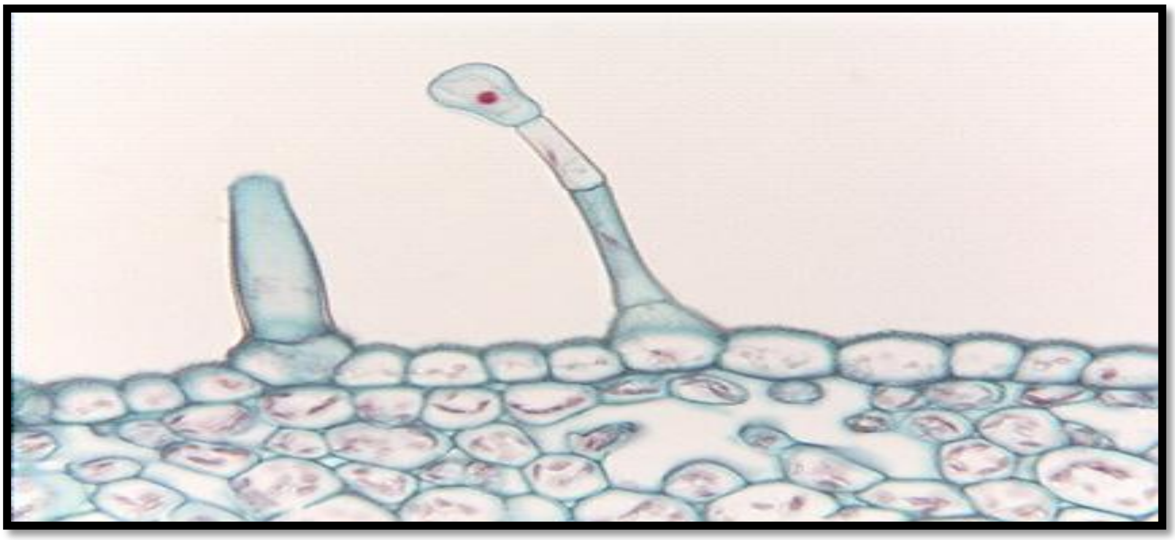


Diagram showing epidermal appendage; Trichomes

- **Paracytic type (parallel-celled type)**

In this type the guard cells are accompanied by 2 subsidiary cells, the longitudinal axis of which is parallel to that of the guard cells .e.g. Family Rosaceae, Family Convolvulaceae.

- **Diacytic type (cross-celled type)**

In this type the guard cells are surrounded by 2 subsidiary cells, the common wall of which is at right angle to the longitudinal axis of the stoma .e.g. *Salvia officinale*, Family Lamiaceae.

- **Actinocytic type(Cyclocytic type)**

In this type the stomata are surrounded by a circle of radiating cells .e.g. *Chenopodium album.*

- **Types Of Stomata In Monocots**

  - The guard cells are surrounded by 4-6 subsidiary cells .e.g. Family Cannaceae.
  - The guard cells are surrounded by 4-6 subsidiary cells of which two are roundish .e.g. Family Palmae.
  - The guard cells are accompanied laterally by two subsidiary cells; one on each side .e.g. Family Graminae.
  - The guard cells are not associated with any subsidiary cells.

3.2.2.1.4. To Study Epidermal Appendages

- **Materials**

Stems and leaves of *Helianthus annuus*, or any other plant (having trichomes) needles, safety blade, forceps, slides, coverslips, saffranine, water, microscope, etc.

- **Method**

  - Scrap the surface of the stem or leaf with safety blade.
  - Collect the scrapped material with forceps.
  - Place it on the slide and stain with saffranine.
  - Mount in glycerin after spreading the material almost into individual cells. Observe different types of trichomes and draw them.

- **Observations**

It is a vesicular filiform hair; made of a foot and body. The foot is simple. The body consists of *5-10* cells. It is uniseriate, filiform, cylindrical or slightly tapering above.

- **Definition**

"The outgrowths of the epidermal layer are called epidermal appendages; these may be temporary or permanent outgrowths"

These are of two types:

  - Trichomes
  - Emergences

- **Basic Difference**

Trichomes	**Emergences**
• Originates only from epidermis.	• Originates also from sub epidermal regions.
• E.g. Glands, hairs etc.	• E.g. Thorns, prickles etc.

- **Trichomes**

"The unicellular or multicellular, glandular or non-glandular, branched or unbranched living or dead, persistent or ephemeral structures which develop from epidermal cells are called trichomes"

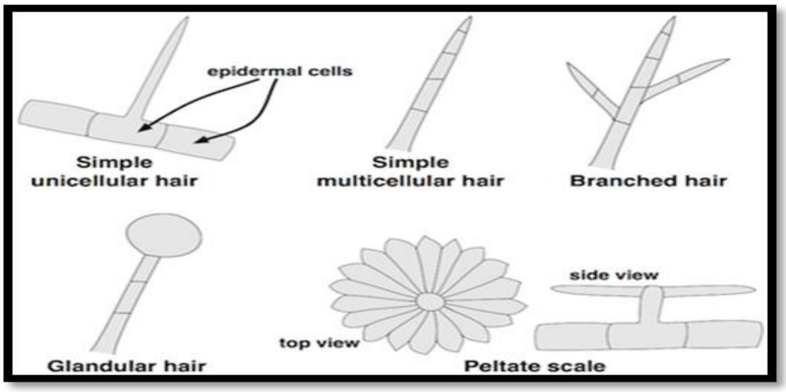


Diagram showing types of Trichomes

Trichomes are of following types:

- **Non Glandular Trichomes**

These trichomes are not involved in the secretion of various substances.

- **Simple** unicellular or multicellular uniseriate, non-flattened hairs are common.
  Examples: *Lauraceae, Triticum, Gossypium*.

- **Squamiform** hairs which are usually flattened and multicellular.

  - **Scales:** Squamiform may be sessile and are then termed scales.
  - **Peltate hairs:** May be stalked and then known as peltate hairs, e.g. *Olea etc*.
  - **Dendroid:** When they are dendritic called dendroid, e.g. In *Cruciferae etc*.

- **Multicellular hairs** which may be :

  - **Stellate:** Star shaped .e.g. in *Styrax* etc.
  - **Branched:** Candelabrum like .e.g. in *Platanus* etc.

- **T-shaped hairs** consisting of long, more or less horizontally oriented terminal cell and a stalk of one cell or of a row of few cells, e.g. in *Astragalus, Canadensis* etc.

- Many non-glandular trichomes of **xeromorphic plants** possess at their base, endodermal cells which prevent apparently apoplastic water leakage.

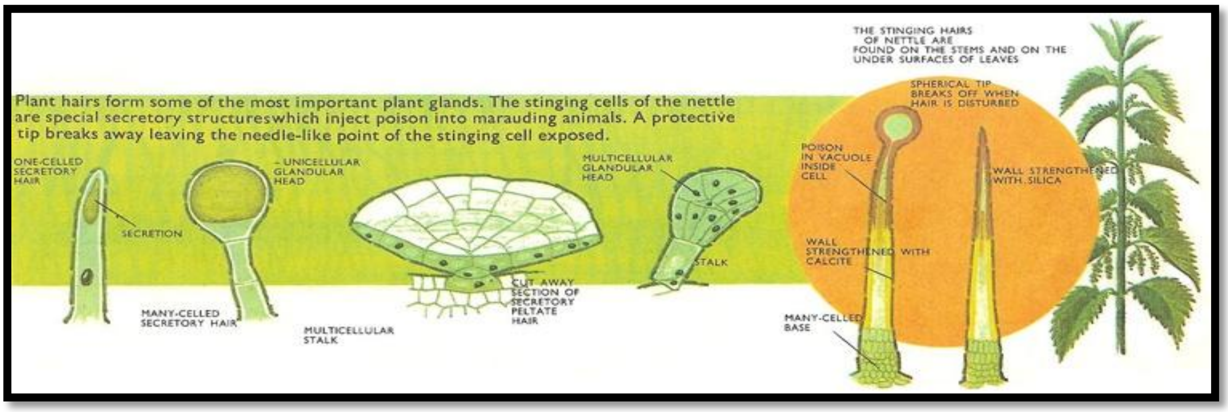
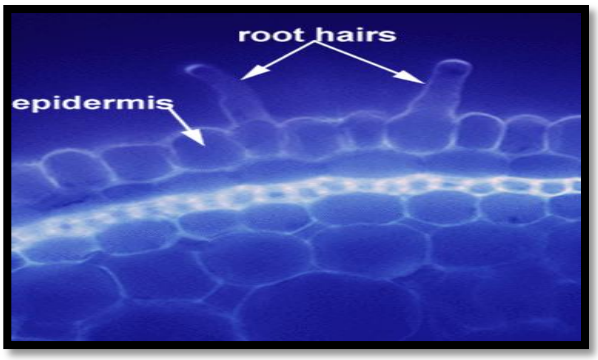


Diagram showing formation of stinging hairs



View of root hairs on epidermis through electron microscope

❖ **Glandular Trichomes**

These are involved in the secretions of various substances, also termed as glands.

- **Salt-Secreting Trichomes:** Present at top of narrow stalk.
- **Nectar-Secreting Trichomes:** Found in calyx and corolla.
- **Mucilage secreting Glands:** Found on membranous sheath arising from leaf base.
- **Glands of carnivorous plants:** Release mucilage for capturing prey.
- **Terpene Secreting Trichomes:** Secrete essential oils.
- **Collectors*:** Trichomes secreting sticky substances.
- **Stinging Hairs:** Having bladder like base and narrow needle like upper part.

➢ **Scales**

Plates like dry appendages that cover the plant body are called scales, their main function is to give protection and they check transpiration rate effectively.

➢ **Water vesicles (Bladders)**

In some members some of the epidermal cells produce sessile or stalked vesicular structures; these are living and store water. Bladders are unicellular.

➢ **Hairs**

Hairs are of following types:

❖ **Unicellular Hairs:** The epidermal cells simply elongate to form unicellular hairs. Single celled hairs may be unbranched or branched. They may straight, coiled, Y shaped, fusiform and so on. These are present on stem, leaf and floral parts. Wall is made up of cellulose.

❖ **Multicellular Hairs:** These may be short or long.

❖ **Root Hairs:** Tubular elongations of epidermal cells, branched only in very few plants, they have large vacuoles and usually thin walled.

In some cases multicellular root hairs are present. Root hairs elongate at their tips where the wall is thinner, softer and more delicate, nucleus is located close to the growing tip of root hair.

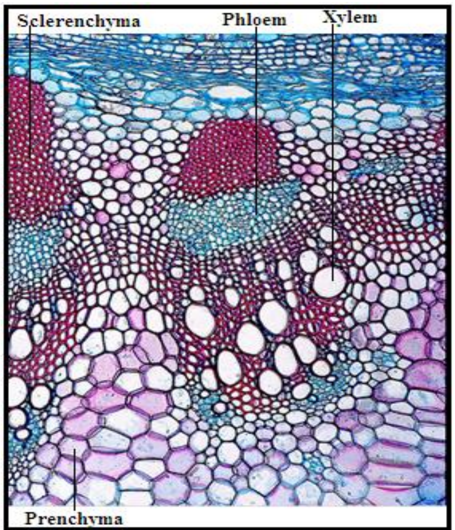
➢ **Emergences**

In some plants epidermal cells and underlying cortical cells collectively produce short and hooked structures called emergences. These are primarily protective in nature.

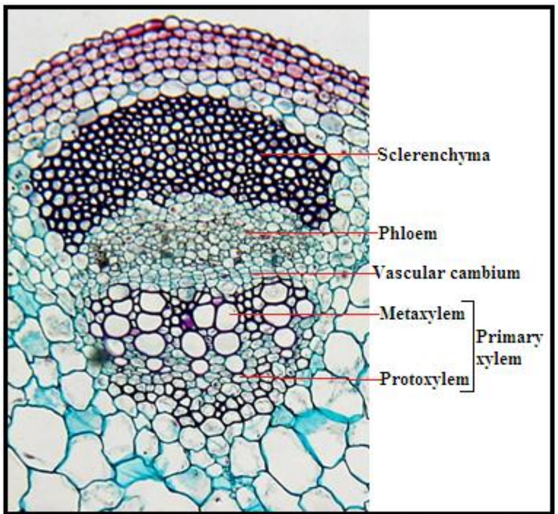
Examples: Thorns, prickles etc.

❖ **Functions of Epidermal Appendages**

- Act as protective layer.
- Helps in prevention of excessive loss of water.
- Can insulate the Mesophyll from excessive heat.
- May serve to remove salts from the leaf tissue so prevent the accumulation of toxic
- salts in the plant
- Defense against insects even sometimes it may houses insects and larvae.
- Secretory trichomes participate in chemical defense (resin, volatile oils, proteolytic enzymes, poisonous substance)
- In Bryophytes, Pteridophytes and certain hydrophytes epidermal cells have chloroplast and manufacture food.



Vascular bundle from a Dicot stem



Vascular bundle of a Dicot stem showing primary xylem

4. Complex Tissues (Xylem And Phloem)

4.1. Anatomical Note on Xylem

4.1.1. Introduction

Xylem is a part of the **vascular system** that conveys **water** and dissolved minerals from the roots to the rest of the plant and may also furnish mechanical support. Xylem consists of specialized water-conducting tissues made up mostly of narrow, elongated, hollow cells. It constitutes the major part of a mature woody stem or root; the **wood** of a **tree** is composed of secondary xylem.

4.1.2. Types of Xylem

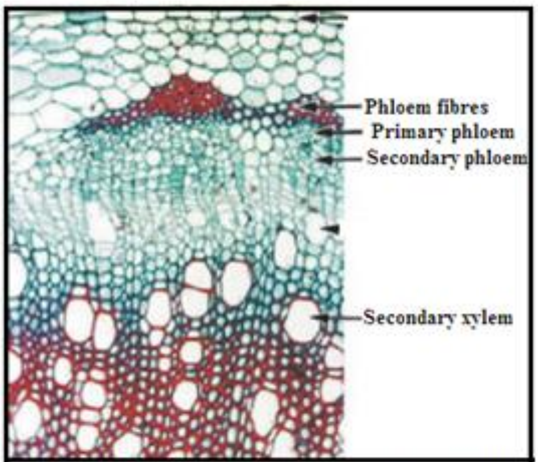
Xylem can be distinguished into two types namely:

- Primary xylem
- Secondary xylem

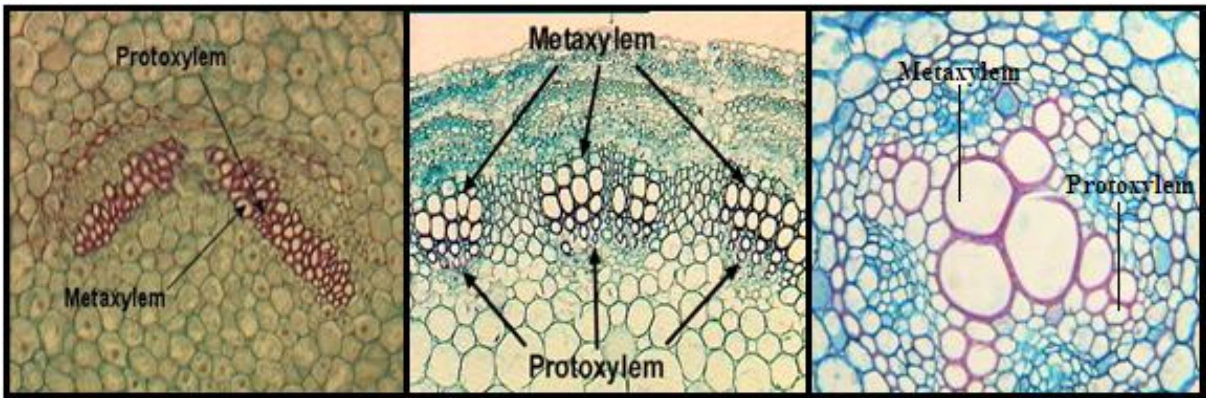
4.1.2.1. Primary Xylem

- It is primary in nature occurring in both monocot and dicots and is derived from procambium.
- Tracheids and vessels are narrow in size and long vessels.
- Xylem fibers are less in number and no differentiation of sapwood and heartwood and no formation of annual ring.
- In the primary xylem, two types of xylem vessels protoxylem and metaxylem are present.

Protoxylem	Metaxylem
• It is represented by vessels that are formed earlier.	• It is represented by vessels that are formed later.
• Lumen is narrow.	• Lumen is wider.
• Vessels exhibit annular and spiral type of thickening.	• Vessels exhibit sclariform, reticulate & pitted thickenings.



T.S of a Dicot stem showing secondary growth



Mesarch xylem in *Ophioglossum.* | Endarch xylem in Dicot stem | Exarch xyle in Dicot root

4.1.2.2. Secondary Xylem

- Secondary xylem is the xylem that is formed during secondary growth (from fascicular and inter fascicular cambium).
- Tracheids and vessels are wide and short.
- Xylem fibers are abundantly present.
- Sapwood and heartwood are distinct and annual ring formation occurs.
- Among angiosperms it is a characteristic feature of only dicots.
- Secondary xylem is commonly known as wood.
- It is of commercial importance since it is extensively used in the manufacturing of doors, windows and furniture.
- Secondary xylem is also found in members of the "gymnosperm" groups Gnetophyta and Ginkgophyta and to a lesser extent in members of the Cycadophyta.
- There are two systems of arrangements in secondary xylem:

    - **Axial system:** It produces tracheary elements, xylem parenchyma and xylem fibres.
    - **Transverse system:** It produces ray parenchyma cells.

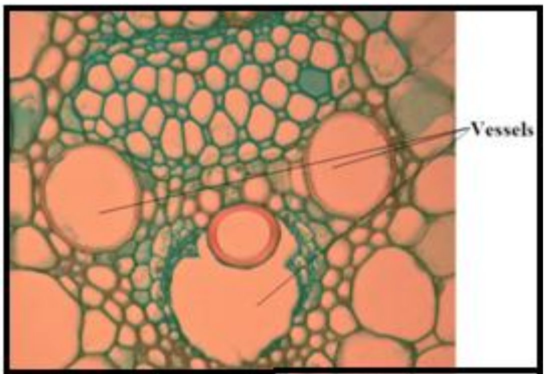
4.1.2.3. Development in Primary Xylem

Xylem development can be described by three terms: **exarch**, **endarch** and **mesarch.**

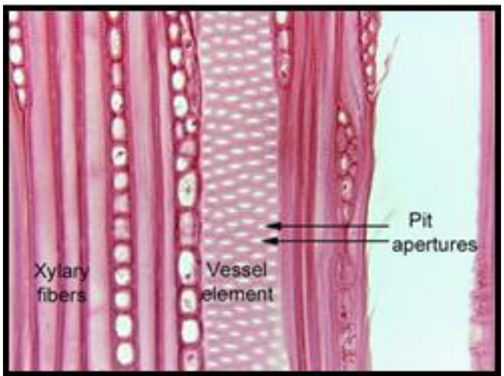
In **mesarch** development, there are several vascular strands and in each of these, protoxylem is located in the center surrounded by the metaxylem. This type of primary xylem development is found in many species of **ferns.**

In **endarch** development the protoxylem begins its development from the innermost procambial cells located adjacent to the pith and development progresses outward. Therefore, the protoxylem is found towards the inside and metaxylem towards the outside of the stem. Endarch development is considered the most highly advanced type of primary xylem development.

Tracheary elements



Vessel elements (Cross section)



Vessel element (Longitudinal section)

In **exarch** development the protoxylem begins developments from the outermost edge of the procambial cylinder (the side closest to the stem) and development proceeds from the outside to the inside. Therefore, the protoxylem is found towards the outside and metaxylem towards the inside of the stem. This type of primary xylem development is considered a primitive condition in vascular land plants.

4.1.2.4. Composition of Xylem

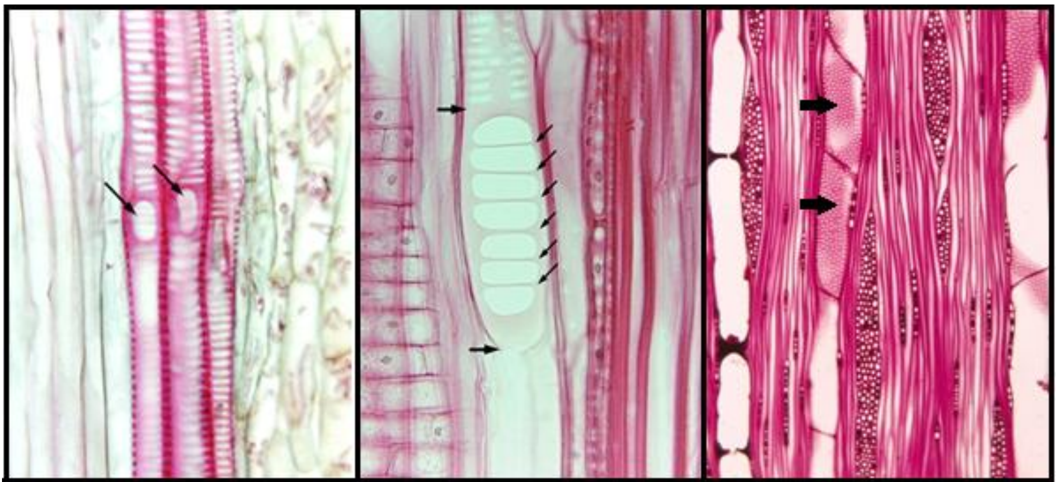
There are three types of xylem cells:

- Tracheary elements
    - Vessel members
    - Tracheids
- Xylem fibres
- Xylem parenchyma

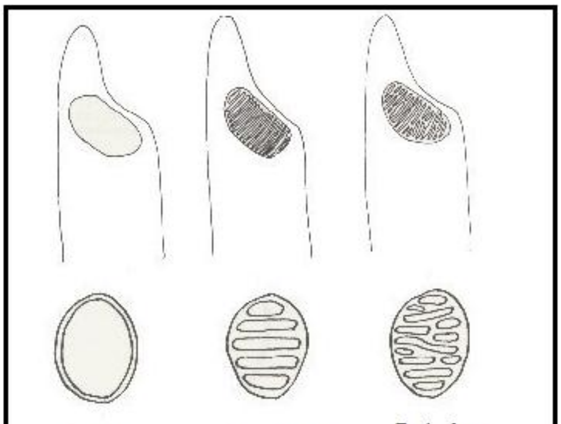
4.1.2.4.1. Tracheary elements

Two basic types of tracheary elements are vessel members and tracheids.

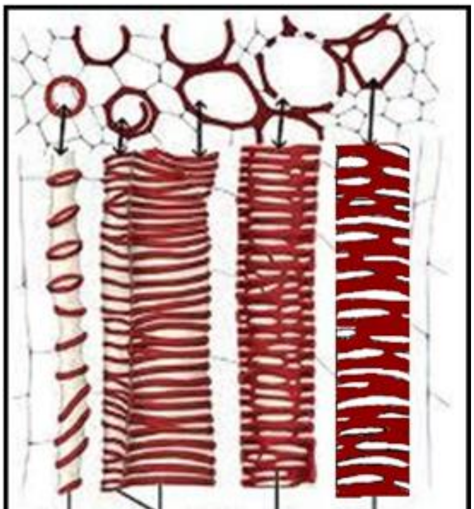
- **Vessel members**
    - Vessel members are the most active water conducting elements in all higher angiosperms.
    - They are found arranged parallel to each other, extending from one end of the plant body to another and are the long cylindrical dead cells.
    - They are characterized by a thick cell wall consisting of a primary wall and a secondary wall. The primary wall is made up of cellulose where as the secondary wall is made up of lignin.
    - There is a spacious lumen that extends throughout the length of the vessels.
    - The vessel members are usually perforated at the end walls, and these end walls are called **perforation plates**.



Simple perforation plate | Scalariform perforation plate | Retculate perforation plate



Types of perforation plates in vessels (Graphical representation)



Pattern of secondary thickening in vessels

- By these perforation plates vessel members become joined to form a tube-like series of cells which is termed as **vessel** or **trachea**.

- **Types of Vessels Members**

Based on the:

- Types of perforation plates
- Pattern of secondary thickening

i. Types of Perforation Plates

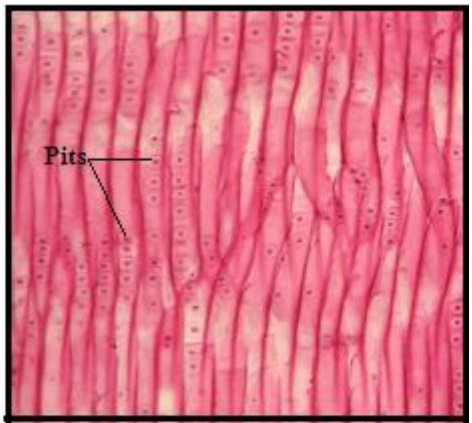
Based on the types of perforations, perforation plates may be of following types:

- **Simple perforation plate:** The perforation plate may contain one large perforation and then it is termed as simple perforation plate.
- **Multi perforation plate:** The perforation plate contains numerous perforations. In this case there are following possible ways in which the perforations can be arranged.
- **Sclariform perforation plate:** When the perforations are elongated and are arranged in a parallel series the plate is termed as sclariform perforation plate.
- **Reticulate perforation plate:** When the perforation plate is in a reticulate manner it is called reticulate perforation plate.

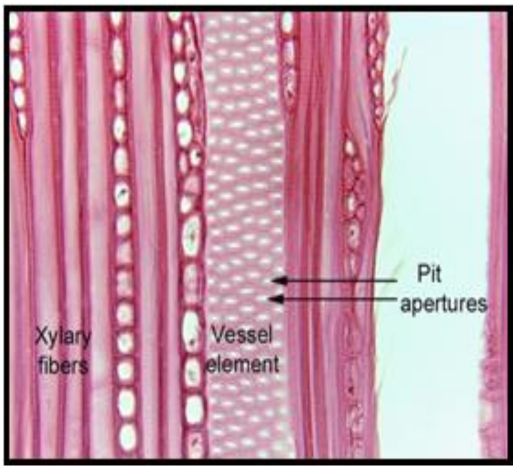
ii. Pattern of secondary thickening

The deposition of lignin in the secondary wall of vessel members is not always uniform. As a result, they exhibit the following different types of secondary thickenings:

- **Annular thickening:** The secondary thickening is in the form of rings placed more or less at equal distance from each other.
- **Spiral thickening:** The secondary thickenings are present in the form of a helix or coil.
-



Tracheids with tapering ends



T.S. of stem showing vessel elements having pit apertures

T.S. of stem showing xylary fibers

- **Sclariform thickening:** The secondary thickenings appear in the form of cross bands resembling the steps of a ladder.

Reticulate thickening: The secondary thickenings are irregular and appear in the form of a network.

❖ Tracheids

They are found abundantly in pteridophytes, gymnosperms and primitive angiosperms. In these groups of plants, the tracheids represent the most active water conducting elements. In advanced angiosperms, the tracheids are found restricted to leaf margin and leaf tip.

The tracheids are elongated, dead cells, with tapering ends. They are characterized by the absence of perforation plates and presence of a thick cell wall consisting of primary wall and a secondary wall. The primary wall is composed of cellulose where as the secondary wall is made up of lignin. There is a spacious lumen that extends throughout the length of the tracheid.

In some cases, due to the deposition of lignin, the primary wall develops numerous concave depressions called **pits**. When pits are present, the tracheid is described as pitted and when pits are absent, it is described as simple. Pitted elements are the characteristics of the late primary and of the secondary xylem.

As in the case of vessels, there is a differentiation between **annular, spiral, sclariform** and **reticulate tracheids** due to uneven thickening of the secondary walls.

❖ Xylem Fibres

The fibres are long dead cells with lignified secondary walls. They have thicker walls than the tracheids. Fibres associated with xylem are known as xylary fibres and they are found in between the vessels and the tracheids. Xylary fibres are of two types, i.e., **libriform fibres** and **fiber tracheids**. Both types of fibres provide mechanical strength to the essential elements.

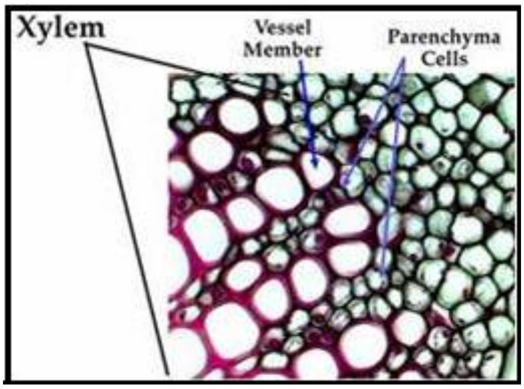
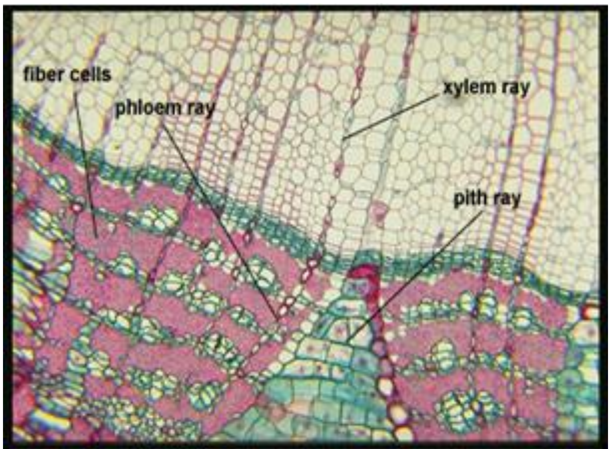
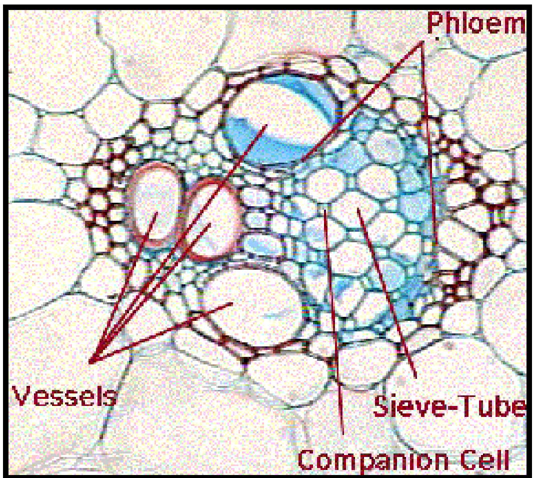


Diagram showing axial parenchyma in xylem



Ray parenchyma



Vascular bundle of a Monocot stem

- **Libriform Fibres**

Libriform fibres resemble phloem fibres and they are usually longer than the tracheids of plant in which they occur. These fibres have extremely thick walls and simple pits.

- **Fiber tracheids**

Fiber tracheids are forms intermediate between tracheids and libriform fibres. Their walls are of medium thickness; not as thick as those of libriform fibres but thicker than those of tracheid. The pits in fiber tracheids are bordered pits.

- **Xylem Parenchyma**

This is the only living component in the xylem tissue. It is represented by axial parenchyma and ray parenchyma.

- **Axial parenchyma** is a part of axial system and is found in between the vessels and the fibers. It is meant for the storage of reserve food.
- **Ray parenchyma** constitutes the horizontal system and meant for the lateral conduction of water.

4.2. Anatomical Note on Phloem

4.2.1. Introduction

Phloem is a complex tissue, in vascular plants that conducts food from the leaves and other photosynthetic tissues to other plant parts.

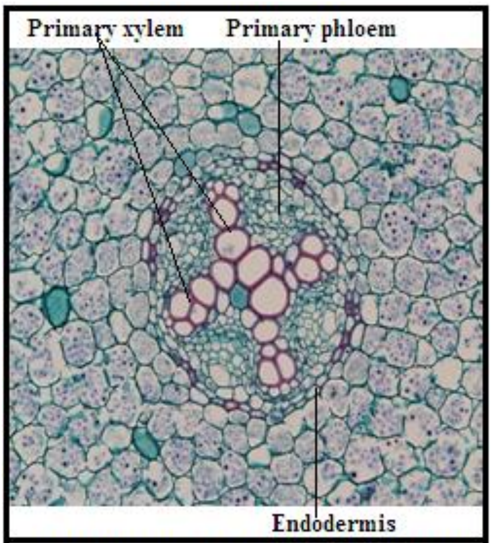
Its name derived from the Greek word *phloios* meaning **bark**.

The phloem is concerned mainly with the transport of soluble organic material made during photosynthesis. This is called **translocation.**

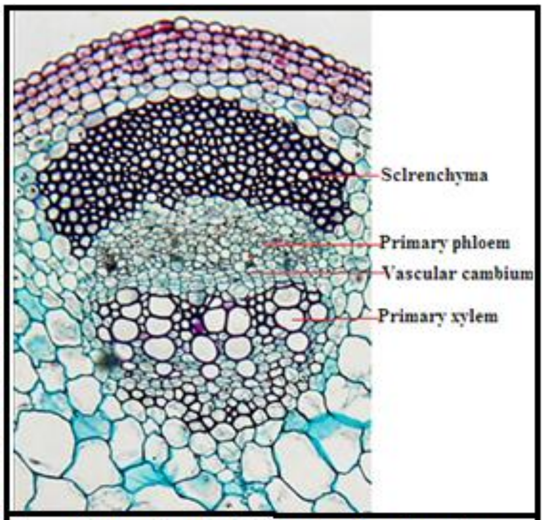
4.2.2. Types of Phloem

4.2.2.1. Primary Phloem

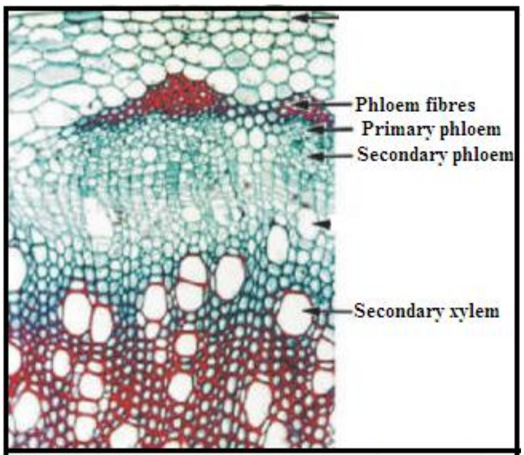
Primary phloem is the phloem that is formed during normal growth in the plant body. It is a derivative of primary meristem i.e., procambium.



T.S of Dicot root showing primary phloem



Vascular bundle of a Dicot stem showing primary phloem



T.S of a Dicot stem showing secondary growth

It is found in both monocots and dicots. The primary phloem is further composed of **protophloem** and **metaphloem**.

The sieve tubes and the companion cells, which appear earlier during normal growth, represent protophloem, while metaphloem is represented by the sieve tubes and companion cells that appear later. However, there is no significant morphological difference between protophloem and metaphloem.

4.2.2.2. Secondary phloem

Secondary phloem is the phloem that is formed during secondary growth. It is a derivative of secondary meristem i.e., vascular cambium.

Secondary phloem is characteristic feature of only dicots. It is also known as **bast**. It is also of commercial importance since it yields **bast fibers**.

Similar to secondary xylem, there are two systems of arrangements in secondary phloem:

- **Axial system:** It produces sieve elements, phloem parenchyma and phloem fibers.
- **Transverse system:** It produces ray parenchyma cells.

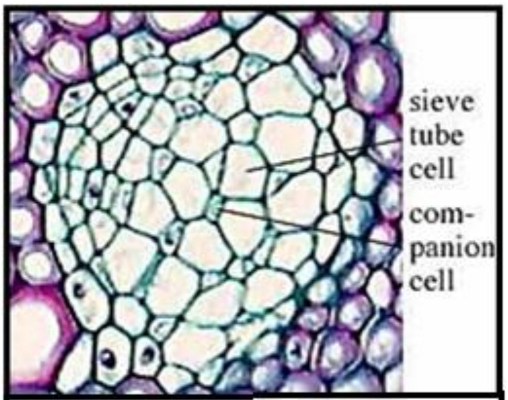
4.2.3. Origin

Phloem is produced in phases. Primary phloem is laid down by the apical meristem and develops from the procambium. Secondary phloem is laid down by the vascular cambium to the inside of the established layer(s) of phloem.

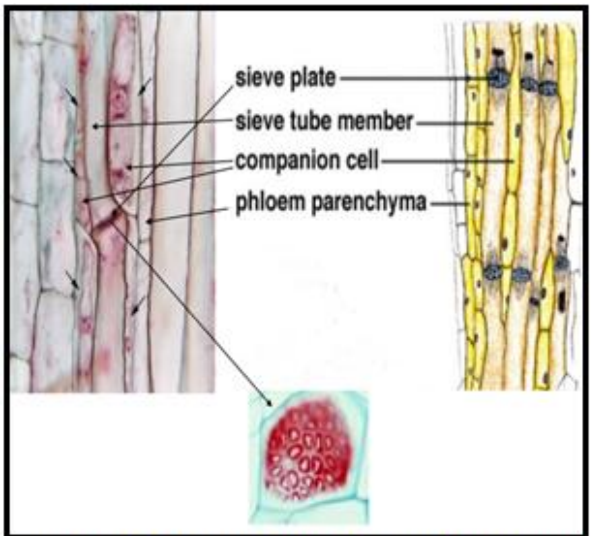
4.2.4. Composition of Phloem

Phloem tissue consists of:

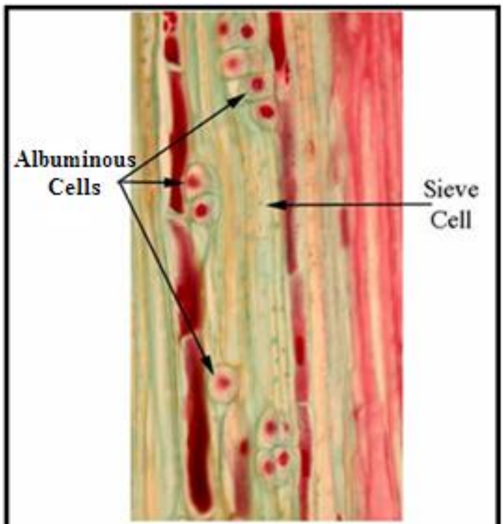
- Conducting cells, generally called **sieve elements**
- Parenchyma cells, including both specialized **companion cells** or **albuminous cells** and unspecialized cells
- Supportive cells, such as **phloem fibres.**



Sieve tubes and companion cells (cross view)



Sieve tubes and Companion cells (Longitudinal view)



L.S of phloem from a Gymnosperm showing sieve cells

- **Sieve elements (Conducting cells)**

The cells of the phloem that conduct sugars and other organic materials throughout the plant are called sieve elements. Two types of sieve elements are recognized:

- Sieve tubes
- Sieve cells

- **Sieve Tubes**

The sieve tubes are found arranged parallel to one another from one end of the plant body to another. Each sieve tube is formed by a series of hollow, cylindrical cells called sieve tube cells arranged one above the other. The sieve cells are separated from each other by horizontal perforated plates called sieve plates. The sieve cells communicate with each other through the **sieve plates**. The sieve-tube cells lack a nucleus, have very few vacuoles, but contain other organelles such as ribosomes.

- **Sieve cells**

Sieve cells are the more primitive of the two main conducting cell types in phloem, and are found in the gymnosperms (conifers, Ginkgo, etc.) and the seedless vascular plants (e.g., ferns, club mosses, horsetails). Sieve cells have relatively narrow, uniformly sized pores in the sieve areas.

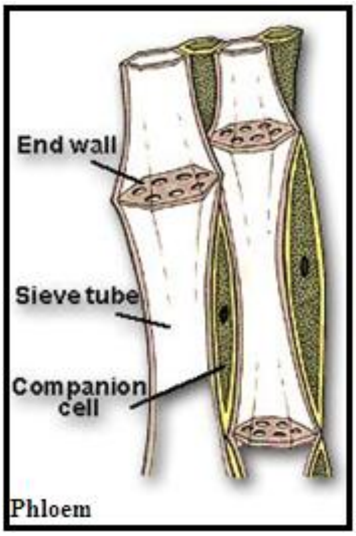
- **Parenchyma cells**

Phloem Parenchyma is living and has thin cell walls. Parenchyma cells within the phloem may b specialized or unspecialized.

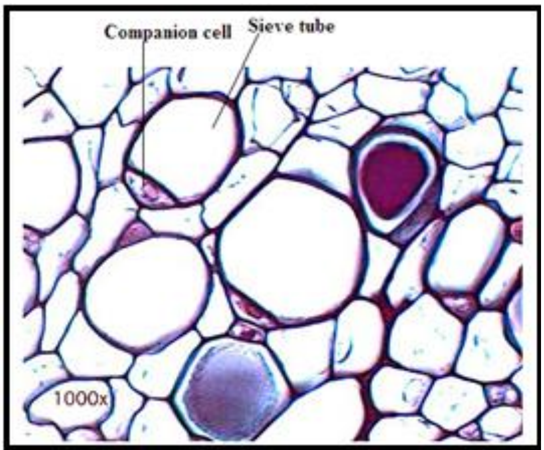
- **Specialized parenchyma cells**

    - **Companion cells**

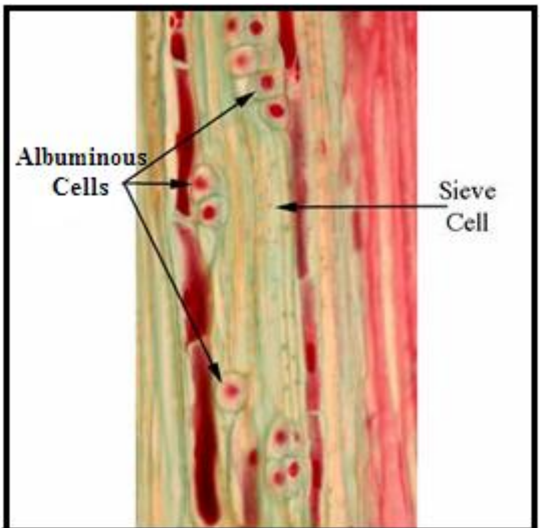
Companion Cells are specialized parenchyma cells which always appear with the sieve tube element. They are more or less spindle shaped, thin-walled and there is a distinct nucleus in the cytoplasm of the companion cell. Companion cells are linked with the sieve tubes by small canals filled with cytoplasm, which are smaller than pits.



Labeled diagram of LS of phloem



Phloem From an Angiospermic plant showing Companion cells in association with Sieve tubes



L.S of phloem from a gymnosperm showing albuminous cells in association with sieve cells

The metabolic functioning of sieve-tube members depends on a close association with the companion cells, a specialized form of parenchyma cell.

All of the cellular functions of a sieve-tube element are carried out by the (much smaller) companion cell; a typical nucleate plant cell except the companion cell usually has a larger number of ribosomes and mitochondria. The cytoplasm of a companion cell is connected to the sieve-tube element by plasmodesmata.

There are three types of companion cells:

- **Ordinary companion cells**

They have smooth walls and few or no plasmodesmata connections to cells other than the sieve tube.

- **Transfer cells**

They have much-folded walls that are adjacent to non-sieve cells, allowing for larger areas of transfer. They are specialized in scavenging solutes from those in the cell walls that are actively pumped requiring energy.

- **Intermediary cells**

They have smooth walls and numerous plasmodesmata connecting them to other cells.

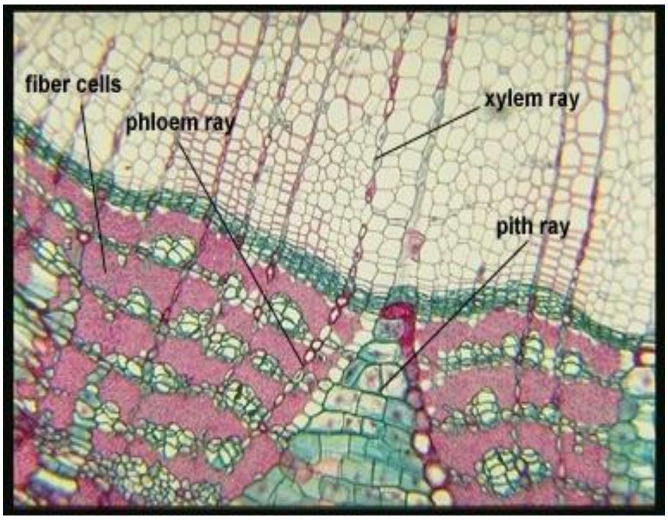
The first two types of cell collect solutes through apoplastic (cell wall) transfers, while the third type can collect solutes via the symplast through the plasmodesmata connections.

- **Albuminous cells**

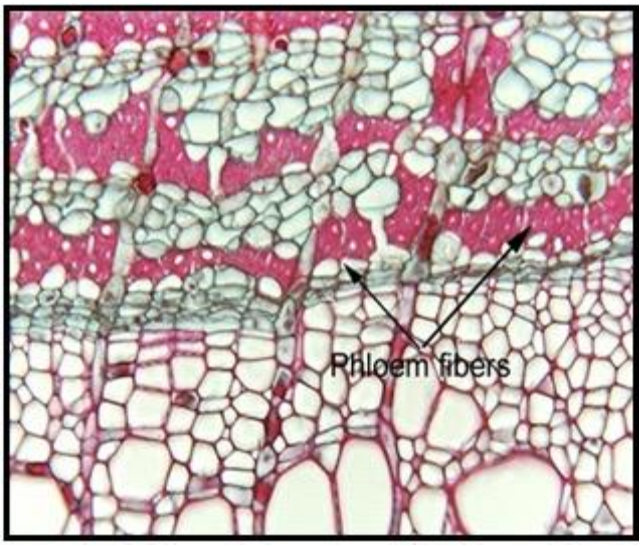
Albuminous cells have a similar role to companion cells, but are associated with sieve cells only and are therefore found only in seedless vascular plants and gymnosperms.

- **Unspecialized parenchyma cells**

Other parenchyma cells within the phloem are generally unspecialized and are found in two forms, i.e., axial parenchyma and ray parenchyma.



Labeled diagram of TS of Phloem showing its elements

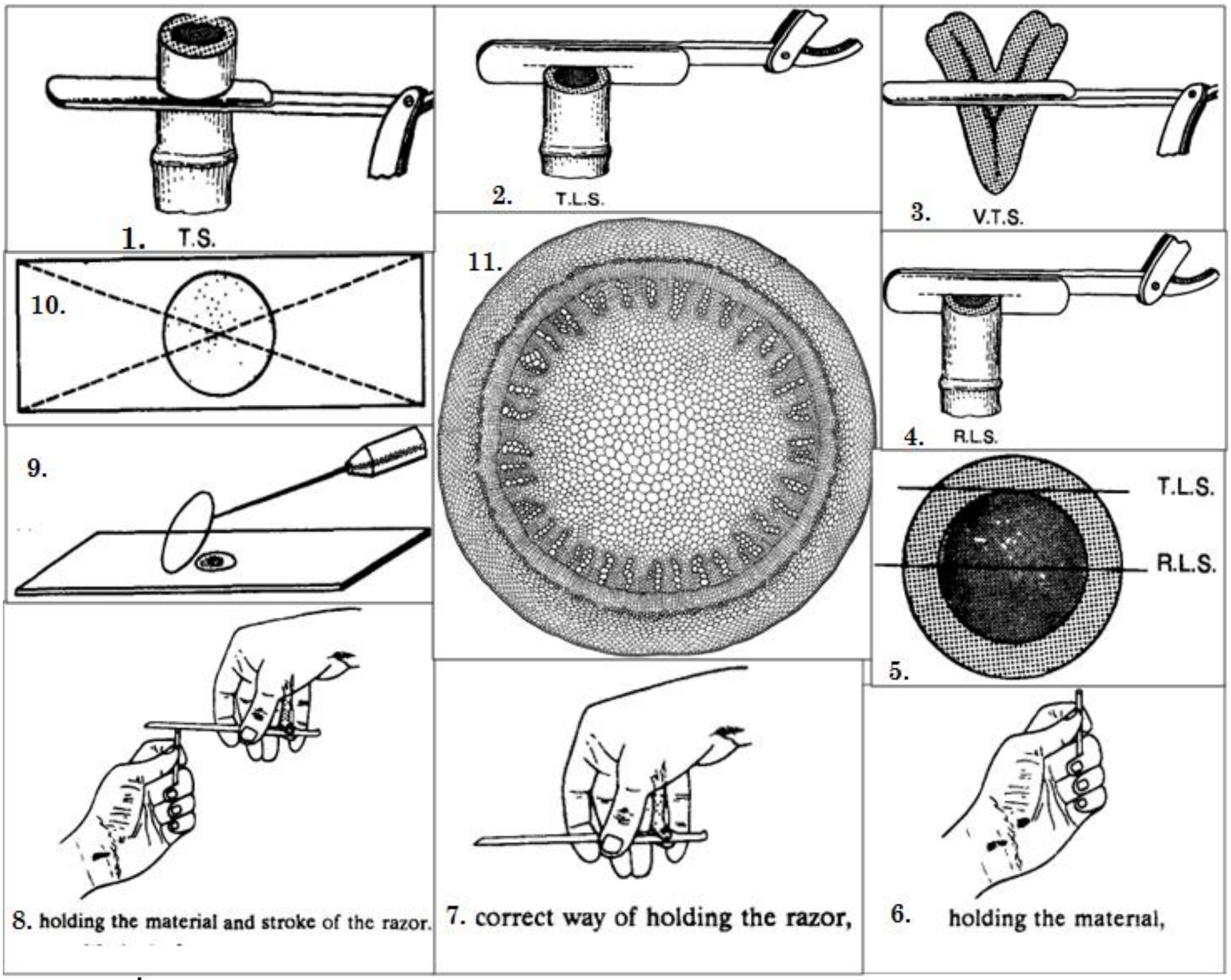


Labeled diagram of TS of phloem showing phloem fibers

Axial parenchyma is found in-between the sieve tubes and meant only for storage of organic food. Whereas, **ray parenchyma** is meant for lateral transport of food and it forms the horizontal rays.

- **Phloem Fibres**

Phloem fibres are represented by the dead sclerenchyma fibres that are found in between the sieve tubes. They are meant only for providing mechanical support.



Methods and planes of section cutting

5. Section Cutting

For the purpose of anatomical study, sections are to be cut of plant parts. In higher plants cylindrical parts like root, stem, leaf etc., may be cut for the study of internal structure.

5.1.Planes of Cutting

In order to study the internal structure from various angles, sections are cut in various planes.

5.1.1. Transverse Section (T.S)

The section is cut parallel to the long axis (right angle to the transverse axis). It is also called cross section.

5.1.2. Longitudinal Section (L.S)

The longitudinal section may be cut along the radius i.e. at 180° degree of main axis (Radial longitudinal section-RLS) or along the tangent (Tangential longitudinal section-TLS)

Cylindrical organs like roots and stems are cut transversely or longitudinally, while dorsiventral organs like thalli of bryophytes, leaves etc. are usually cut in vertical transverse plane.

5.2.Types of Section Cutting

There are usually two types of section cutting methods employed for plant parts. These are

- Free hand sectioning
- Microtome sectioning

Labeled diagram of a microtome

5.2.1. Free Hand Sectioning

For the purpose of laboratory study where slides are not made permanent, usually free hand sectioning is employed. Free hand sections are cut mostly with the help of a good sharp razor.

5.2.1.1. Method of Cutting

- Open out the razor and bend the handle backwards. Hold the razor in between the index finger and thumb. The handle should be free. The remaining fingers of the hand will be touching the back edge of the razor blade.

- In order to cut the transverse section of cylindrical part like stem or root, follow the procedure given below.

  - The stem or root should be trimmed into a 2-3" long piece.

  - It should be entering into a piece of carrot or potato which should be cut into cubes. It should be held into hand in an erect position between the thumb and index finger.

  - The material should be exactly at right angle to razor's edge. Flood the edge of the razor with water.

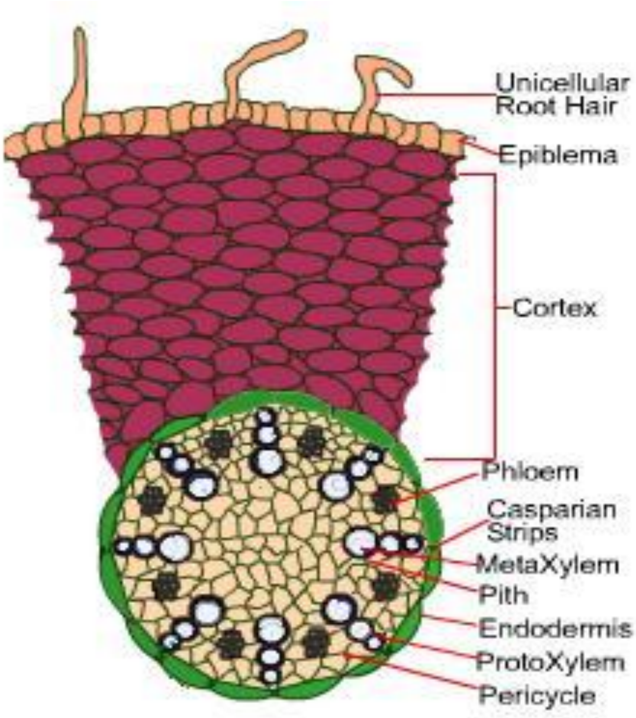
  - Now using the index finger as the platform move the razor quickly several strokes across the material.

  - During this process sections are cut and they will be collected on the blade of the razor. The sections now may be carefully transferred with the help of a fine brush on to a petri dish containing water.

- For cutting section of delicate and fragile materials like leaves are suitable supporting medium has to be used.

  - For this purpose a carrot or potato may be used.

  - These are to be cut into rectangular cubes and split in the centre.



Labeled diagram of cross section of a Monocot Root

- The material for sectioning should be inserted in the split and sections are cut.
- After section cutting the razor should be wiped dry. It should be greased and encased.

5.2.2. Microtome Sectioning

This is generally employed very frequently in the study of bryophytes, pteridophytes and other higher plants. The microtome sectioning is a long and complicated process. It takes anywhere between 15-20 days to process a material and to obtain a section.

Microtome sectioning involves the following steps:

- Killing and preserving a material
- Dehydration and infiltration
- Paraffin embedding
- Section cutting

5.2.2.1. Paraffin

- In order to cut a material, it has to be embedded into a paraffin block.
- Prepare a paper boat or take a porcelain rectangular dish and smear glycerin to the inner surface.
- Pour molten paraffin into the porcelain dish and empty the contents of the vial into a dish.
- Carefully remove the solidified paraffin block from the dish and cut it into suitable pieces.

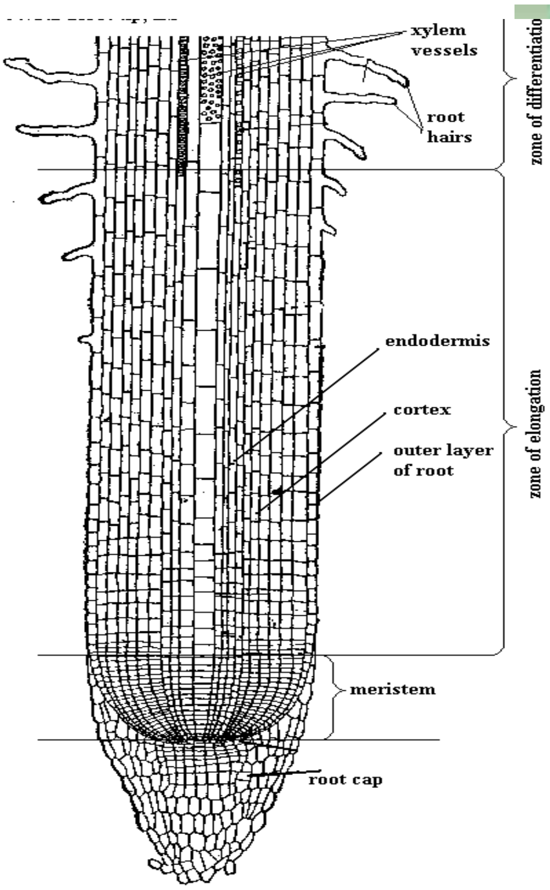
5.3. Section Cutting of Monocot Root

5.3.1. Apparatus

Sharp blade, needle, watch glass, potato tuber, slide, cover slip, microscope

5.3.2. Material Required

Fresh roots of a monocot plant e.g. Maize etc.



Labeled diagram of L.S. of a monocot root

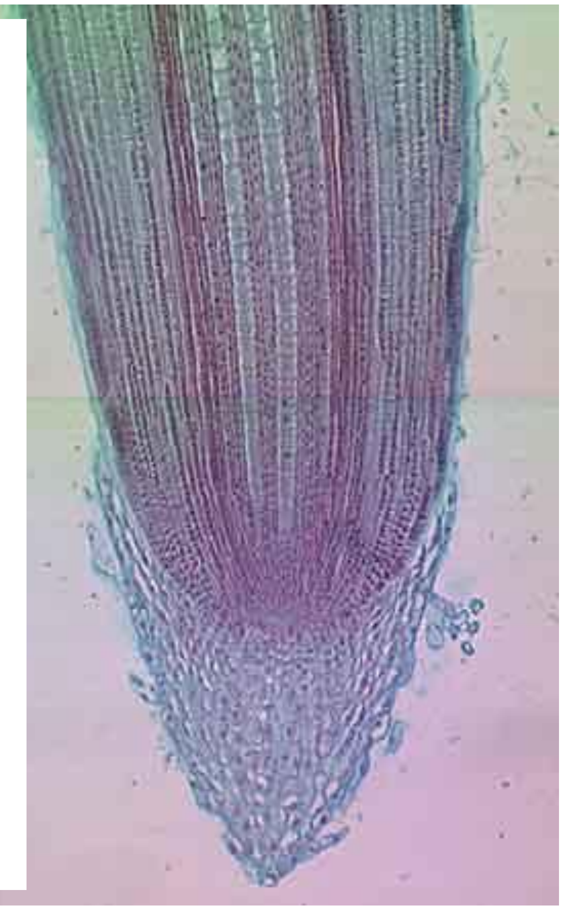


Diagram showing L.S. of a monocot root under microscope

5.3.3. Procedure

- Take a small soft portion of root from a monocot plant.
- Make a hole in the cylindrical potato tuber with the help of needle.
- Place the portion of root in the hole and cut thin slices of potato tuber with the help of a sharp blade.
- Dip the thin slices in water present in watch glass.
- Take the thinnest section of root and place it on the slide.
- Cover it with the cover slip and observe it under the microscope.

5.3.4. Characteristics of a Good Section

- A section should be thin.
- It should not be oblique.
- It should be dipped in water to prevent desiccation.

5.3.5. Anatomical Note

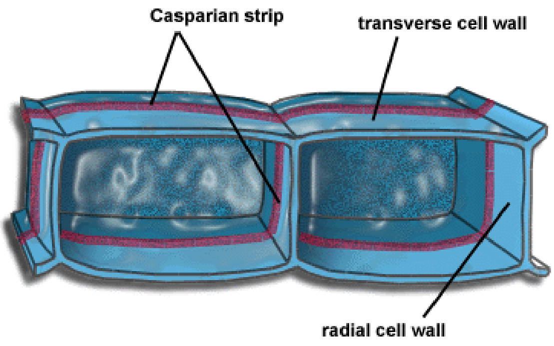
A transverse section passing through the Maize root reveals the following details:

5.3.5.1. Epiblema

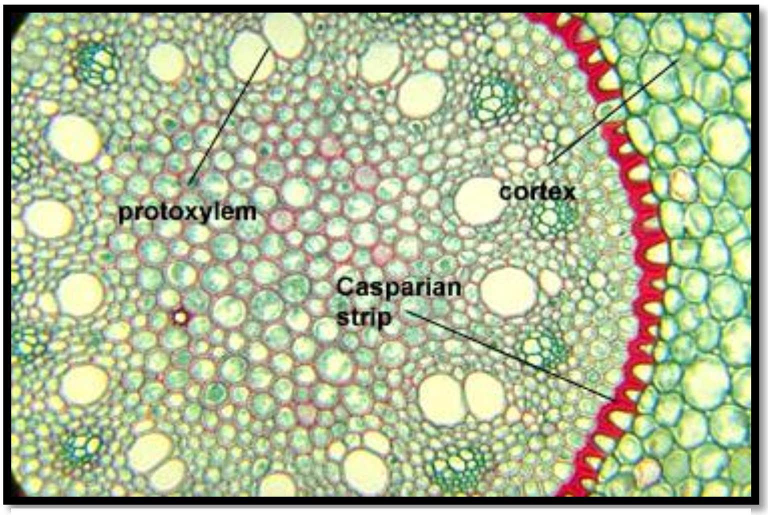
- Epiblema is the outermost covering of the root formed by a single layer of compactly arranged barrel-shaped parenchyma cells.
- The cells are thin-walled and are involved in absorption of water.
- A cuticle and stomata are absent.
- Some epiblema cells are produced into long unicellular projection called **root hairs**; hence epiblema is also known as **piliferous layer**.

5.3.5.2. Cortex

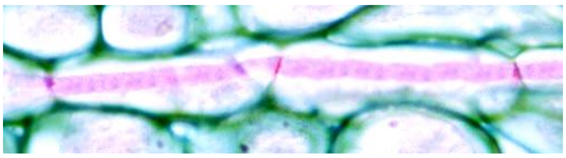
- Cortex is a major component of ground tissue of root.
- It is represented by several layers of loosely arranged parenchyma cells.
- Intercellular spaces are prominent.



Labeled diagram of L.S. of a portion of a root endodermis showing casparian strips



Endodermis showing casparian strips



T.S. of a portion of a root endodermis showing casparian strip

- The cortex is mainly meant for storage of water.
- The cells also allow a free movement of water into the xylem vessels.

5.3.5.3. Endodermis

- It is the innermost layer of cortex formed by compactly arranged barrel-shaped cells.
- Some of the cells in endodermis are thin-walled and are known as **passage cells**. These cells allow water to pass into the xylem vessels.
- Remaining cells are characterized by presence of thickening on radial walls known as **casparian thickenings**. They are formed by deposition of a waxy substance called **suberin**.
- The casparian thickenings play an important role in creating and maintaining a physical force called **root pressure**.

5.3.5.3.1. Casparian Strips

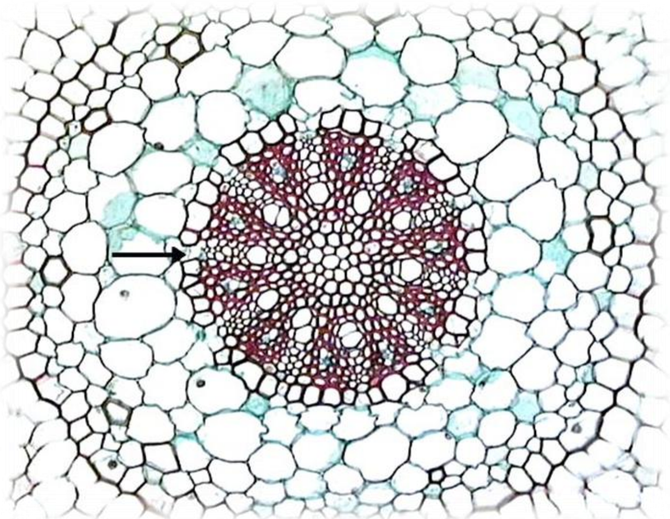
The **radial walls** of endodermis, i.e., all the walls touching other endodermis cells, except those facing toward the axis and the surface of the root or stem; are **encrusted** with **lignin** and **suberin**, both of which cause the wall to be **waterproof**.

The bands of **altered** wall, called **Casparian strips**, are involved in controlling the types of minerals that enter the xylem water stream.

- **Formation**

The strip forms during the early ontogeny of the cell and is a part of the primary wall. It varies in width and is often much narrower than the wall in which it occurs.

The Casparian strip is initiated as a localized deposition of phenolic and unsaturated fatty substances in the middle lamella between the radial walls, as partly oxidized films. The primary wall becomes encrusted with and later thickened by deposits of similar substances on the inside of the wall. In monocots they are present in U shaped and in dicots, they occur in the form of linear strips.



T.S. of a monocot root; arrow shows the presence of passage cells

- **Importance of Casparian strips**

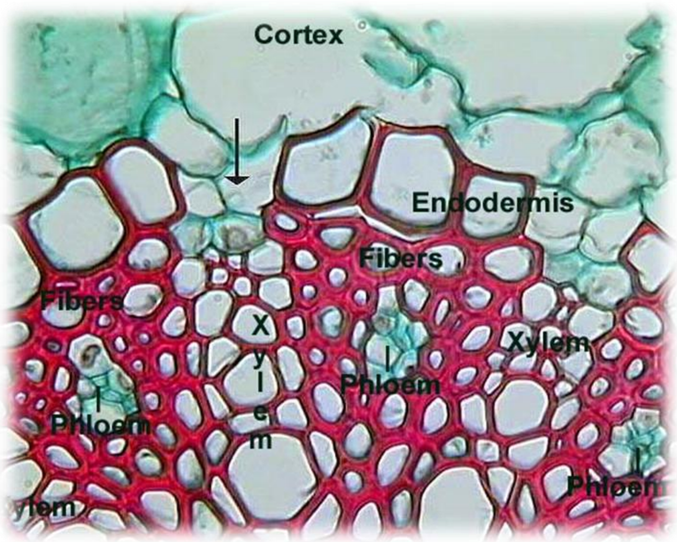
- Cortex cells exert no control over the movement of minerals within the intercellular spaces; without an endodermis, minerals of any type could move from the soil into the spaces, then into the xylem, and then into all parts of the plant.
- However, because Casparian strips are impermeable, minerals can cross the endodermis only if the endodermal protoplasts absorb them from the intercellular spaces of the cortex apoplast or from cortical cells and then secrete them into the vascular tissues.
- They block the movement of water in the apoplast and it is redirected towards the symplast. It also blocks the radial apoplastic flow of water from inside to outside.
- Casparian strips prevent the pressurized xylem water escaping through the apoplast of the root into the soil. They prevent diffusion between cortex and central cylinder.
- Many harmful minerals can be excluded by the endodermis. It is not a perfect barrier against uncontrolled apoplastic movement, because in the zone of elongation, where the endodermis is not yet mature, minerals do have free access to the protoxylem, but this seems to represent only a low level of uncontrolled movement.
- There are many glands and secretory products from seeping into the surrounding tissues.

5.3.5.3.2. Passage Cells

These are endodermal cells of older roots which have retained thin walls and Casparian strips rather than becoming thickened and waterproof like the other cells around them, to continue to allow some symplastic flow to the inside.

- **Evidences about passage cells**

Experimental evidence suggests that passage cells function to allow transfer of solutes such as calcium and magnesium into the stele; in order to eventually reach the transpiration system.



Labeled diagram of T.S. portion of a monocot root

For the most part, however, old roots seal themselves off at the endodermis, and only serve as a passageway for water and minerals taken up by younger roots "downstream".

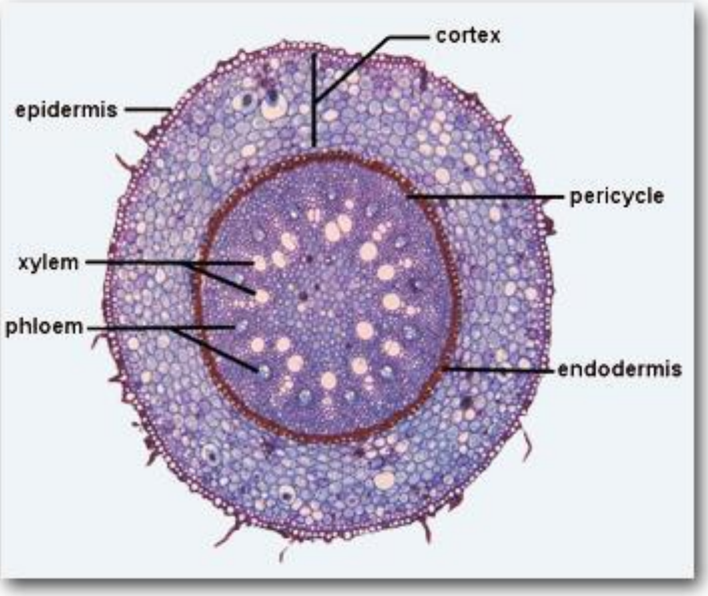
- **Occurrence**

Passage cells frequently occur in the endodermis and exodermis but are not ubiquitous in either layer. They mainly occur opposite to the primary xylem.

Passage cells occur in the form of short cells in the dimorphic type of exodermis. In both layers, Casparian bands are formed in all cells, but the subsequent development of suberin lamellae and thick, cellulosic walls are delayed or absent in the passage cells.

- **Function**

➢ Available evidence suggests that passage cells of the endodermis are important for the transfer of calcium and magnesium into the stele and thus into the transpiration stream.
➢ They become the only cells which present a plasma lemma surface to the soil solution (and are thus capable of ion uptake) when the epidermis and central cortex die.
➢ This occurs naturally in some herbaceous and woody species and is known to be promoted by drought.
➢ Most evidence indicates that the development of suberin lamellae in both the endodermis and exodermis increases the resistance of the root to the radial flow of water. Passage cells thus provide areas of low resistance for the movement of water, and the position of these cells in the endodermis (i.e., in close proximity to the xylem) is explained in terms of function.
➢ It is clear that passage cells of the endodermis and exodermis play a variety of roles in the plant root system.



Labeled diagram of T.S of a monocot root

5.3.5.4. Stele

- It is the central cylindrical of root consisting of pericycle, conjunctive tissue, pith and vascular bundles.
- It is an **actinostele** stele (protostele).

5.3.5.4.1. Pericycle

It is the outermost covering of stele represented by a single layer of parenchyma cells.

5.3.5.4.2. Conjunctive tissue

It is represented by loosely arranged parenchyma cells found in between the vascular bundles. The cells are specialized for storage of water.

5.3.5.4.3. Pith

It is the innermost region of root representing the central axis. It is composed of few loosely arranged parenchyma cells.

5.3.5.4.4. Vascular bundle

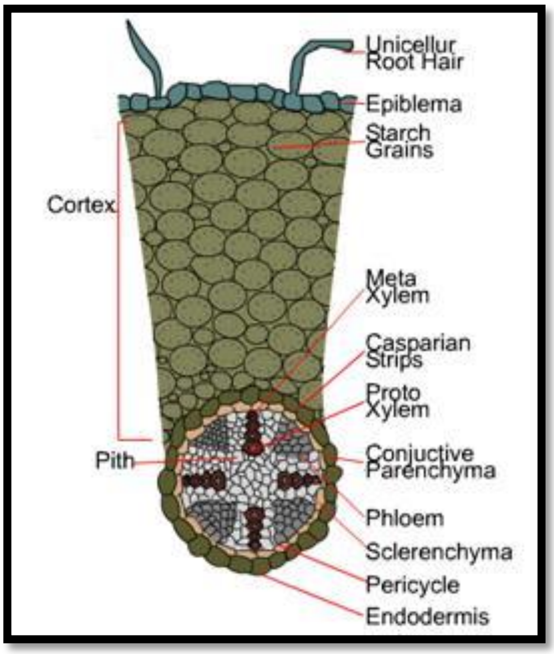
It is **radial** in arrangement consisting of xylem and phloem and is **polyarch.**

- **Xylem**

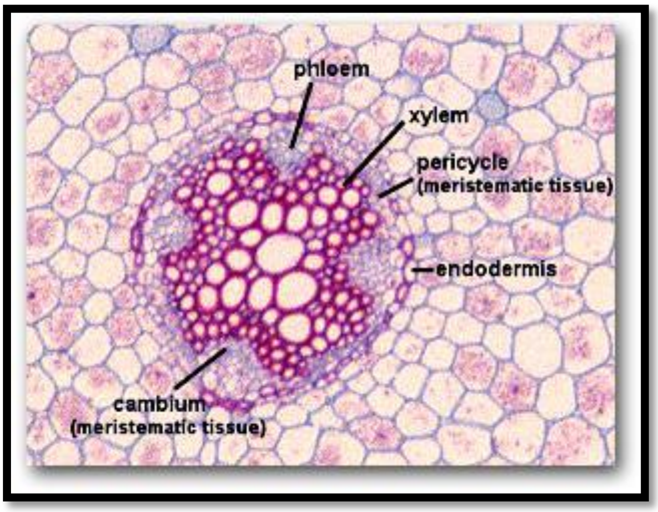
Xylem shows **exarch** arrangement and is composed of a single metaxylem vessels present towards pith and one or two thick-walled protoxylem vessels present towards periphery.

- **Phloem**

It is found in the form of small patches alternating with xylem and is composed of sieve tubes, companion cells and phloem parenchyma.



T.S of a Dicot Root



Cross section of a Dicot Root

5.3.6. Diagnostic features of a monocot root

- Presence of thin-walled cells in epiblema and parenchymatous cells in pericycle.
- Absence of cuticle and stomata and presence of conjunctive tissue.
- Presence of unicellular root hairs and actinostele with distinct pith.
- Presence of passage cells and casparian thickenings in endodermis.
- Presence of radial vascular bundle with polyarch condition and an exarch xylem.

5.4. Section Cutting of Dicot Root

5.4.1. Apparatus

Sharp blade, needle, watch glass, potato tuber, slide, cover slip, microscope

5.4.2. Material Required

Fresh roots of a dicot plant e.g. *Solanum nigra* etc.

5.4.3. Procedure

- Take a small soft portion of root from a dicot plant.
- Make a hole in the cylindrical potato tuber with the help of needle.
- Place the portion of root in the hole and cut thin slices of potato tuber with the help of a sharp blade.
- Dip the thin slices in water present in watch glass.
- Take the thinnest section of root and place it on the slide.
- Cover it with the cover slip and observe it under the microscope.

5.4.4. Characteristics of a Good Section

- A section should be thin.
- It should not be oblique.
- It should be dipped in water to prevent desiccation.

5.4.5. Anatomical Note

A transverse section cutting observed primary structure of a dicot root is following:

5.4.5.1. Epiblema

- The outermost layer made up o single layer of parenchymatous cells without intercellular spaces. Stomata and cuticle are absent.
- Root hairs are always single celled.

5.4.5.2. Cortex

1. Cortex consists of oval or rounded loosely arranged parenchymatous cells.
2. These cells may store food reserves.

5.4.5.3. Endodermis

- It is made up of single layer of barrel shaped parenchymatous cells.
- The radial and the inner tangential walls of endodermal cells are thickened with suberin. These thickenings are known as casparian strips.
- But these casparian strips are absent in the endodermal cells (Passage cells) which are located opposite to the protoxylem elements.

5.4.5.4. Stele

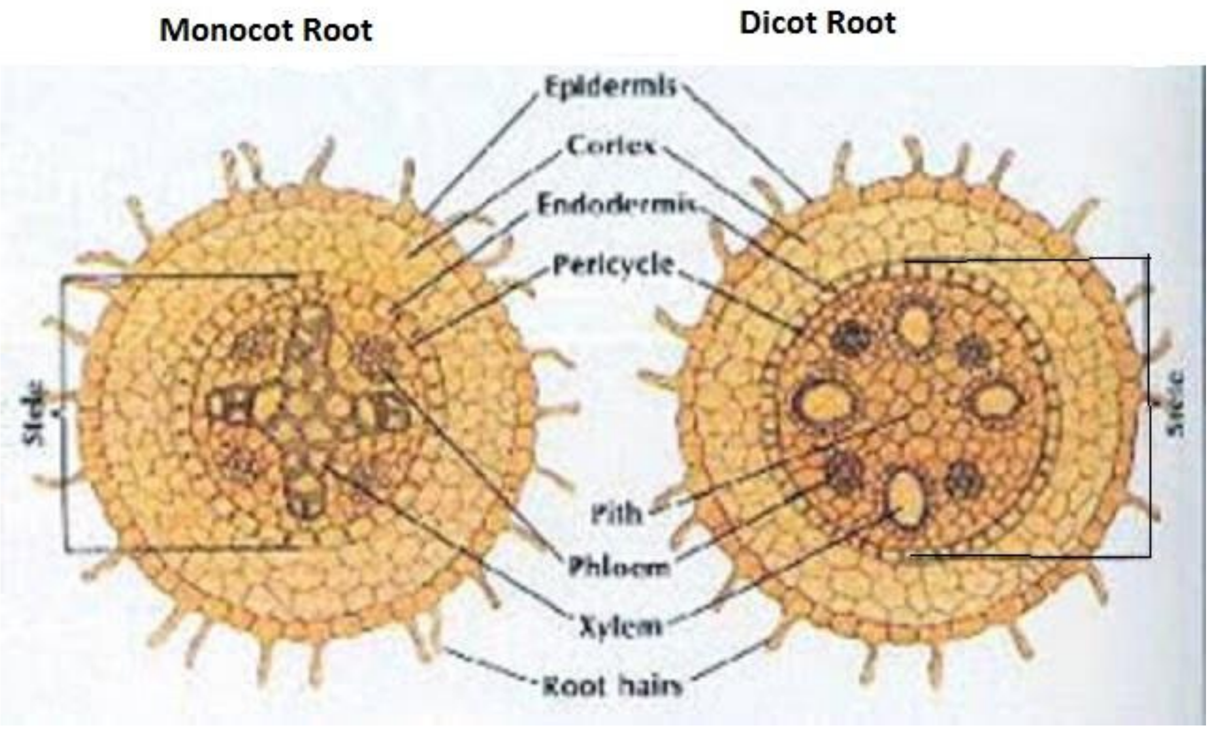
All the tissues present inside endodermis comprise the stele.

5.4.5.4.1. Pericycle

- Pericycle is generally a single layer of parenchymatous cells found inner to the endodermis. Lateral roots originate from the pericycle.

5.4.5.4.2. Vascular system

- Vascular tissues are in radial arrangement.
- The tissue by which xylem and phloem are separated is called conjunctive tissue.



Diagrammatic representation of Dicot root and Monocot root

- Xylem shows exarch and tetrarch condition.
- Metaxylem vessels are generally polygonal in shape.
- **Pith** is mostly absent.

5.4.6. Diagnostic features of a dicot root

- Presence of thin walled cells in the epiblema.
- Absence of cuticle and stomata.
- Presence of unicellular root hairs.
- Presence of passage cells and casparian thickenings in the endodermis.
- Presence of parenchyma cells in the pericycle.
- Presence of conjunctive tissue.
- Presence of distinct pith.
- Presence of radial vascular bundles with polyarch condition and an exarch xylem.

5.4.7. Comparison of Dicot and Monocot Root

Dicot Root	Monocot Root
• Epidermis is a single layered and cortex homogenous and parenchymatous nature. • Epidermis is a single layered, distinct and well developed. • Pericycle is usually single layered. • The number of phloem and xylem bundles is 2-6, rarely 8. • Xylem vessels appear circular in outline and metaxylem usually meets in center due to which pith is rather absent or highly reduced. • Secondary growth is found.	• Epidermis and cortex are similar to dicots. • Same as in dicot roots. • Pericycle is usually 2-3 layered. • The number of phloem and xylem bundles is usually more than 8. • These are usually polygonal in outline. • Pith remains distinct, well developed and large. • Secondary growth is not found.

5.5.Section Cutting of Monocot and Dicot Stem

5.5.1. Preparation of Slide

5.5.1.1. Apparatus and Material

Potato tuber, watch glass, microscope, glass slide, cover slip, blade, plant stem or leaf

5.5.1.2. Procedure

- First of all, potato was cut in a cylindrical shape for stem and in a square or rectangular shape for leaf cutting and was put in the water for a while.
- Potato slice was then cut from its centre into two equal halves.
- Then, the stem or leaf was taken in the potato tuber slice in such a way that it was tightly packed in it.
- Then, with the help of blade, fine sections of stem or leaf were cut and placed in water.
- After putting a drop of water on the slide, the finest section was placed on the glass slide and covered carefully with the cover slip.
- Section was then stained and mounted.
- Then, it was ready for observing under the microscope.

5.5.1.3. Anatomy of a Monocot stem

5.5.1.3.1. Epidermis

Epidermis is the outermost covering of the stem represented by a single layer of compactly arranged, barrel-shaped parenchyma cells. Intercellular spaces are absent. Trichomes are absent. Cuticle is present. The epidermis contains numerous minute openings called stomata.

5.5.1.3.2. Hypodermis

Hypodermis is a region that lies immediately below the epidermis. It is represented by a few layers of compactly arranged sclerenchyma cells.

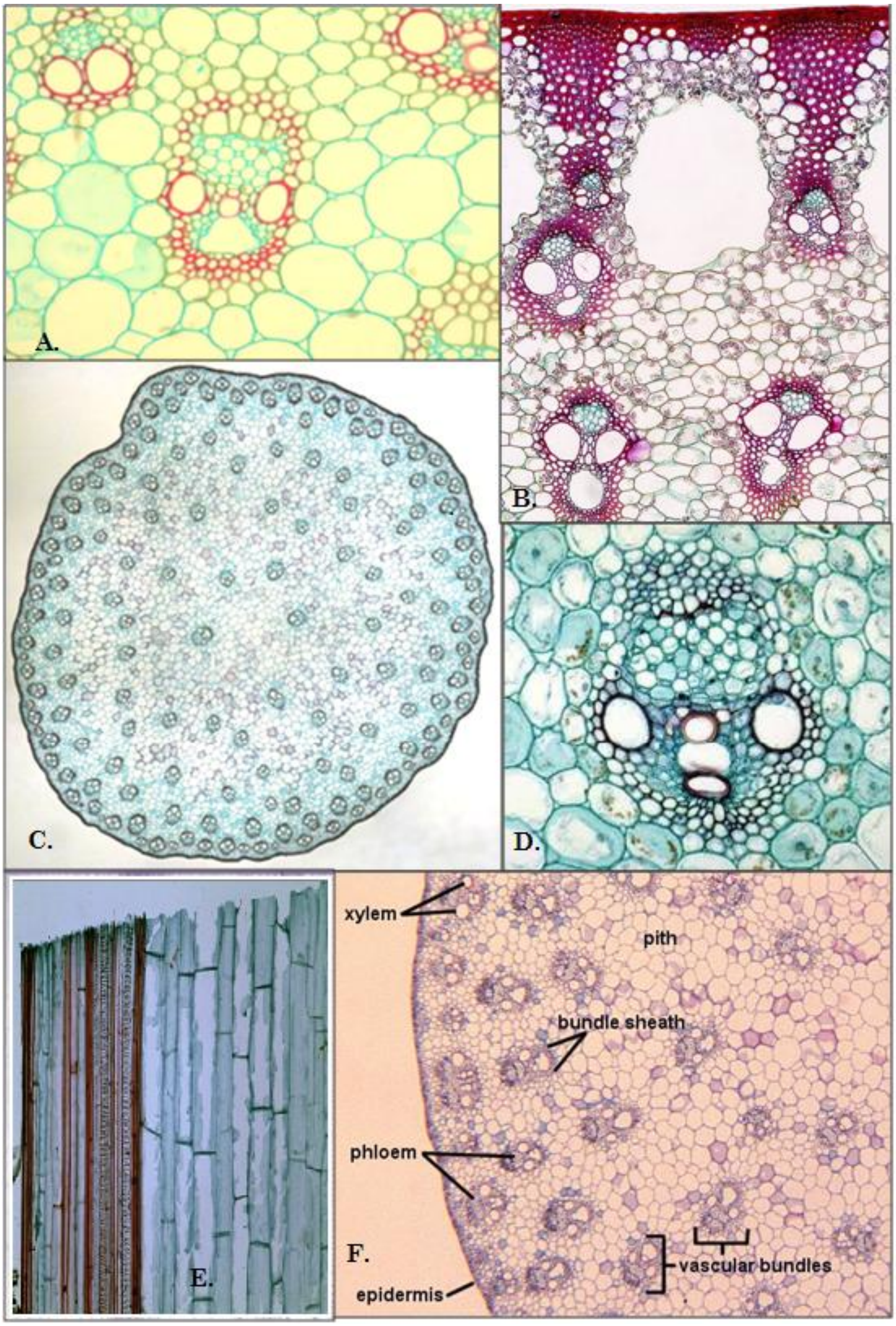


Figure A, B and D: T.S. of Monocot Stems showing **Y** shaped arrangement of Vascular bundles. **Figure C:** T.S. of Monocot Stem. **Figure E:** L.S. of Monocot Stem (*Zea mays*) **Figure F:** Labeled diagram of T.S. of Monocot Stem

5.5.1.3.3. Ground Tissue

Ground tissue is a major component of the stem. It is undifferentiated. The ground tissue is represented by several layers of loosely arranged parenchyma cells enclosing prominent intercellular spaces. The ground tissue is meant for storage of food.

- **Vascular Bundle**

They are found irregularly scattered in the ground tissue. Each vascular bundle has a covering called **bundle sheath** formed by a single layer of sclerenchyma cells. Cambium is absent. Hence the vascular bundles are described **as conjoint, collateral** and **closed**. The vascular bundle encloses both xylem and phloem.

- **Xylem**

Xylem is found towards the inner surface and phloem towards the outer surface. In the xylem, there are two **metaxylem** and two **protoxylem** vessels arranged in 'the shape of 'Y'. The lower protoxylem vessel is nonfunctional and remains as water filled cavity called **protoxylem cavity**. Xylem is described as endarch.

- **Phloem**

In the phloem, sieve tubes, companion cells and phloem fibres are present. Phloem parenchyma is absent.

5.5.1.4. Anatomy of a Dicot Stem

5.5.1.4.1. Epidermis

Epidermis is represented by a single layer of compactly arranged, barrel-shaped parenchyma cells. Intercellular spaces are absent. The cells are slightly thick walled. Epidermis shows the presence of numerous multicellular projections called trichomes. Cuticle is present. The epidermis also contains numerous minute opening called stomata.

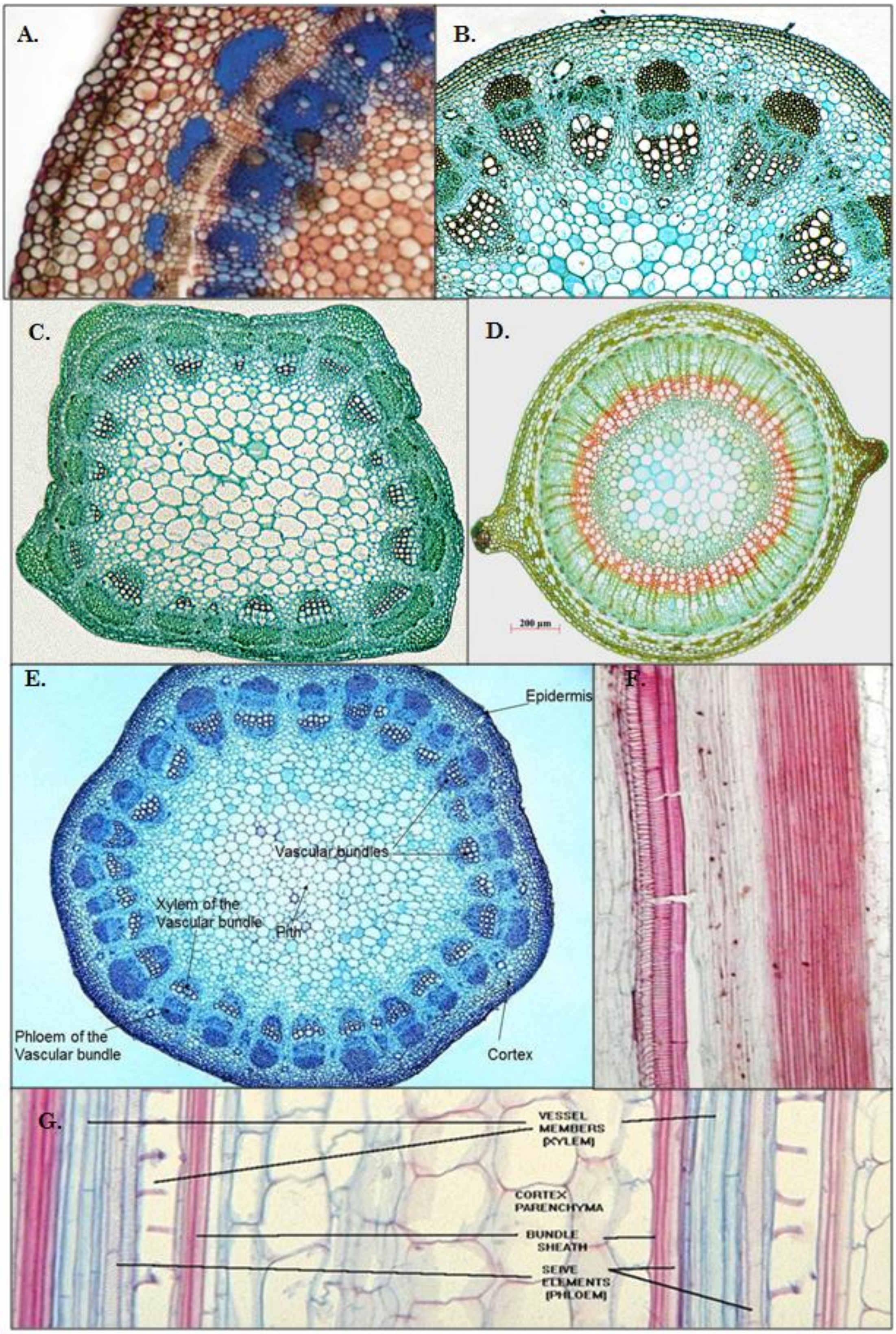


Figure A and B: T.S. of Stem of *Pereskia guamacho* and *Helianthus annu*, showing arrangement of vascular bundles, respectively. **Figure C and D:** T.S. of Stem of *Helianthus annus* and *Hypericum perforatum*, respectively. **Figure E:** Labeled diagram of T.S. of dicot stem. **Figure F:** L.S. of a dicot stem **and Figure G:** Labeled diagram of L.S. od a dicot stem.

5.5.1.4.2. Hypodermis

Hypodermis is a region lying immediately below the epidermis. It is represented by a few layers of collenchyma cells with angular thickenings. The cells are compactly arranged without any intercellular spaces. Hypodermis provides mechanical support and additional protection.

5.5.1.4.3. Cortex

Cortex is the major part of the stem represented by several layers of loosely arranged parenchyma cells. Intercellular spaces are prominent. Cortex is the major storage organ in the stem.

5.5.1.4.4. Endodermis

Endodermis is the innermost layer of cortex represented by compactly arranged barrel shaped cells, without any intercellular spaces. The endodermis is wavy in appearance. The cells are richly deposited with starch grains and hence, endodermis is commonly described as starch sheath.

5.5.1.4.5. Stele

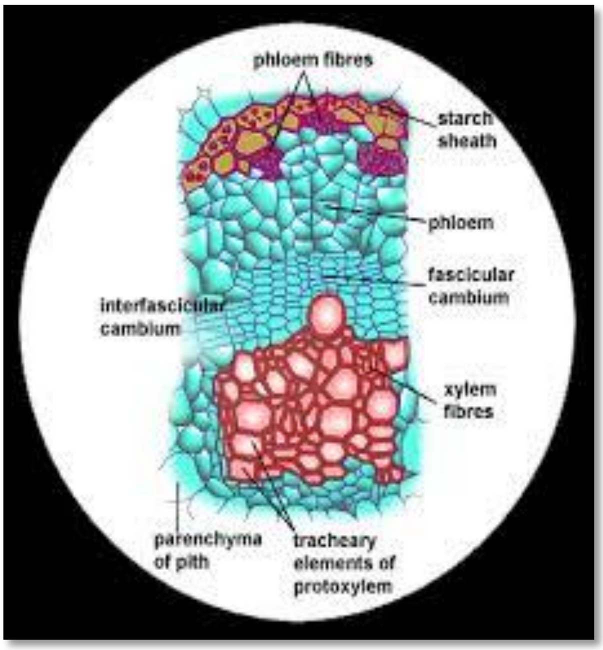
Stele is the central cylinder of the stem, consisting of pericycle, medullary rays, pith and vascular bundles.

5.5.1.4.5.1. Pericycle

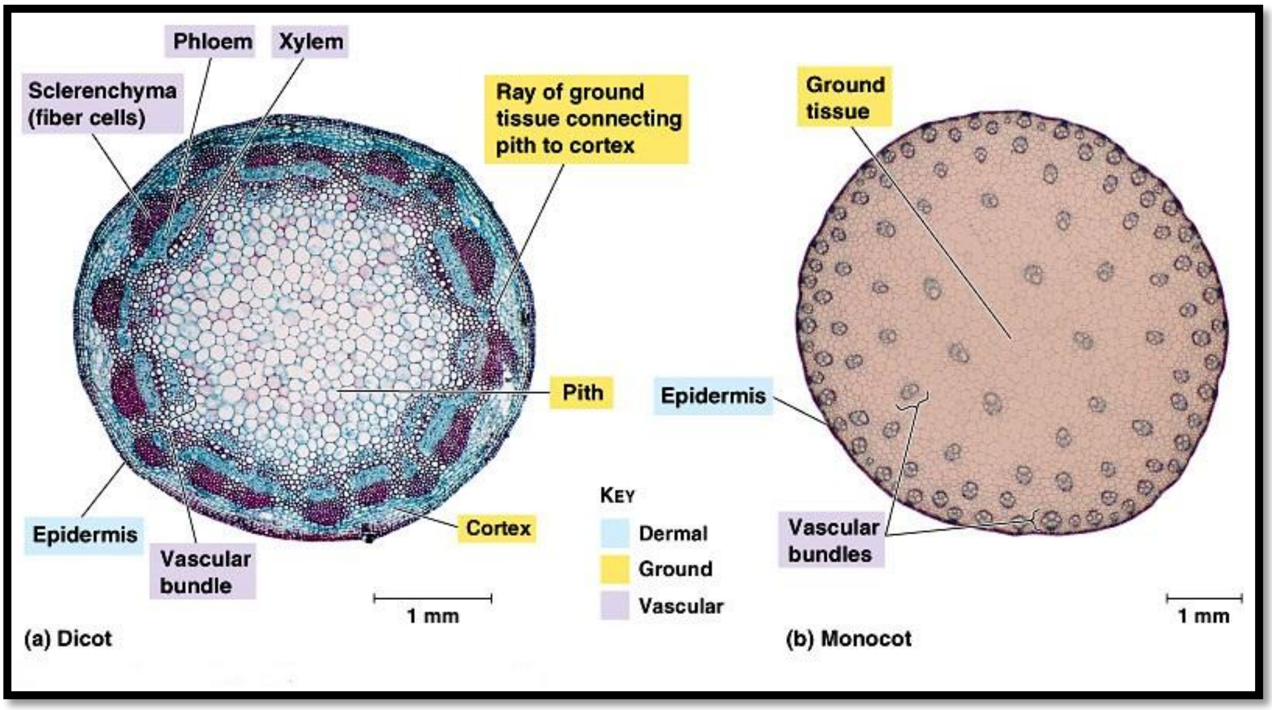
Pericycle is the outermost covering of the stele, which lies immediately below the endodermis. It is represented by a few layers of compactly arranged sclerenchyma cells. Above each vascular bundle, the pericycle forms a distinct cap-like structure known as bundle cap.

5.5.1.4.5.2. Medullary Rays

These are found in between the vascular bundles. They are meant for the storage of food.



A cross-section through a vascular bundle of a dicotyledonous plant



Diagrammatic representation of Dicot stem and Monocot stem

5.5.1.4.5.3. Pith

Pith is the innermost part of the stem formed by a group of loosely arranged parenchyma cells. Intercellular spaces are prominent. The pith is also meant for storage of food.

5.5.1.4.5.4. Vascular bundles

They are eight in number, arranged in form of a broken ring. The vascular bundles are conjoint, collateral and open. Xylem is on the inner surface and phloem on the outer surface.

- Xylem is described as endarch.

5.5.2. Comparison of dicot and monocot stem

Dicot Stem	Monocot Stem
• Several multicellular hairs usually arise from epidermis in dicot stem. • Hypodermis consists of chollenchymatous cells. • Cortex is distinct. • Epidermis and pericycle are distinctly present. • Vascular bundles are arranged in a ring. • Vascular bundles are conjoint, collateral and open type. • Sclerenchymatous bundle sheath is not found. • In vascular bundles, several vessels are present and are linearly arranged. • Phloem parenchyma is found. • Lysigenous cavity in vascular bundle is absent. Both pith (medulla) and medullary rays are present. • Secondary growth is found.	• Epidermal hair usually is not found. • Hypodermis is usually sclerenchymatous. • Hypodermis and cortex are not distinguishable and ground tissue is present next to hypodermis. • Endodermis and pericycle are not present. • Vascular bundles are found scattered in the ground tissue. • Vascular bundles are conjoint, collateral and closed type. • Each vascular bundle remains surrounded by sclerenchymatous sheath. • Vessels in each vascular bundle are arranged in V-shaped and are fewer in number. • Phloem parenchyma is absent. • Lysigenous cavity in each vascular bundle is present. Medulla and medullary rays are absent. • Secondary growth is not found.

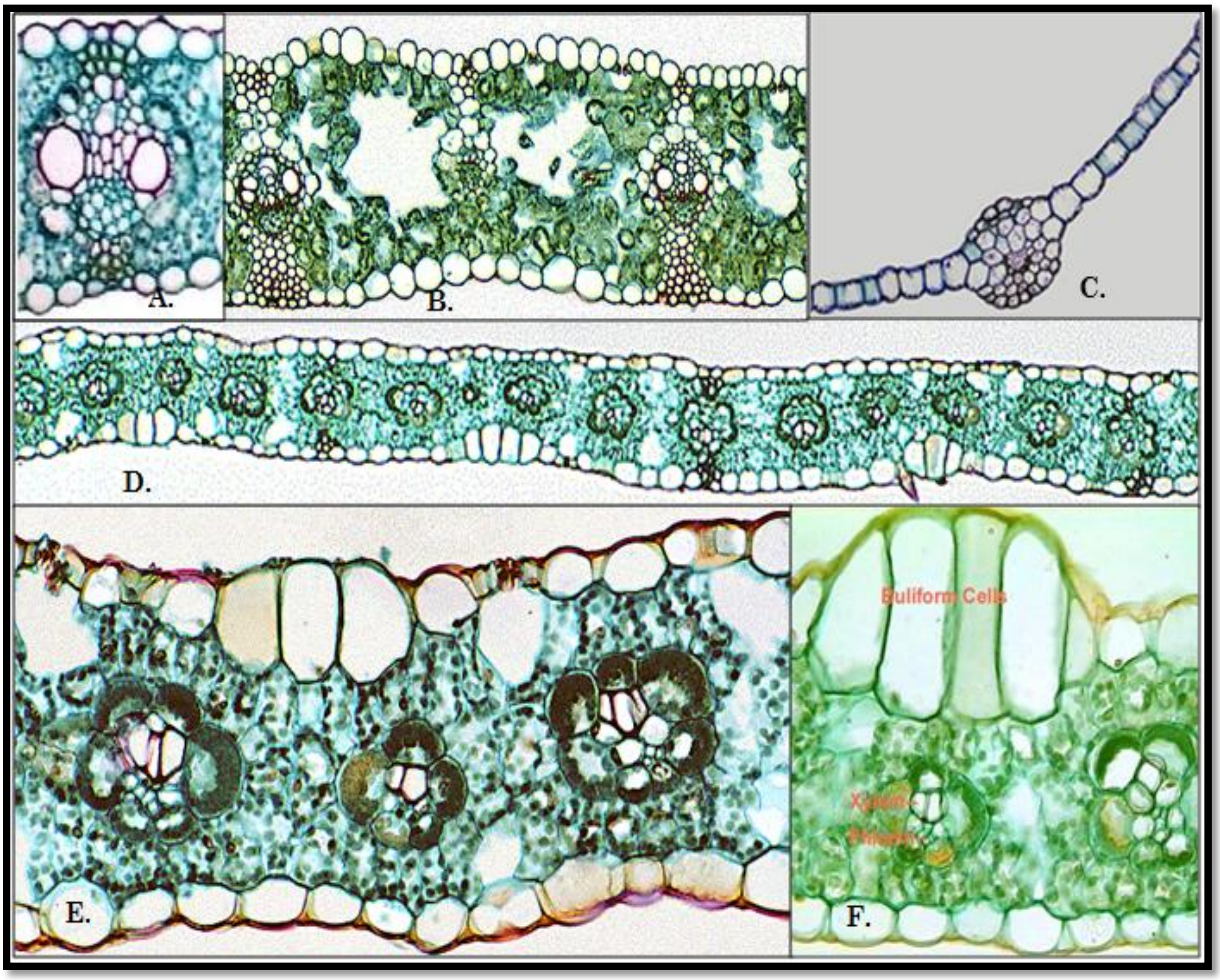


Figure A: T.S. of leaf of *Maize* showing arrangement of vascular elements. **Figure B:** T.S. of a monocot leaf showing aerenchyma in them. **Figure C:** T.S. of leaf of *Minum stellar* (Monocot plant). **Figure D and E:** T.S. of leaf *Zea mays*. **Figure F:** Labeled diagram of T.S. of a monocot leaf.

5.6. Section Cutting of Leaf

5.6.1. Anatomy of a Monocot Leaf

5.6.1.1. Epidermis

Both upper and lower epidermises are usually made up of a single layer of cells that are closely packed. Cuticle and trichomes are present in both layers. Stomata are equal in number in both layers. This condition is described as **amphistomatic.**

A few cells in the upper epidermis are enlarged to form motor cells called the **bulliform cells** that help in rolling and unrolling.

5.6.1.2. Mesophyll

It is a ground tissue that occurs between the two epidermal layers not differentiated into palisade and spongy parenchyma.

It is composed of many layers of loosely arranged, spherical or oval chlorenchyma cells. It has few intercellular spaces as well.

5.6.1.3. Vascular Bundle in Veins

Each vascular bundle is surrounded by a **bundle sheath** composed of a single layer of compactly arranged cells.

Xylem is found towards upper epidermis and phloem is towards lower epidermis.

The vascular bundle is described as **conjoint** and **collateral with endarch xylem**. The oldest and the largest vascular bundle are found in the centre. It is known as **midrib vein**.

The bundle sheath of the midrib vein is connected to the upper and lower epidermal layers by sclerenchyma cells representing bundle sheath extensions or hypodermal sclerenchyma.

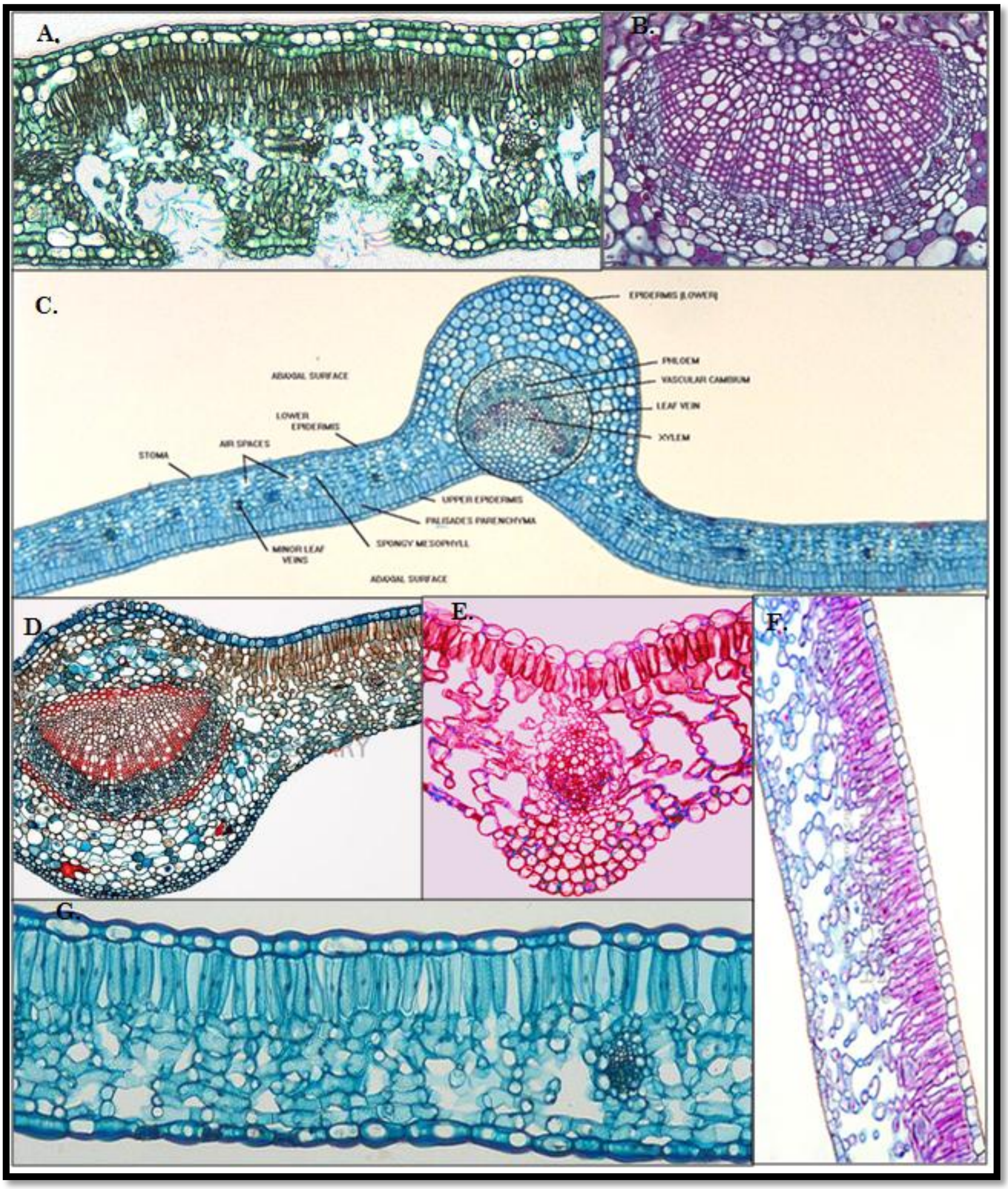


Figure A: T.S. of Leaf of *Oleander spp*. showing stomatal crypts. **Figure B:** T.S. of Leaf of *Ligustrum spp*. showing mid vein. **Figure C:** Labeled diagram of T.S. of leaf of a dicot plant. **Figure D, E, F and G:** T.S. of Leaf of different dicot plants, (D: Tea plant).

5.6.2. Anatomy of a Dicot Leaf

5.6.2.1. Epidermis

Both upper and lower epidermises are usually made up of a single layer of cells that are closely packed. The cuticle on the upper epidermis is thicker than that of lower epidermis. Stomata are more in number on the lower epidermis than on the upper epidermis. Epidermis is present to give protection to mesophyll. The cuticle helps to check transpiration. Stomata are used for transpiration and gas exchange.

5.6.2.2. Mesophyll

The entire tissue between the upper and lower epidermis is called the mesophyll, differentiated into palisade and spongy parenchyma.

5.6.2.2.1. Palisade Parenchyma

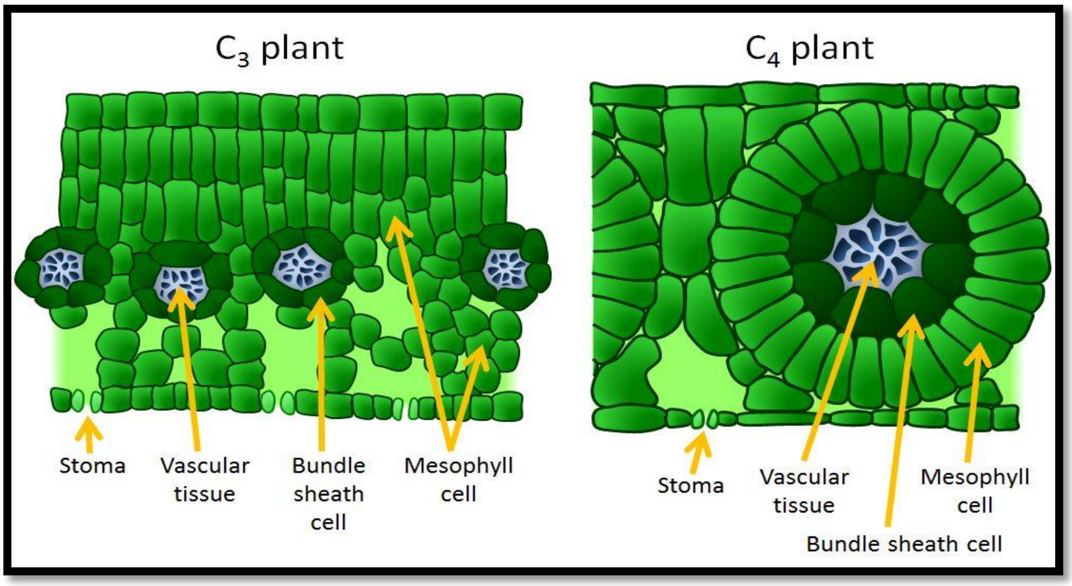
Below the epidermis, vertically elongated cylindrical cells in one or more layers without intercellular spaces form palisade parenchyma. Palisade parenchyma cells contain more chloroplasts than the spongy parenchyma cells. The function of palisade parenchyma is photosynthesis.

5.6.2.2.2. Spongy Parenchyma

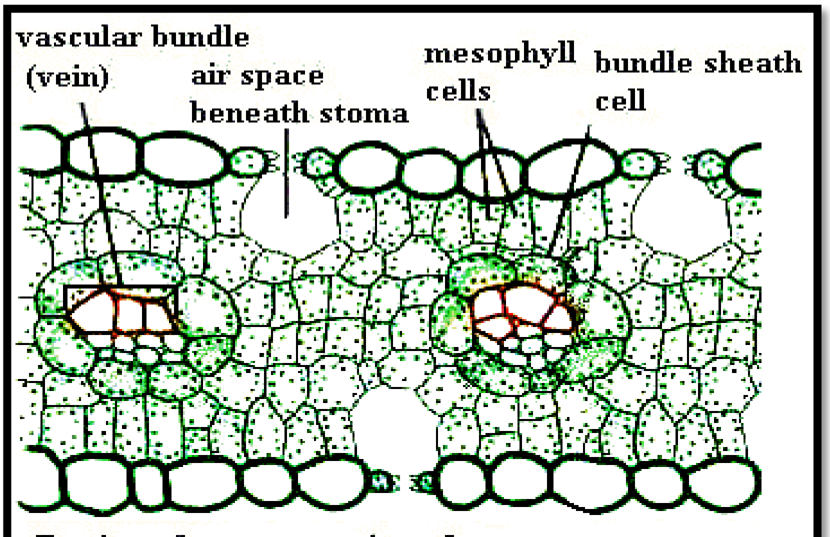
Below palisade parenchyma towards lower epidermis, irregularly shaped, loosely arranged cells with numerous air spaces form spongy parenchyma. Spongy cells facilitate the exchange of gases with the help of air spaces. The air space that is found next to the stoma is called **respiratory cavity** or **sub-stomatal cavity.**

5.6.2.3. Vascular bundle in Veins

Vascular bundles are **conjoint**, **collateral** and **closed**. Protoxylem is present towards the upper epidermis, while the phloem, consisting of sieve tube and companion cells, is present towards the lower epidermis. They are surrounded by a compact layer of parenchymatous cells called **bundle sheath** or border parenchyma. Phloem fibres are absent. Tracheids and xylem fibres are absent.



Leaf Anatomy of C_3 & C_4 Plants



Portion of a cross section of a leaf with C_4 photosynthesis

5.6.3. Leaf Anatomy of C_3 & C_4 Plants

5.6.3.1. C_3 Plants

5.6.3.1.1. Definition

***C_3* plants,** accounting for more than 95% of earth's plant species, use rubisco to make a three-carbon compound as the first stable product of carbon fixation (3-PGA). C_3 plants flourish in cool, wet, and cloudy climates, where light levels may be low.

5.6.3.1.2. Leaf Anatomy

- C_3 plant's leaves have only mesophyll cells between the veins and the surface.
- Only mesophyll cells have chloroplast in them.
- If bundle sheath cells are present they are non-photosynthetic.

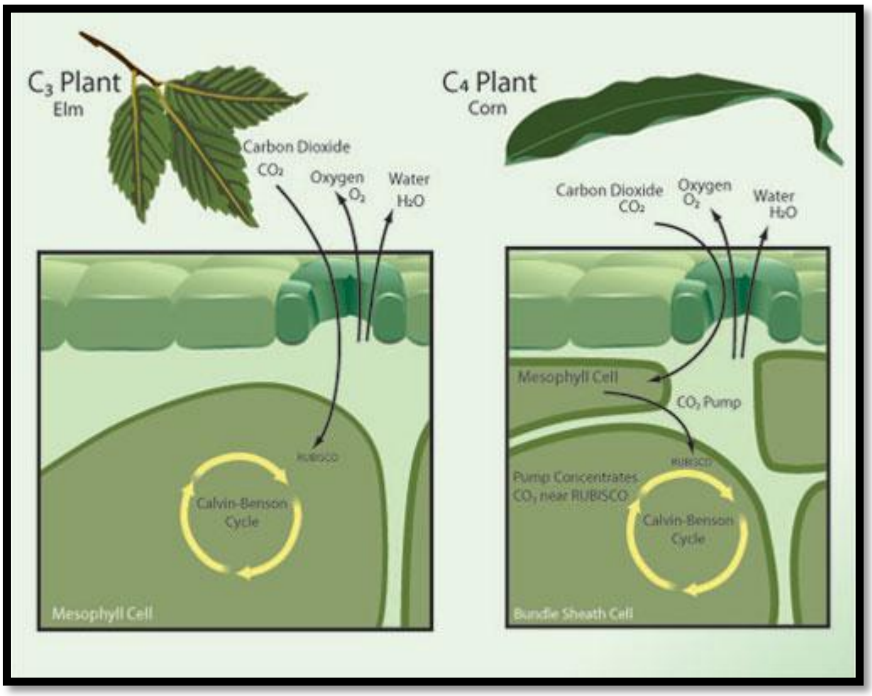
5.6.3.2. C_4 Plants

5.6.3.2.1. Definition

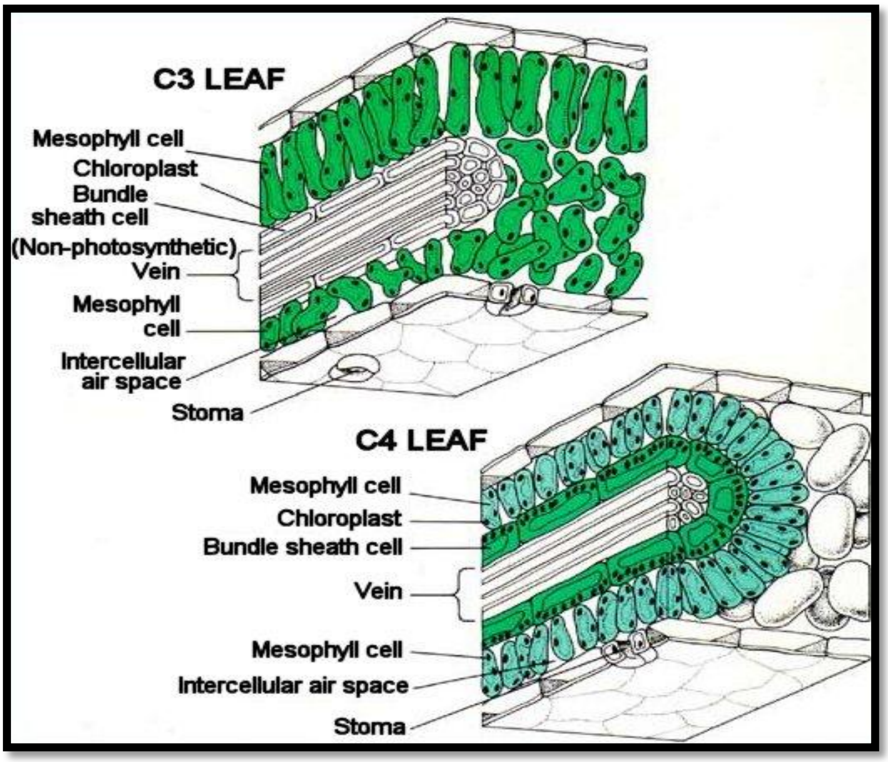
***C_4* plants** possess biochemical and anatomical mechanisms to raise the intercellular carbon dioxide concentration at the site of fixation, and this reduces, and sometimes eliminates, carbon losses by photorespiration. C4 plants, which inhabit hot, dry environments, have very high water-use efficiency, so that there can be upto twice as more photosynthesis as per gram of water as in C3 plants, but C4 metabolism is inefficient in shady or cool environments. Less than 1% of earth's plant species can be classified as C4.

5.6.3.2.2. Leaf Anatomy

- C4 plants have bundle-sheath cells that are arranged in tightly packed sheaths around the veins of the leaf.
- Then between the bundle sheath and leaf surface are the more loosely packed mesophyll cells.
- Their mesophyll cells as well as bundle sheath cells both have chloroplast in them means photosynthetic.



Difference between Leaf Cycles and Anatomies of C_3 & C_4 Plants



5.6.4. Kranz Anatomy

Kranz is the German word for **‘wreath’** (in the form of ring)

“The leaves of C_4 plants typically are characterized by an orderly arrangement of mesophyll cells around a layer of large bundle sheath cells, so that the two together form concentric layers around the vascular bundle. This wreath-like, two-layered arrangement of the chlorenchyma is termed **Kranz anatomy”**

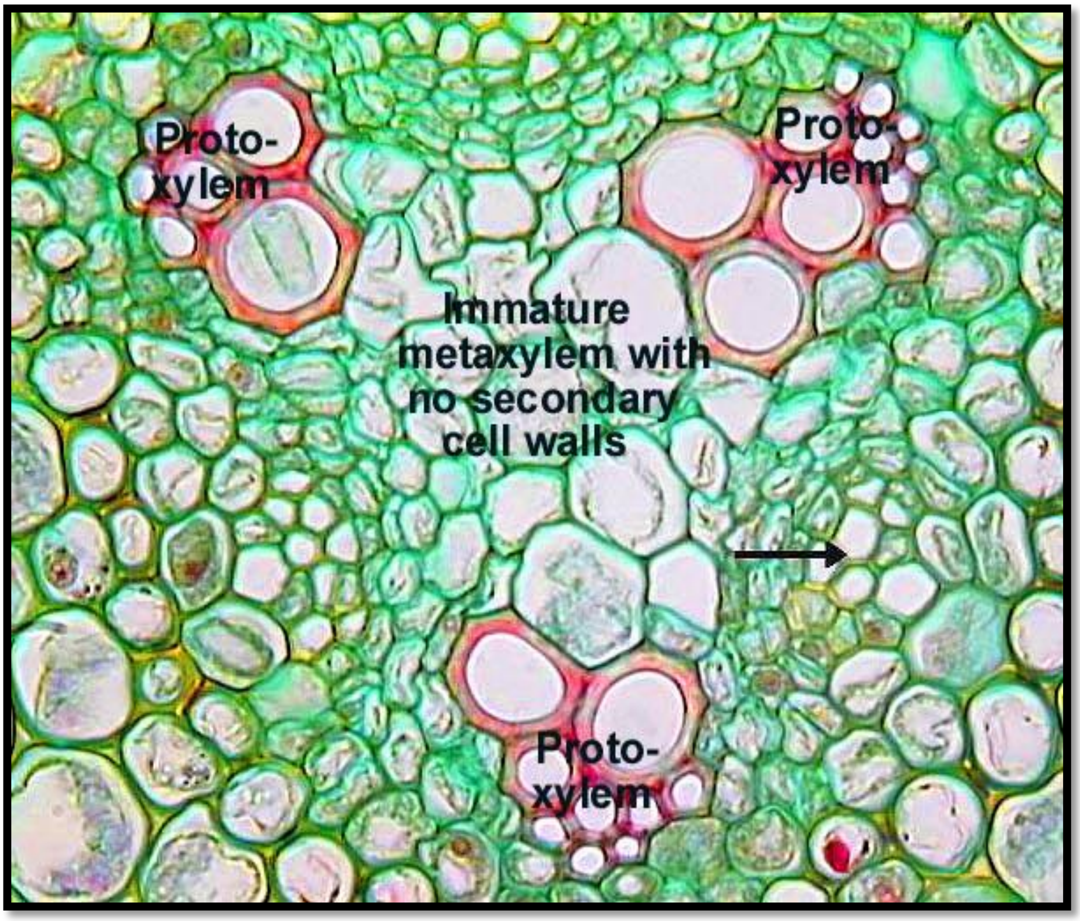
C_4 photosynthesis incorporates novel leaf anatomy, metabolic specializations and modified gene expression.

Plants that utilize this pathway typically possess a distinctive Kranz (or wreath) leaf anatomy, consisting of two photosynthetic cell types. These are the bundle sheath cells, which surround the vascular centers, and the mesophyll (mp) cells, which surround the bundle sheath cells.

5.6.5. Difference between Leaf Anatomies of C_3 & C_4 Plants

Sr #	**Characteristic**	**C_3 Plants**	**C_4 Plants**
1.	**Leaf Anatomy**	C_3 plants have only one type of photosynthetic cells, (i-e) mesophyll cells, if bundle sheath cells present they are without chloroplast.	C_4 plants have two types of photosynthetic cells, bundle-sheath cells and mesophyll cells, arranged in the leaf.
2.	**Primary CO_2 Acceptor**	**RuBP** (Ribulose bisphosphate)	**PEP** (Phosphoenol pyruvate)
3.	**First Stable Product**	3- Phosphoglyceric Acid **(3-PGA)**	Oxaloacetate **(OAA)**
4.	**Chloroplast**	Only one type of chloroplast present.	Two type of chloroplasts (dimorphic).

Sr #	Characteristics	C_3 Plants	C_4 Plants
5.	**Environmental Conditions**	C_3 plants are relatively inefficient in using CO_2 and have their photosynthetic apparatus in the outer mesophyll cells. To compensate for this inefficiency stomata must remain open longer exposing them to potentially increased evapo-transpiration and respiration rates. As a result these plants grow better in cooler moist environments with elevated CO_2 concentrations.	The enzymes of C_4 plants located in the mesophyll are more efficient in fixing CO_2 which decreases the time stomata must remain open and decreases the evapotranspiration and respiration rates compared to C_3 plants. Consequently, C_4 plants are better adapted to warmer and dryer environments.
6.	**Examples**	Wheat, Rice, Barley, Potato	Maize, Sugar cane, Millet



Parts shown due to staining

6. Staining

6.1.Introduction

Staining is a technique used in microscopy to enhance contrast in a microscopic image. Stains and dyes are frequently used to highlight structures in microbes for viewing, often with the aid of different microscopes. Stains may be used to define organelles within individual cells (e.g., mitochondria or chloroplasts)

The selected sections need to be stained. The stains help to distinguish different tissues, cells or inclusions from one another by developing specific colours. Fast green, light green and saffranine are some of the commonly used stains.

6.2.Specificity

Most of the stains are specific in reactions and are purposely used so that definite structures or substances are stained.

The following are some of the stains used for staining different structures.

Cellulose cell wall	**Lignified cell wall**
Light green	Crystal violet
Fast green	Safranin
Suberinized cell wall	**Cytoplasm**
Safranin	Light green
	Fast green
Secondary cells	**Primary cells**
Safranin	Fast green

Scheme for staining technique for Safranin and Fast green

↓

Dehydrate with 30% alcohol + Fast green

↓

50% alcohol + Safranin

↓

70% alcohol

↓

100% alcohol

↓

100% alcohol + xylene

↓

Pure xylene

↓

Clove oil

Mounting with Canada balsam

6.3. Types of Dyes

Certain dyes show a great affinity toward wood than for other types of tissues, while with other dyes reverse is the case. From this point of view we may recognize two main groups of dyes:

- **Acidic dyes:** This shows great affinity towards non-woody tissues.
- **Basic dyes:** This shows great affinity towards wood.

6.4. Types of Staining

Staining may be of two types:

- **Single staining** this shows low level of differentiation.
- **Double staining** this is highly organized and show high level of differentiation. The dyes uses for this purpose are *saffranine* and *crystal violet.*

Staining may be primary or secondary:

- **Primary Stains**

The type of stains actually dyes the primary cell body of plants or non-woody tissues commonly dyes in blue or green color in case of crystal violet or fast green respectively.

- **Secondary Stains or counter stains**

The stains used to dye the secondary cell body of plants or woody tissues commonly dye red in case of safranin.

Counter stains are selected to be contrasting color so that the target of the primary stain can easily be differentiated on a contrasting background.

6.4.1. Single Staining Method

- Safranin or fast green is used alone to stain filaments of algae, fungi, sections of bryophytes, spores of pteridophytes, pollen grains of gymnosperms, etc. Aniline blue of saffranine is suitable for algae.
- This method of plant section cutting involves fixation, dehydration, staining, clearing and mounting.

6.4.2. Double Staining Method

Commonly two or more stains are employed wherever tissues differentiation is found. Combination of acidic and basic dyes for contrasting colours is of general use. This permits the distinction of primary (non-woody) and secondary (woody) tissues. Here we are concerned with following combination:

- Safranin and Fast green

6.5. Staining Procedures

There are two types of preparations:

1. Permanent
2. Semi-permanent

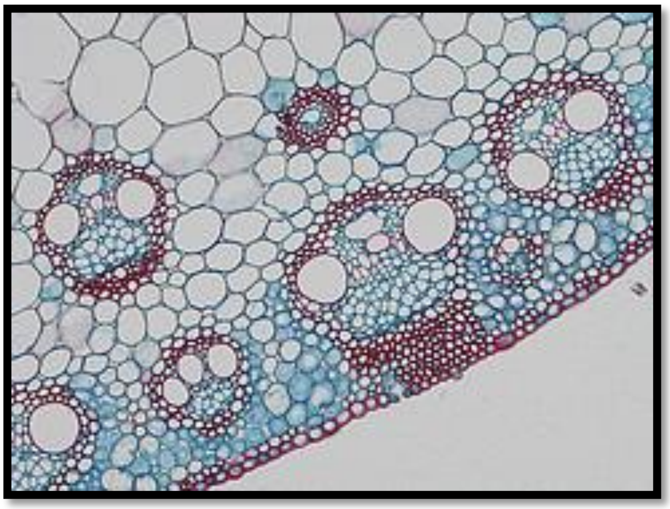
For the preparation of permanent slide for the future record or conservation purpose the following method to be followed:

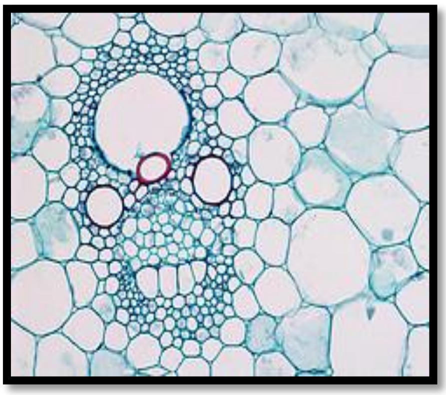
6.5.1. Permanent Preparation

6.5.1.1. Washing

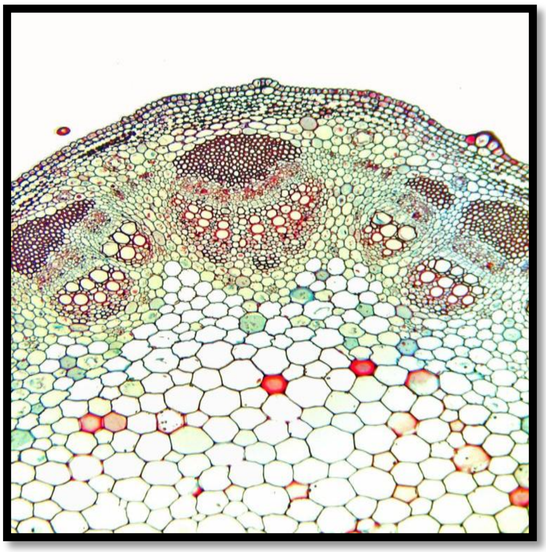
Take a clean watch glass containing water and transfer the thin section of given material in it for removal of waste material such as starch grains of potato etc.

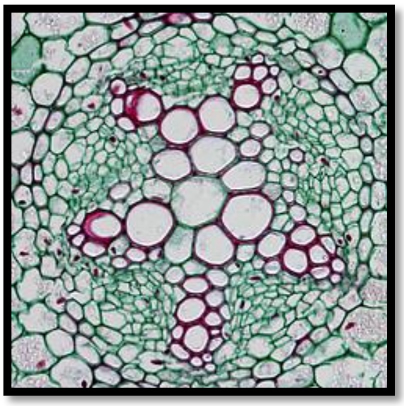
Below are stained parts of T.S of Monocot Stem





Below are stained parts of T.S of Dicot Stem





6.5.1.2. Dehydration and Staining

Section is passed through a graded series of alcohol for dehydration.

- Transfer the thin section into 30% ethanol for 10 minutes and then add 2-3 drops of fast green in it and leave it for 10 minutes.
- Then transfer the section into 50% ethanol and add 2-3 drop of safranin and leave it for 15 minutes.
- Shift the section into 70% ethanol and allow staying for 15 minutes.
- Destaining is done by leaving section in 100% ethanol for 7 minutes.
- In 100% ethanol containing section add xylene add leave it for 10 minutes
- Transfer the section in pure xylene for 5 minutes.
- Wash the section water carefully after each step, given above.
- Transfer the section to clove oil and allow staying for 5 minutes.

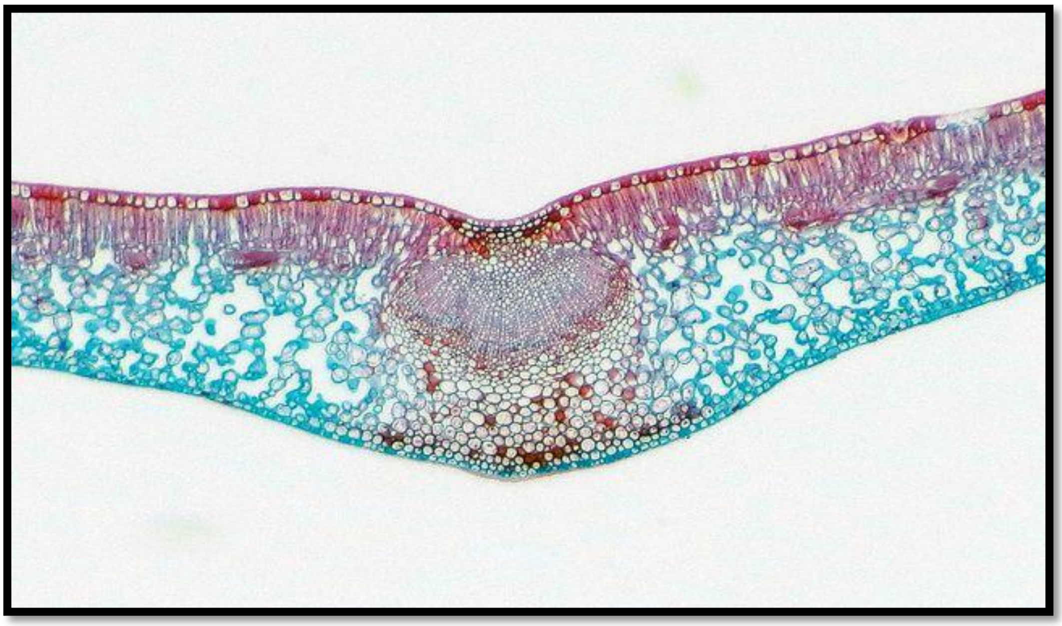
Pure xylene is the last stage of clearing. Section is now ready for mounting. Mounting is done in Canada balsam.

6.5.1.3. Mounting

Mounting is necessary to properly position an object for clear view. Canada balsam is used for permanent mounting.

6.5.1.4. Canada balsam

- It is a resin obtained from conifer (*Abies balsamea*), most suitable for permanent slide preparation. The material to be mounted should come through alcohol (dehydration) and xylene (clearing) series. Take a neat and clean slide; place 1-2 drops of **Canada balsam** on it. No air bubbles should be present on it.
- Transfer the material to Canada balsam. Place the cover slip on the specimen and slightly press the cover slip.
- The excess of Canada balsam can be wiped off with cotton wool dipped in xylene.



T.S of Dicot Leaf (Stained)

6.5.1.5. Sealing the cover slips

Sealing is done by painting the edges with sealing agent (Canada balsam) in such a way that the space between the slide and the cover slip gets filled with the agent. I t will prevent the mounting medium from drying.

6.5.1.6. Labeling

After mounting the slides are labeled with printed labels or handmade labels.

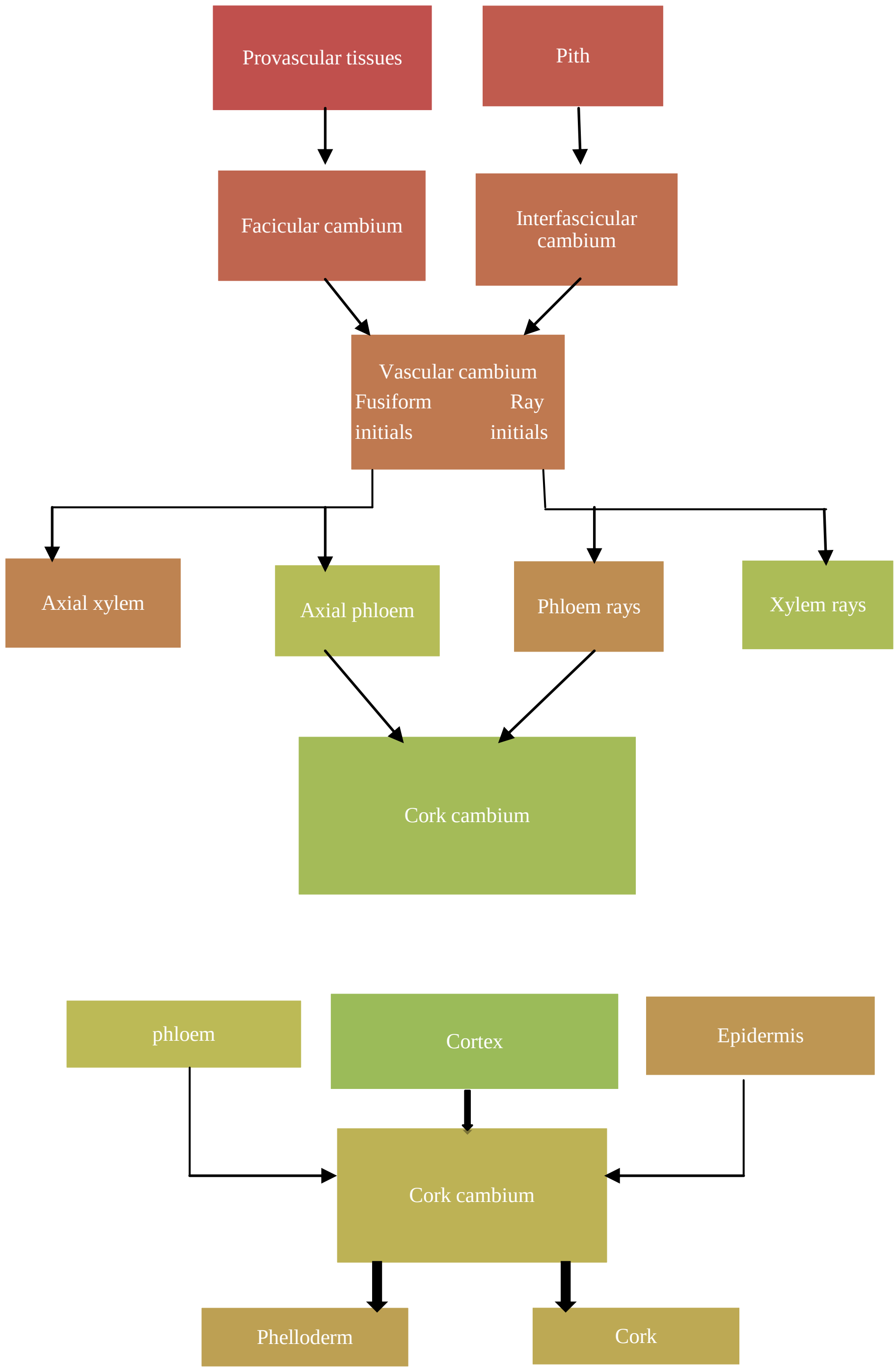
6.6.Discussion

- Initially, we collect the fresh plant material and cut thin section of it, select the thinnest and finest section for staining. Double staining technique is used for this purpose.
- **Safranin** is used for staining xylem and fast green is used to stain other tissues. Using different grades of alcohol we dehydrate the material to cut down all metabolic activities.
- Xylene is used for check test we put our sample to xylene, if any layer is formed its mean that dehydration is not completed.
- Then the sample is transfer to clove is used for hardening and bettering of section.
- Finally the specimen is carefully transferred to a clean slide containing a drop of Canada balsam on it such that no air bubble is formed and covered the slide with cover slip.
- Clean the slide by removing the excessive Canada balsam by xylene and labeled it with printed or handmade labels.
- The method follows the **Johansen's method of staining** (Johansen, 1940), widely agreed that this method yields a more brilliant staining of plant tissues.

6.7.Precautions

Following care should be taken during mounting:

- Object should be mounted in the centre of the slide.
- No air bubbles should enter the medium while mounting. This results in drying of medium.
- Use the small amount of mounting medium so that it do not flow on the slide
- Preparation should be clean, hence the edges of slide and cover slip alone should be held between fingers.



An Outline of Secondary Growth In Plants

7. Secondary Growth in Plants (Cambium)

7.1. Secondary Growth

"The increase in thickness or girth of the plant body is termed as secondary growth"

Secondary growth results from the activity of two lateral meristems: **vascular cambium** and **cork cambium**. Secondary growth is found only in gymnosperms and dicots and absent in monocots.

7.1.1. Significance of Secondary Growth

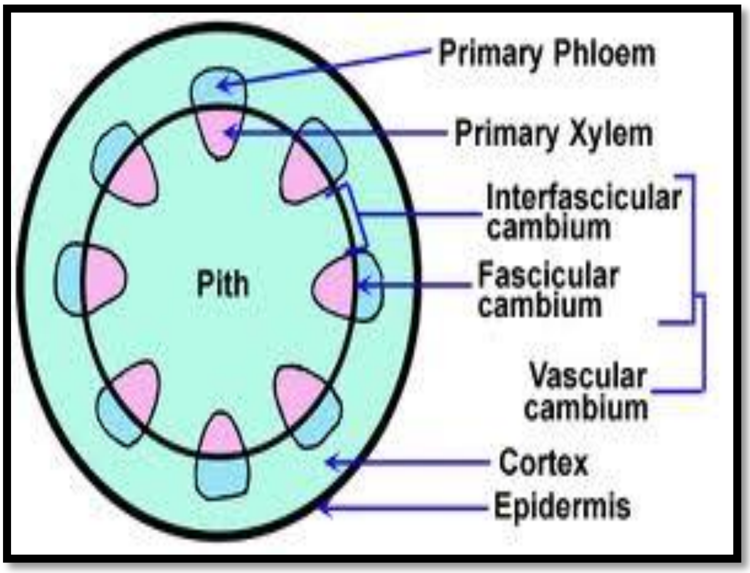
- As plants grow larger, more vascular tissue is needed for water conduction and the transport of nutrients.
- The vascular tissue that results from primary growth is not sufficient, so more vascular tissue is made from the ***vascular cambium***.
- The additional vascular tissues do not function exclusively as water and nutrient conduits. Older xylem, in the core of the axis plays an important role in support in larger plants such as woody trees while older phloem, along with tissues produced by the ***cork cambium***, can act as a protective covering for a plant, replacing the epidermis in older parts of the plant.

7.2. Cambium

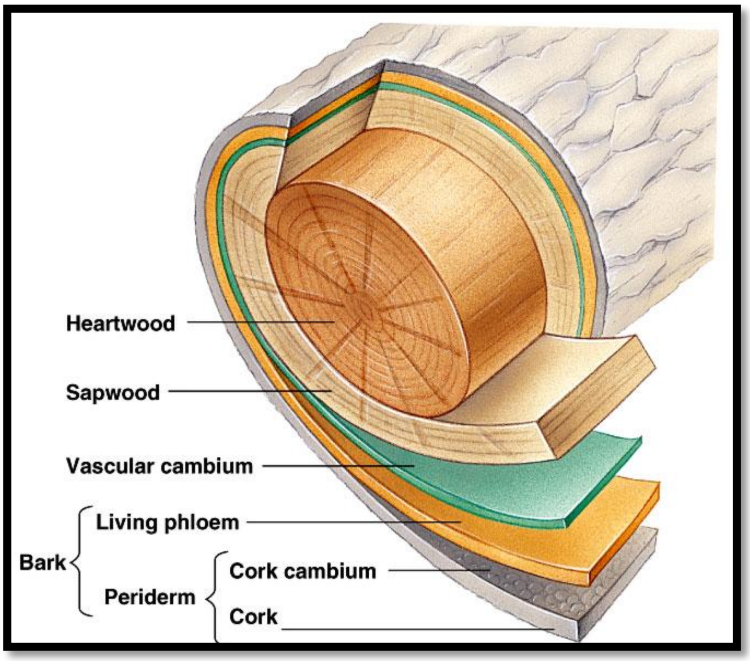
Once a plant cell is differentiated, it is unable to grow again. To allow for growth, certain bands of cells remain undifferentiated retaining the ability to divide. Cambium is made of such cells.

7.2.1. Definition

"Meristematic plant tissues commonly present in the form of a thin layer which forms new cells on both sides of vascular cylinder. Located either in vascular tissue (vascular **cambium**), forming xylem on one side and phloem on the other or in cork (cork Cambium or phellogen)".



T.S of stem showing vascular cambium



Section of wood showing different layers of cambium

7.2.2. Origin

Vascular cambium arises from the primary meristem, **procambium** that remains undifferentiated between the primary xylem and primary phloem.

- Upon maturity, this region is known as the **fascicular cambium**
- And the area of cells between the vascular bundles (fascicles) called pith rays becomes what is called the **inter fascicular cambium**.

7.2.3. Organization of the cambium

The cells of the vascular cambium do not fit the usual description of meristematic cells, as those that have dense cytoplasm, large nuclei and an approximately isodiametric shape. Although the resting cambial cells are densely cytoplasmic, they contain many small vacuoles.

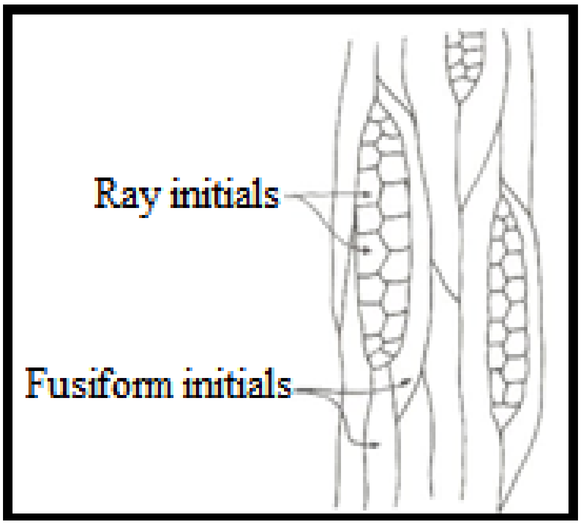
7.2.4. Types

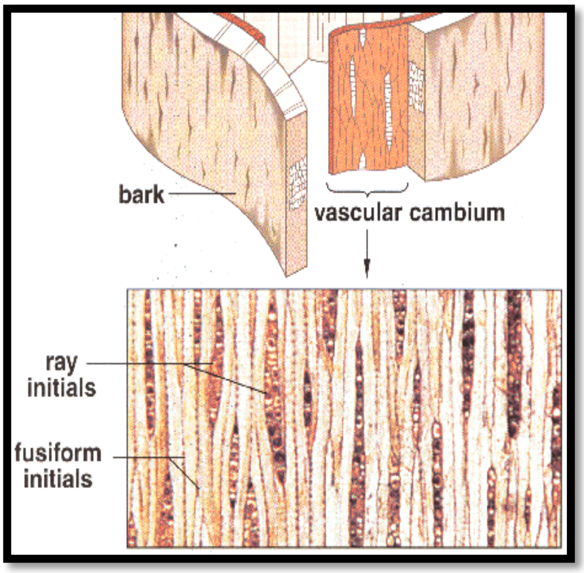
There are two main types of cambium:

- ❖ **Vascular Cambium:** It produces new xylem on inside and new phloem on outside of vascular cylinder leaving narrow bands of thin walled cells that allow nutrients and gases to diffuse to the center of the plant.
- ❖ **Cork Cambium:** It forms a cylinder just below the epidermis and produces cork cells to replace the epidermis which ruptures as the stem and root expand forming the bark & corky outer layer of the older root.

7.2.4.1. Vascular Cambium

- ➢ The vascular cambium (pl. cambia or cambiums) is a lateral meristem in the vascular tissue of plants. It is a cylinder of unspecialized meristematic cells that divide to give rise to cells that further divide, differentiate and specialize to form the secondary vascular tissues.
- ➢ The vascular cambium is the source of both the secondary xylem (inwards, towards the pith) and the secondary phloem (outwards).





Types of vascular camb ium

7.2.4.1.1. Types of Vascular Cambium

The vascular cambium contains two types of initials:

7.2.4.1.1.1. Fusiform initials

Several times longer than wide, the term fusiform implies that the cell is shaped like a spindle. The fusiform initials give rise to all cells of the xylem and phloem. Fusiform initials show **periclinal division** which is parallel to the plant body.

7.2.4.1.1.1.1. Types of fusiform initials

- **Storied cambium:** The fusiform initials are arranged in horizontal tiers, with the ends of the cells of one tier appearing at approximately the same level. It is the characteristics of the plant with short fusiform initials.
- **Non-storied cambium:** This is common in plants with long fusiform initials, which have strongly overlapping ends.

7.2.4.1.1.2. Ray initials

They are slightly elongated to nearly isodiametric. The ray initials give rise to the ray cells, that is, the elements of the radial system of the xylem and phloem. The ray initials show **anticlinal division** which is perpendicular to the plant body.

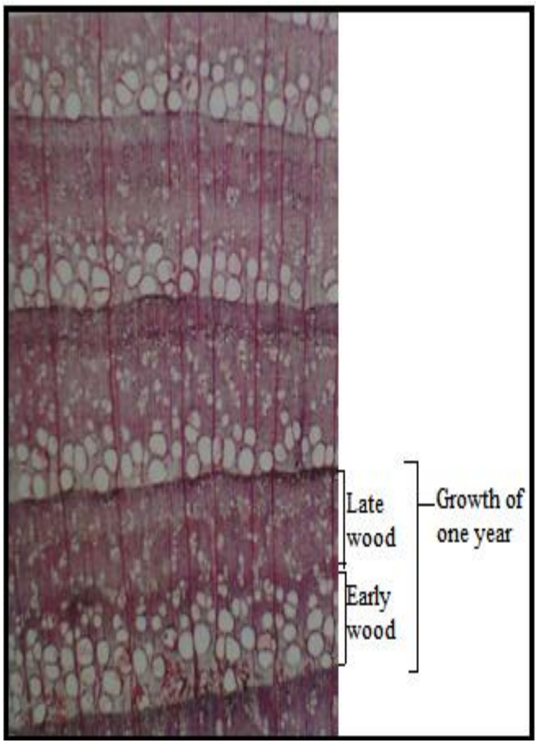
7.2.4.1.2. Role of Vascular Cambium

i. In Root Growth

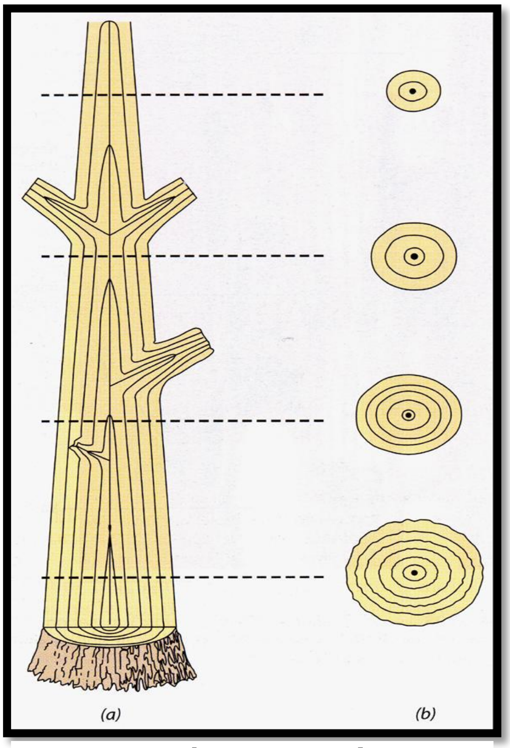
The older roots of woody plants form secondary tissues, which lead to an increase in girth. These secondary tissues are produced by the vascular cambium and the cork cambium.

ii. In Stem Growth

Secondary growth, resulting in an increase in the width of the axis, is produced by meristematic tissue between the primary xylem and phloem called vascular cambium.



T.S of stem showing annual rings



Sections showing annual rings

iii. Wood structure

In dicotyledonous and coniferous (i.e., woody) trees and shrubs, the defining structure that permits this conversion is a layer of meristematic cells, called the vascular cambium, that organizes between the primary xylem and primary phloem of the vascular cylinders. The cambium forms the wood and the inner bark of the tree and is responsible for thickening.

iv. Seasonal Activity of the Vascular Cambium

The secondary growth originating in the vascular cambium is greatly influenced by the seasonal fluctuations. Depending upon the periodic activity of vascular cambium, secondary growth may be of two types.

a. Continuous secondary growth

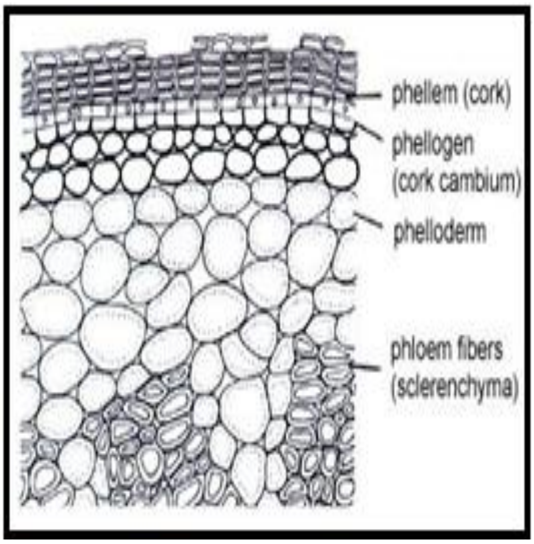
In the plants growing in tropical regions, the cambium may remain active throughout the entire life of the plant, i.e., the cambial cells divide continuously and the resulting cells undergo gradual differentiation to form the xylem and phloem elements.

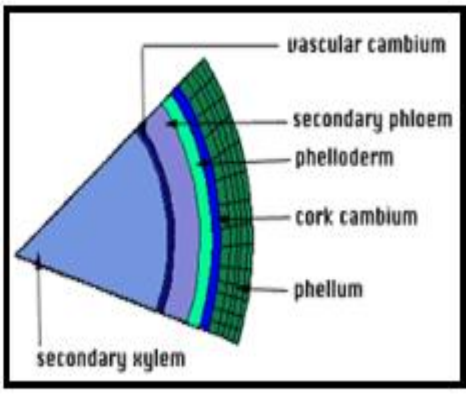
In this case wood of one year is difficult to distinguish from that of another. Such type of secondary growth is called continuous secondary growth.

b. Discontinuous secondary growth

In regions with strongly seasonal climates such as temperate regions, the vascular cambium is quiescent during times of stress, either winter cold or summer drought. But when quiescence ceases, the vascular cambium becomes active and cell division begins. Thus the first wood formed is **early wood**, also called spring wood, and it must have a high proportion of wide vessels.

Later the wood formed is known as **late wood** or summer wood, can have a lower proportion of vessels. Late wood and early wood, the two together making up 1 year’s growth, an **annual ring** and such type of secondary growth is called discontinuous secondary growth.





Sections showing cork cambium

7.2.4.2. Cork Cambium

As the vascular cambium produces secondary xylem and secondary phloem, the epidermis produced by primary growth splits and falls the stem. It is replaced by a new protective tissue (periderm) produced by a lateral meristem called **phellogen** or **cork cambium.**

7.2.4.2.1. Origin

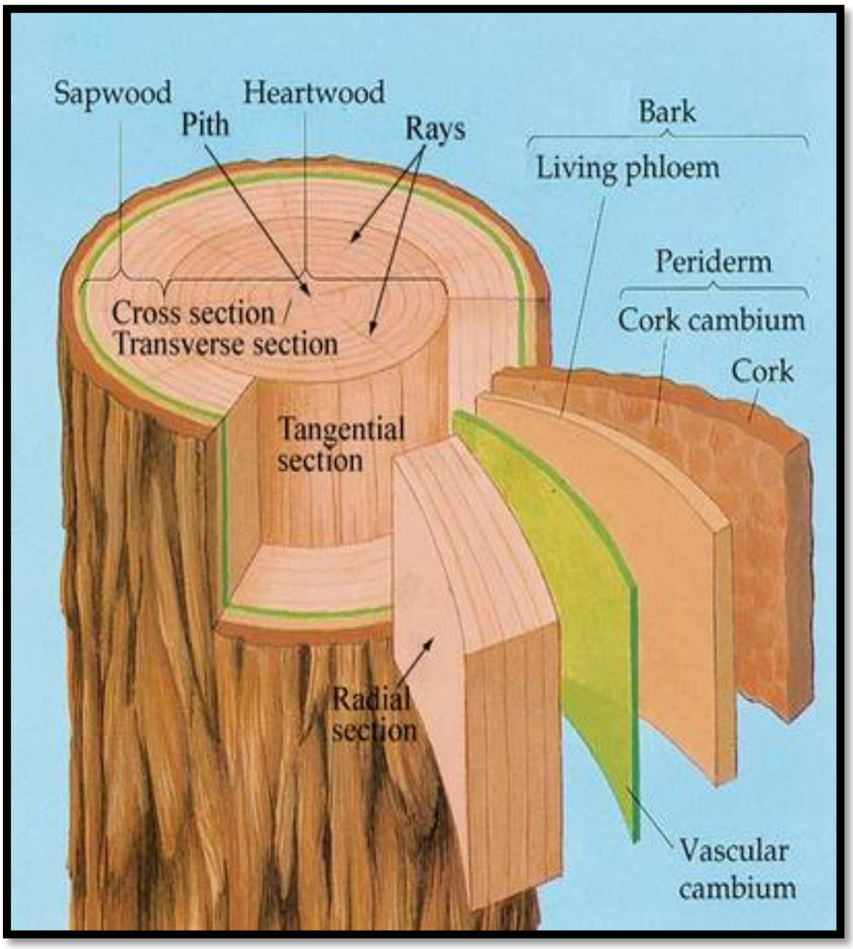
Cork cambium is initially forms from the outer cortex of the stem.

7.2.4.2.2. Organization

The cork cambium differs greatly from the vascular cambium in both structure and morphogenic activity. All its cells are cuboidal, like ray initials. After each division, the inner cell almost always remains cork cambium while the outer cell differentiates into a **cork** cell (also called a **phellem** cell).

In a few species, the cork cambium may produce a cell or two to the inside which matures into a layer of parenchyma called **phelloderm**.

The cork cambium, the layer of cork cells, and the phelloderm (if any) are known as **periderm**.



Three dimensional structure of wood

8. Wood

Wood is a hard, fibrous structural tissue found in the stems and roots of trees and other woody plants. Wood is sometimes defined as only "The secondary xylem in the stems of trees".

8.1. Basic Structure of Wood

The most distinctive feature characterizing the secondary xylem is the existence of two systems of elements:

i. Vertical or axial system

Vertical system consists of treachery elements, fibers and wood parenchyma.

ii. Horizontal or radial system

While horizontal system comprises the xylem rays. The cells of rays and axial system are usually interconnected to form a continuous system of living cells.

iii. Planes of Section

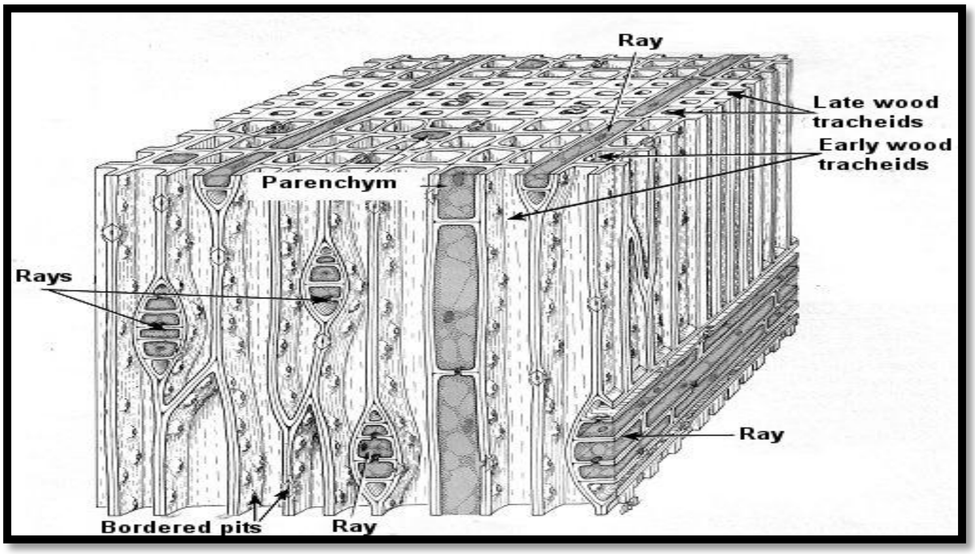
Although wood can be cut in any direction for examination, the organization and inter relationship between the axial and radial systems give rise to three main perspectives from which they can be viewed. These three perspectives are:

- **Transverse plane of section (the cross section)**

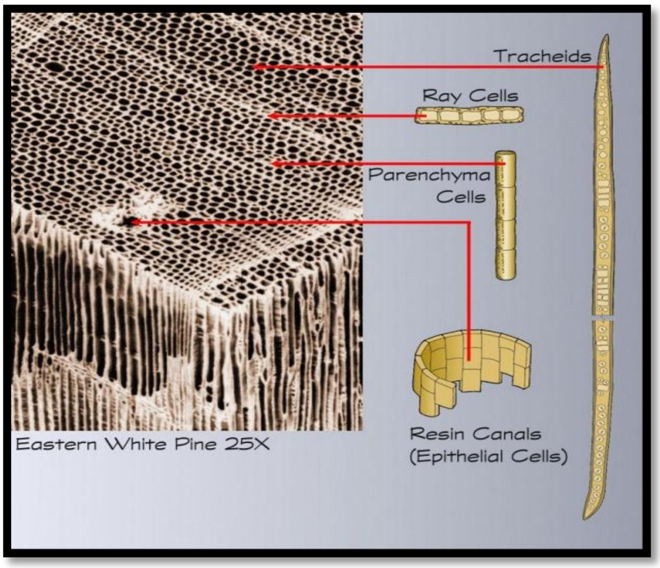
The transverse plane of section is the face that is exposed when a tree is cut down. It provides information about features that vary both in the pith to bark direction. It does not provide information about variations up and down the trunk.

- **Radial plane of section**

Radial and tangential sections are referred to as longitudinal sections because they extend parallel to the axial system.



Block of coniferous wood



Cells that make softwood

The radial plane of section runs in a pith-to-bark direction and it is parallel to the axial system, so it provides information about longitudinal changes in the stem and from pith to bark along the radial system.

- **Tangential plane of section**

The tangential plane is at a right angle to the radial plane. The tangential plane of section does not provide any information about features that vary in the radial direction, but it does provide information about the tangential dimensions of features.

8.2. Anatomical Structure of Wood

8.2.1. Softwood

In coniferous or softwood species the wood cells are mostly of one kind, tracheids, and as a result the material is much more **uniform** in structure than that of most hardwoods.

There are **no vessels** ("pores") in coniferous wood such as one sees so prominently in oak and ash; for example.

Softwood contains only two types of cells:

- Longitudinal wood fibers (or tracheids)
- Transverse ray cells

In addition to these parenchyma & resin canals are also present.

8.2.1.1. Tracheids

Within a conifer’s trunk, the majority of the wood is comprised of long, thin cells called tracheids.

In addition to giving the tree most of its strength, tracheids also double as “pores” in a sense-since conifers lack true pores, they rely on tracheids for sap conduction.

Hard Wood

8.2.1.2. Medullary Rays

With the exception of special fusiform rays, which occur in conjunction with resin canals, regular softwood rays are usually only one to two cells wide (called uniseriate and biseriate, respectively) because these normal rays are much narrower, and lack unique characteristics.

8.2.1.3. Parenchyma

Much like tracheid, parenchymas are oriented along the length of the tree-trunk, and are sometimes referred to as longitudinal or axial parenchyma. In softwoods, these parenchyma cells are roughly the same diameter as tracheids .Because tracheids account for over 90% of a softwood’s cells, parenchyma cells are comparatively sparse-(many softwoods don’t have any parenchyma at all, such as: pine, spruce, and yew).

8.2.1.4. Resin Canals

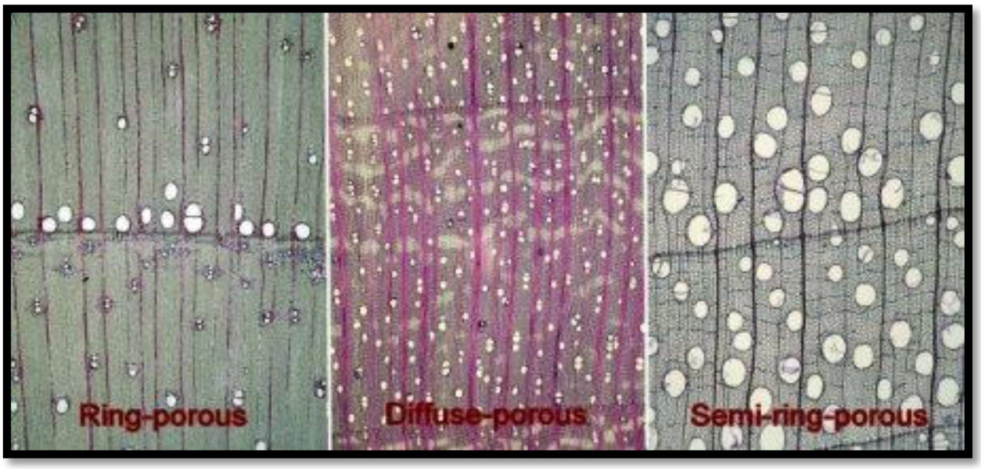
Resin canals**,** sometimes referred to as **resin ducts,** are unique to conifers; they are technically not individual cells, but are actually open, tube-like spaces bordered by special cells that have the ability to secrete pitch or resin into the neighboring opening (canal). One of the apparent purposes of these ducts is to protect and seal up a wound by exuding resin to cover the damaged area of the tree.

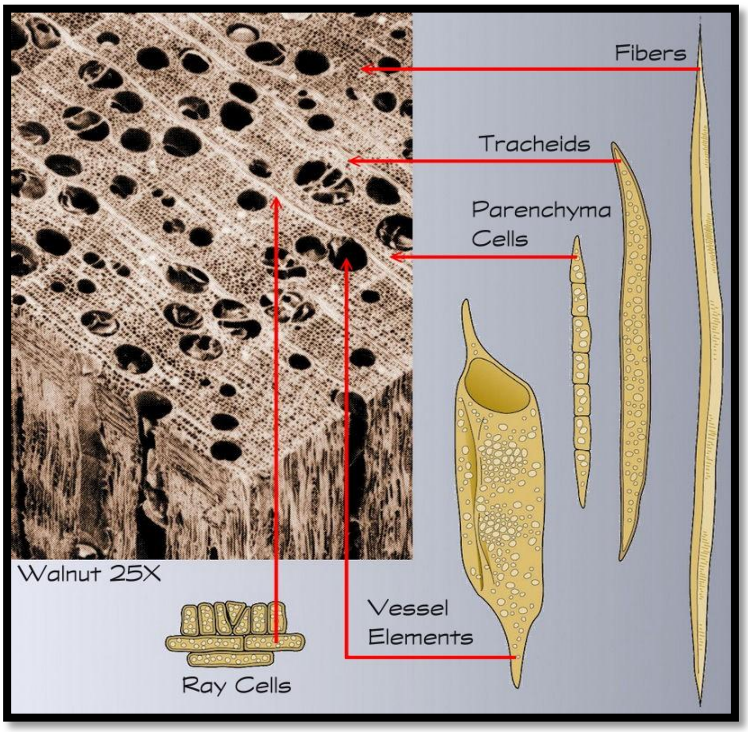
Examples

- European yew (*Taxus baccata*)
- *Pinus sp*.
- Fir (*Abies*)
- Cedar (*Cedrus*) etc

8.2.2. Hard Wood

Hardwoods have a more complex structure than softwoods. The dominant feature separating "hardwoods" from softwoods is the presence of pores, or vessels. The vessels may show considerable variation in size, shape of perforation plates (simple, sclariform, reticulate, foraminate), and structure of cell wall, such as spiral thickenings. Cell structure of hardwood contains four cell types:





Cells that make hard wood

8.2.2.1. Vessels elements

Hardwood trees have evolved specialized conductive cells called vessel elements, which are distinct in having relatively large diameters and thin cell walls. They form in the tree in end-to-end series in which the end walls become perforated, thus forming continuous vessels ideal for sap conduction.

8.2.2.1.1. Ring-porous

Species such as oak, ash, elm and sweet chestnut the largest pores are concentrated in the early wood. Such woods are said to be ring-porous.

8.2.2.1.2. Diffuse-porous

Woods (maple, birch, lime, poplar etc.) whose pores are more uniform in size and evenly distributed across the growth ring are said to be diffuse-porous.

8.2.2.1.3. Semi-ring porous

A third classification, semi ring porous (also called semi-diffuse porous), refers to woods in which the first-formed pores in a growth ring are large, but decrease in size gradually to small pores in the late wood.

8.2.2.1.4. Tyloses

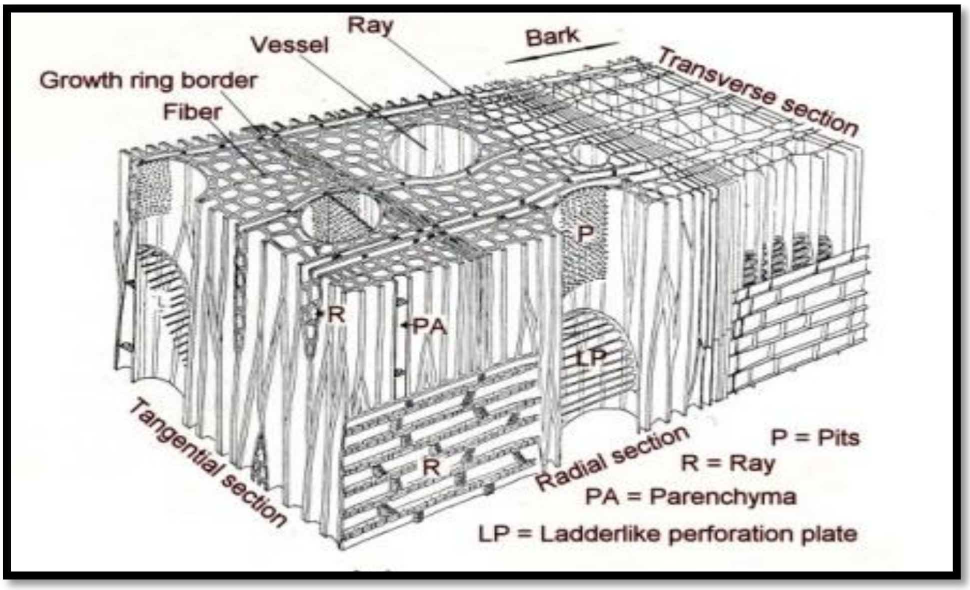
These are bubble-like structures that form in the cell cavities of some. Other significant vessel contents include whitish or chalky deposits, and reddish or brown gummy deposits.

8.2.2.1.5. Other types

Hardwoods have three other types of longitudinal cells:

- Fibres,
- Tracheids
- Parenchyma

All are uniformly small in diameter (mostly in the range of 15–30 µm), and therefore can be seen individually only under a microscope.



Angiospermic wood

8.2.2.2. Rays

- Rays are quite variable among hardwood species.
- If the rays are uniseriate, that is, only one cell wide and therefore visible only with a microscope.
- Although hardwood rays consist entirely of ray parenchyma cells, there are two types of these distinguished on the basis of overall shape.
- As seen in radial view, procumbent ray cells are elongated horizontally upright ray cells are either square or they are vertically oriented.
- If only one type of cell is present in the ray, it is termed **homocellular** or **homomentous**.
- If both types are present, it is called **heterocellular** or **heterogenous.**

8.3.Monocot Wood

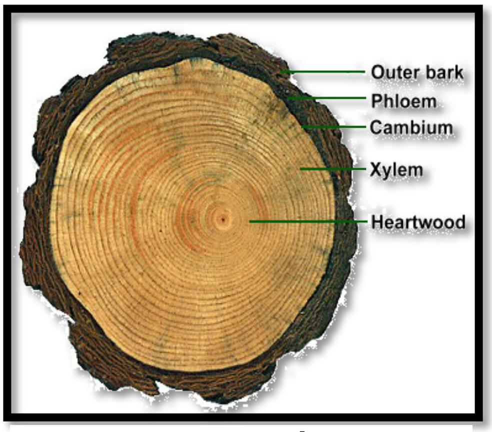
Anatomically, the "wood" of monocots is diverse from both hardwoods and softwoods can usually be spotted easily, even without magnification.

Viewing the end grain reveals a fairly simple structure of darker-colored fibro-vascular bundles embedded throughout a mass of lighter-colored parenchyma cells.

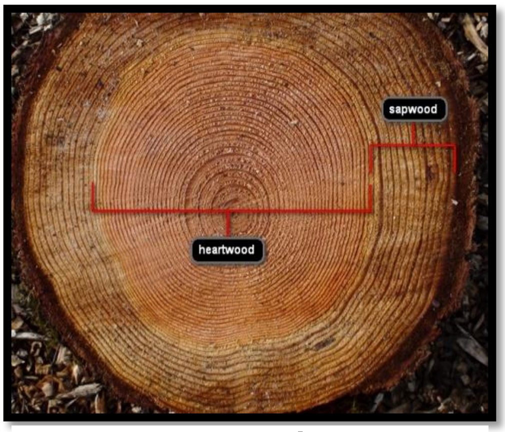
Growth rings, sapwood/heartwood, and medullary rays are all completely absent.

Examples

- Beech (*Fagus*)
- Aspen (*Populus*)
- birch (*Betula*)
- Cherry (Prunus) etc.



Heartwood



Sapwood

8.4.Difference between Wood of Gymnosperm and Angiosperms

Sr #	Wood of Gymnosperms	Wood of Angiosperms
1.	Wood is simpler and homogenous	Wood is complex and heterogenous.
2.	Vessels are not found	Vessels are seen in plenty
3.	It is non-porous in nature and is called soft wood.	It is porous in nature and is called hard wood
4.	There is the presence of small amount of axial parenchyma	More amount of axial parenchyma is seen in varied distribution
5.	It contains schizogenously developed resin ducts	Resin ducts are absent

8.5.Types of Wood

8.5.1. Heartwood

It is the older inactive central wood of a tree or woody plant usually darker and denser than the surrounding sapwood also called as duramen.

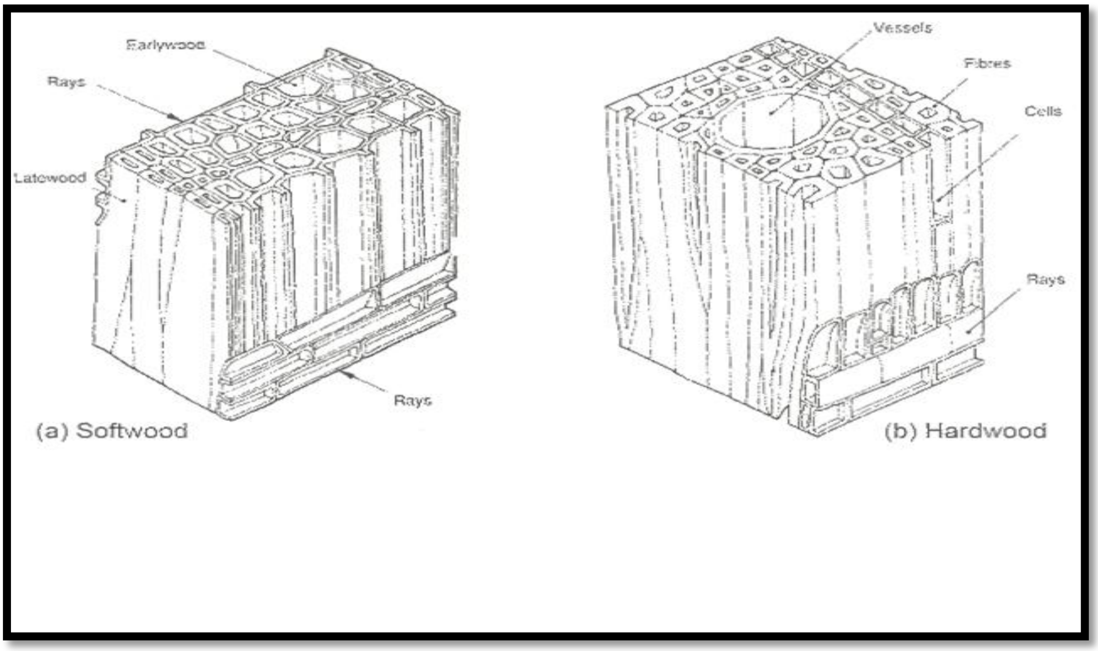
This is accompanied by disintegration of protoplast, loss of cell sap and removal of reserved material from cells that stored them.

Its name derives solely from its position and not from any vital importance to the tree.

8.5.2. Sapwood

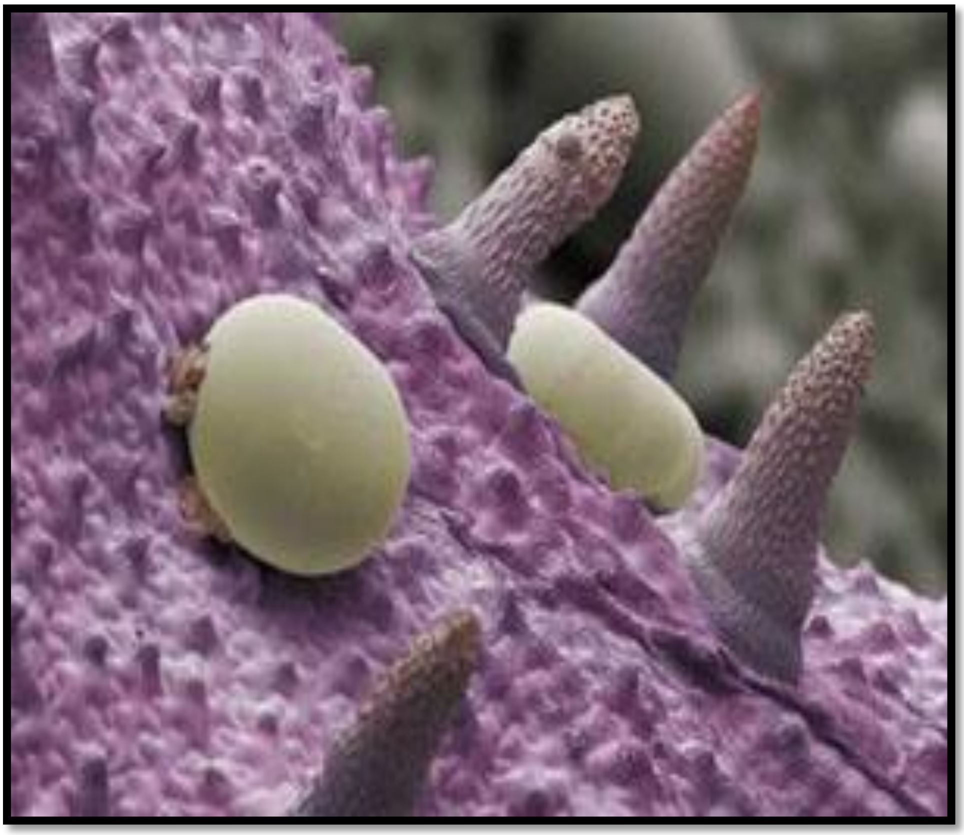
Sapwood is living wood in the growing tree. It is also called as alburnum.

Its principal functions are to conduct water from the roots to the leaves.


Earlywood
Rays
Latewood
Rays
(a) Softwood
Vessels
Fibres
Cells
Rays
(b) Hardwood

8.5.3. Difference between Heartwood and Sapwood

Sr #	Heart wood	Sap wood
1.	Heartwood is produced after of a few years of secondary growth	This is also produced due to secondary growth
2.	Most of the heartwood nears the center of the axis forms a dark coloured region is called heartwood or **duramen**	There is a small outer region, however, remains lightcoloured is known as sapwood or **alburamen**
3.	Heartwood is formed due to accumulation of organis compounds, such as oils gums, and resins, etc.	Sapwood is lighter coloured and it is the outer region of the secondary xylem. It is formed due to the cambial activity of the secondary xylem
4.	The Heartwood is dark coloured and non-functional. The major function of this wood is mechanical support.	The cells of the sapwood are functionally active. So it helps in conduction of water
5.	Amount of heartwood increases as the tree grows older	The amount of sapwood, however, remains almost constant



Calyx surface showing yellow rounded sessile secretory glands and pointed non-secretory trichomes

9. Secretory Tissues

"A cell or group of cells specialized for the active release or accumulation of certain substances, these substances may be called secretion products**"**

Secretory structures vary greatly in their form and function, and there is an endless variety of secretion products, in one sense all cells are secretory (production of cell wall, for example).

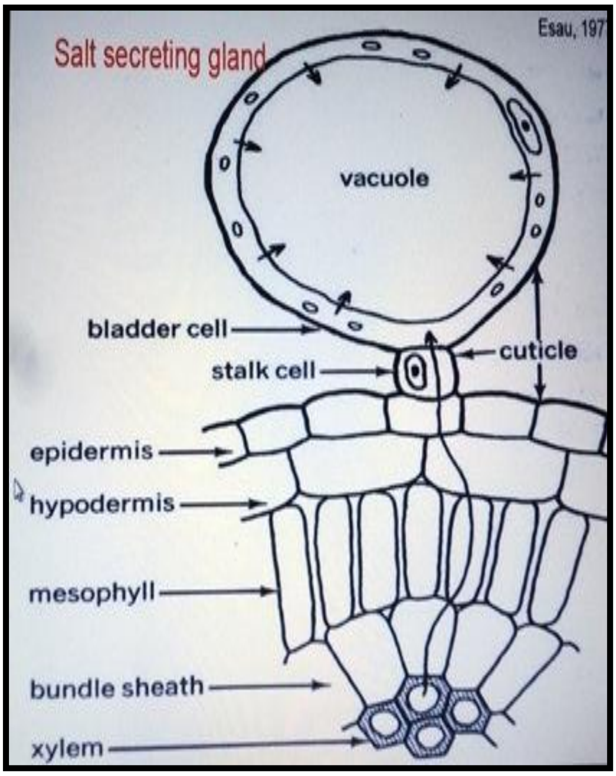
9.1. Types

9.1.1. External Secretory Structures (found on surface of plant)

- They secrete a variety of substances; the two large classes of compounds are mucilaginous and resinous, but also volatile oils.
- Mucilaginous compounds soluble in water; resinous compounds soluble in organic solvents.
- Epidermal cells are considered secretory in one sense because they secrete the Cuticle.
- **Types**
    - Trichomes
    - Glands
    - Nectaries
    - Hydathodes

9.1.1.1. Trichomes

- Essentially are outgrowths of the epidermis.
- Trichomes have unicellular or multicellular head composed of cells producing the secretion found on a stalk of non glandular cells.
- Secretory products diverse, from mucilage to resin.
- **Oil secreting trichomes**
    - Oil could be stored in vesicle in cytoplasm or stored in plastids (mint, geranium, and lavender).
    - Trichomes in leaves of insectivorous secrete mucopolysaccharides to trap insects and proteolytic enzymes to digest the insects and the secretion is trapped by nitrogenous material trapped on the surface.



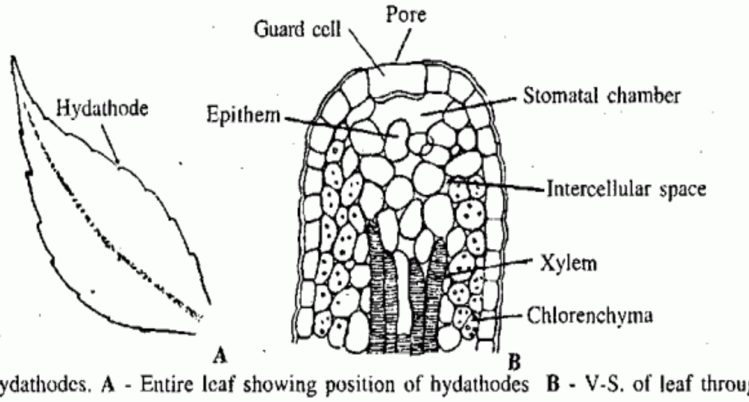


Fig. 4.4.2.2 : Hydathodes. A - Entire leaf showing position of hydathodes B - V-S. of leaf through hydathode.

9.1.1.2. Glands

Cytological there are two types of glands:

- Glands that secrete **hydrophilic substances** (abundance of mitochondria, ER and dictyosomes)
- Glands that secret **oil** (hydrophobic substances) [degeneration of the dense protoplast e.g. no dictyosomes).

9.1.1.2.1. Salt excreting glands

Vary in structure and method of secretion, carried to gland by transpiration stream. In *Atriplex* plant, bladder like cells attached to epidermis where ions are secreted into large central vacuole, after cells collapse, ions are deposited on the surface of the leaf.

9.1.1.2.2. Digestive glands

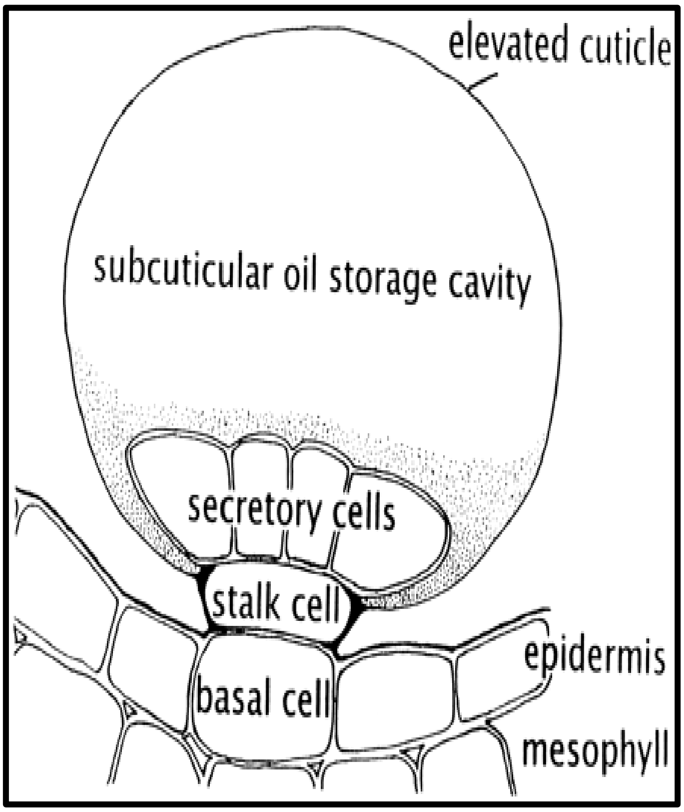
Insectivorous plants posses the power of digesting proteins from bodies of insects by secreting some digestive enzymes by means of gland or glandular hair .e.g. *Nepenthes*, *Drosera* (Sundew).

9.1.1.2.3. Glandular hair

These hairs are present in epidermal layers of leaves and are of various kinds. Contents of hairs are poisonous and are secreted by a gland at the base of a hair.

9.1.1.2.4. Hydathodes

- Involved in the secretion of liquid water, by a process called guttation.
- When ground and atmosphere are saturated, and thus not much transpiration, plants can excrete water and thus relieve excess pressure through hydathodes.
- But main function may be to redistribute minerals and other nutrients.


elevated cuticle
subcuticular oil storage cavity
secretory cells
stalk cell
epidermis
basal cell
mesophyll

Three types of hydathodes:

- Hydathode trichomes
- Active hydathodes
- Passive hydathodes

9.1.1.3. Nectaries

- May be glandular or hydathode-like; unicellular or multicellular.
- Main product is a sugar solution (nectar); conspicuous phloem and little or no xylem associated with nectarines.
- The secretory cells of nectarines have dense cytoplasm and small vacuoles often containing tannins, numerous of mitochondria and ER.
- Nectaries could be:

9.1.1.3.1. Floral

(Inside the flower), floral nectaries attract pollinators.

9.1.1.3.2. Extra floral

(Outside the flower) extra floral nectaries most common on leaves, attract ants, which help to protect the plant.

9.1.2. Internal Secretory Structure (embedded in various tissues)

- Secretory cells
- Secretory cavities and canals
- Laticifers

9.1.2.1. Secretory cells

Internal secretory cells have a wide variety of contents; secretory cells often appeared as specialized cells dispersed among other less specialized cells. They are then called **idioblast** or **excretory idioblast**.

9.1.2.1.1. Classification

Secretory cells are usually classified on the basis of their contents but many secretory cells contain mixture of substances and in many contents have not identified.

- **Oil Cells**

Some secretory cells contain oily contents. These cells appear like enlarged parenchyma cells and are known to occur in vascular or ground tissues of stem and leaf.

Examples: Plant families, as Calycanthaceae, Lauraceae, Magnoliaceae, Simarubaceae and Winteraceae have secretory cells with oily contents.

- **Resiniferous Cells**

Examples: Some dicotyledon families contain resiniferous cells as in Meliaceae.

- **Mucilage cells**

Mucilage cells also present often contain raphide crystals.

Examples: Cactaceae, Lauraceae, Magnoliaceae, Malvaceae, Tiliaceae.

- **Myrosin cells**

Cells containing the enzyme myrosinase have been identified. The myrosin cells may be elongated and even branched.

Examples: Present in families as Capparidaceae, Brassicaceae and Resedaceae.

- **Tannin cells**

In numerous secretory cells tannin is the most conspicuous inclusion. Tannin is common ergastic substance in parenchyma cells but some cells contain this material in great abundance and in addition to such cells are conspicuously enlarged the tannin cells often form connected systems and may be associated with vascular bundles.

Examples: Crassulaceae, Ericaceae, Fabaceae.

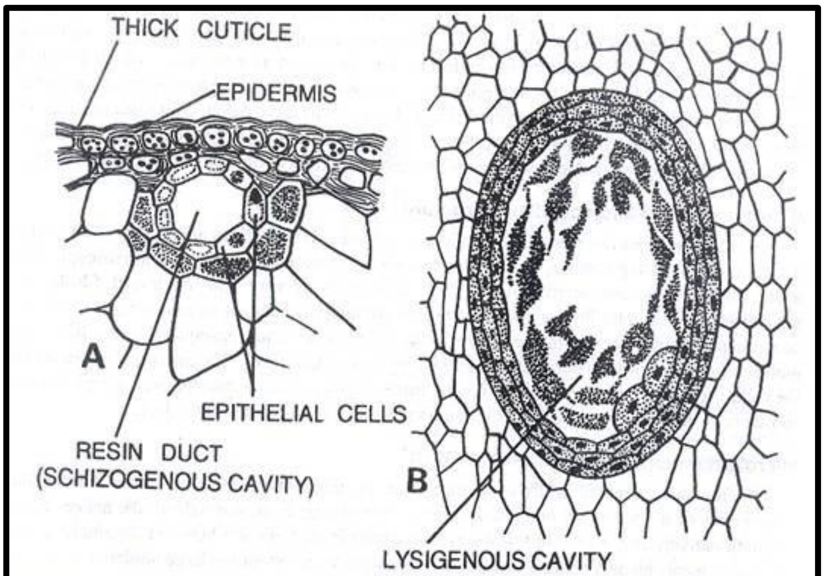


Fig. 34.17. Intercellular spaces. A, a schizogenous intercellular space in *Bryophyllum* stem; B, a schizogenous intercellular space in leaf of *Sequoia sempervirens*.

❖ **Crystal-Containing Cells**

Some excretory idioblast cells containing crystals. Crystal containing cells may not differ from other parenchyma cells but they also may be more or less specialized in form and contents. Such specializations are cystolith-containing cells and raphide cells.

Examples: In *Ficus elastic* the cysoliths occur singly in epidermal cells and each is attached by the mean of a cellulose stalk to the outer epidermal wall**.**

9.1.2.2. Secretary Cavities and Canals

9.1.2.2.1. Secretory Cavities

❖ **Schizogenous Cavities**

The most common intercellular spaces result from separation of cell walls from each other along more or less extended areas of their contact. In such cases, the intercellular substance dissolves partly and an intercellular space develops. Ultimately this becomes quite big in size and is known as schizogenous cavity.

Example: *Bryophyllum* stem, schizogenous oil gland in *Eucalyptus*

❖ **Lysigenous Cavities**

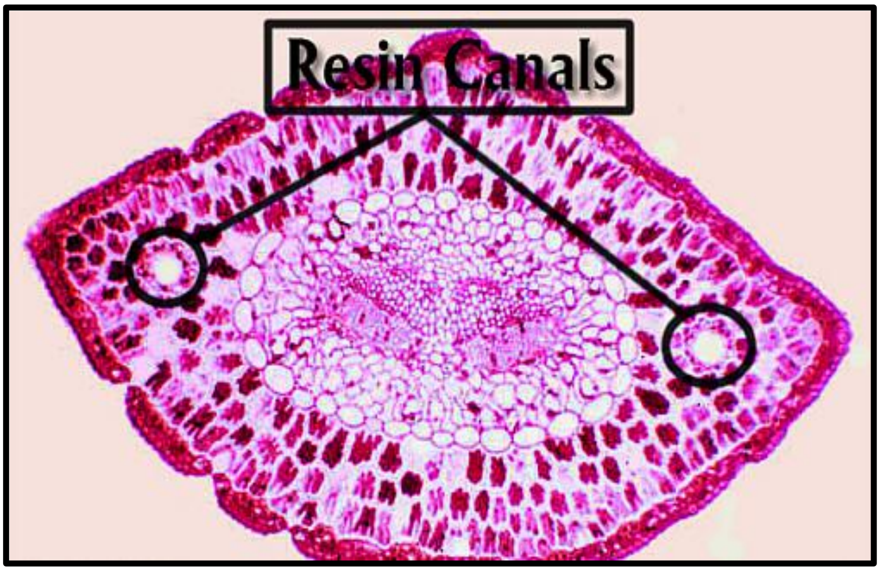
This type of intercellular space arises through dissolution of entire cells, which are therefore called lysigenous intercellular spaces (lysis, loosening, Greek). These cavities of intercellular spaces store up water, gases and essential oils in them.

Example: The examples are commonly found in water plants and many monocotyledonous plants. The secretory cavities in, Citrus and Gossypium, Sequoia are good examples.

9.1.2.2.2. Secretory Canals

❖ **Schizogenous Canals**

Schizogenous canals with resiniferous contents occur in Asteraceae and with unknown contents in Apiaceae. The copal-yielding secretory canals of certain tropical Fabales also arise as schizogenous spaces.



Cross Section of a Pine Needle: Note the Secretory (Resin) Canals

The best known schizogenous canals are the resin ducts of the conifers. Similar ducts in the dicotyledons are called gum ducts.

The conifer resin ducts occur in vascular tissues and ground tissues of plant organs and are structurally long intercellular spaces lined with resin producing epithelial cells.

- **Lysigenous mucilaginous canals**

The mucilage cell like virtually all secretory cells is a parenchyma cell, and even though it has only a thin primary wall, the wall is compact enough to prevent the mucilage from leaking out into the intercellular spaces.

The mucilage is produced by dictyosomes, packaged into dictyosome vesicles, transported to the exterior of the protoplast and deposited outside the cell when the vesicles fuse with the plasma membrane (this is a form of granulocrine secretion) retain water.

Examples: It is found in the bud scales of *Tilia cordata*, stem of a cactus (*Matucana grandiflora),* and stem of cactus (*Opuntia verschaffeltii*).

9.1.2.3. Laticifers

"Laticifers are cells or series of connected cells that contain latex. It is derived from word latex meaning juice in Latin. Latex is a whitish milky fluid**"**

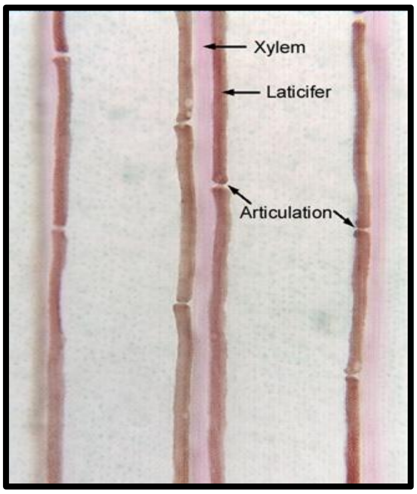
9.1.2.3.1. Composition

Latex consists of a liquid matrix with minute organic suspension. Matrix contains carbohydrates, organic acids, salts, alkaloids, sterols, fats, tannins and mucilage. The dispersed particles are terpenes, resins, camphors, carotenoids and rubber.

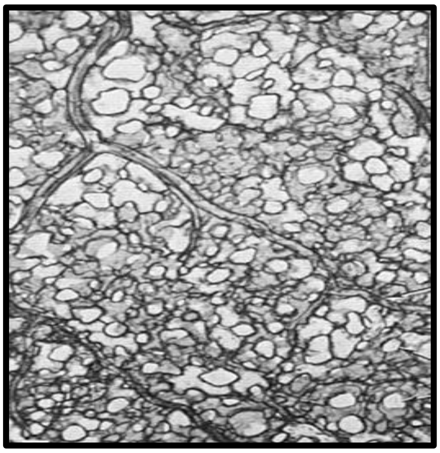
9.1.2.3.2. On the basis of Origin

Laticifers may be simple or compound in origin.

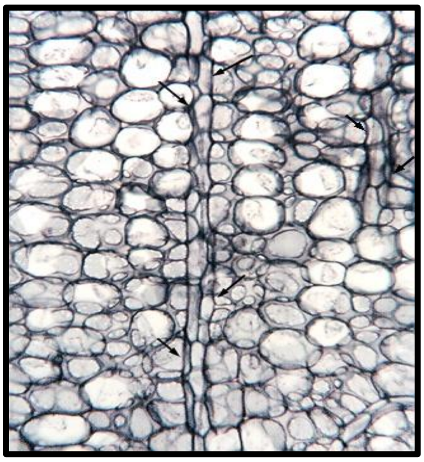
- **Simple Laticifers:** Derived from single cell.
- **Compound Laticifers:** Derived from series of cells.



Articulated Laticifers



Non-articulated branching laticifers of Euphorbia.



Laticifer in spurge stems (*Euphorbia tirucali*).

9.1.2.3.3. On the basis of Structure

Laticifers may be **articulated** and **non-articulated**.

- **Articulated Laticifers (Laticiferous vessel)**

Jointed compound in origin consists of chains of cells. End walls may be perforated or completely removed. Parietal nucleus some may be multinucleated.

- **Types of Articulated Laticifers**

Articulated laticifers may be simple or branched.

- **Simple Articulated Laticifers (Non-Anastomosing)**

They consist of single cell and are unbranched **.e.g.** *Ipomea, Convolvulus, Musa, Allium*.

- **Branched Articulated Laticifers (Anastomosing)**

In these, cell chains are connected with each other laterally and extensive branching present **.e.g.** *Lactuca , Manihot, Sonchus, Carica, Taraxacum, Chickorium.*

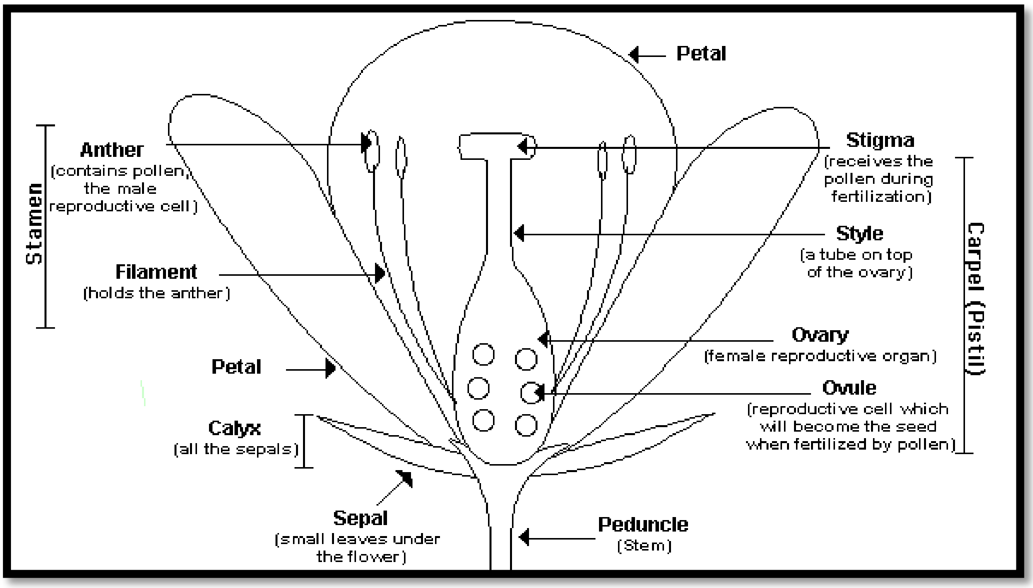
- **Non-Articulated Laticifers (Laticiferous Cells)**

They are enjoined, simple in origin. Through continuous growth develops into a tube like structure. Very elongate cells.

- **Types of Non-Articulated Laticifers**
  - **Simple Non-Articulated Laticifers**

Unbranched: Develops more or less straight tubes **.e.g.** *Vinca, Urtica, Cannabis*

Branched: Each cell forms branch repeatedly forming an immense system of tubes **.e.g.** *Euphorbia, Nerium, Ficus* etc



Labeled Sketch of L.S. of Flower

10. Anatomy of Monocot and Dicot Flower

Angiosperm (flowering plants) any member of the more than 300,000 species of flowering plants (division Anthophyta), the largest and most diverse group within the kingdom *Plantae*. Angiosperms represent approximately 80 percent of all the known green plants now living. The angiosperms are vascular seed plants in which the ovule (egg) is fertilized and develops into a seed in an enclosed hollow ovary. The ovary itself is usually enclosed in a flower, that part of the angiospermic plant that contains the male or female reproductive organs or both. The two main classes of angiosperms are monocot and dicot.

10.1. The Basic Flower Parts

The flower consists of many different parts. Some of the most important parts are being separated into both male and female.

10.1.1. Male Parts

10.1.1.1. Stamen

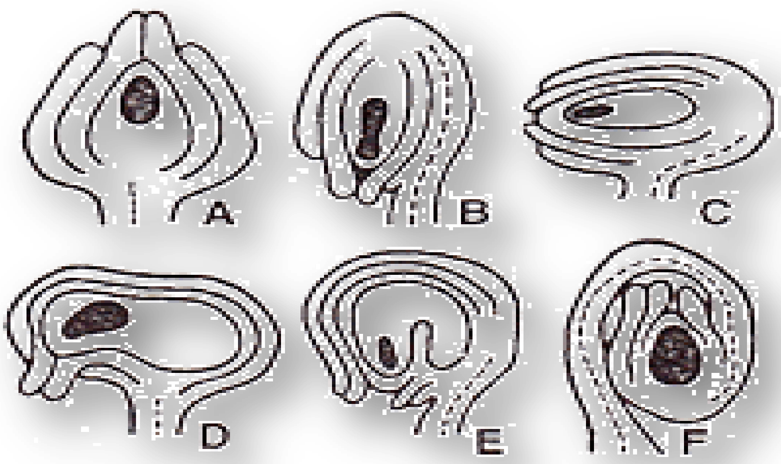
This is the male part of the flower. It is made up of the filament and anther; it is the pollen producing part of the plant. The number of stamen is usually the same as the number of petals.

10.1.1.2. Anther

This is the part of the stamen that produces and contains pollen. It is usually on top of a long stalk that looks like a fine hair.

10.1.1.3. Filament

This is the fine hair-like stalk that the anther sits on top of.



A. Orthotropous, **B**. Anatropous, **C**. Hemianatropous
D. Campylotropous, **E**. Amphitropous, **F**. Circinotropous

10.1.2. Female Parts

10.1.2.1. Pistil

This is the female part of the flower. It is made up of the stigma, style, and ovary. Each pistil is constructed from one to many rolled leaf like structures.

10.1.2.2. Stigma

It is one of the female parts of the flower. It is the sticky bulb that you see in the center of the flowers, it is the part of the pistil of a flower which receives the pollen grains and on which they germinate.

10.1.2.3. Style

It is another female part of the flower. This is the long stalk that the stigma sits on top of.

10.1.2.4. Ovary

It is the part of the plant; usually at the bottom of the flower; that has the seeds inside and turns into the fruit that we eat. The ovary contains ovules.

10.1.2.5. Ovule

The part of the ovary that becomes the seeds

10.1.2.5.1. Types of ovules

- **Orthotropous**

The micropyle, chalaza and funicle are in a straight line. This is the most primitive type of ovule e.g., Piper, Polygonum, Cycas etc.

- **Anatropous**

The ovule turns at 1802 angle. Thus it is inverted ovule. Micropyle lies close to hilum or at side of hilum e.g., found in 82% of angiosperm families.

- **Campylotropous**

Ovule is curved more or less at right angle to funicle. Micropylar end bends down slightly e.g., in members of Leguminosae, Cruciferae.

- **Hemianatropous**

Ovule turns at 902 angle upon the funicle or body of ovule and is at right angle to the funicle e.g., Ranunculus.

- **Amphitropous**

Ovule as well as embryo sac is curved like horse shoe e.g., Lemna, Poppy, Alisma.

- **Circinotropous**

The ovule turns at more than 3609 angle, so funicle becomes coiled around the ovule e.g., Opuntia (Cactaceae), Plumbaginaceae.

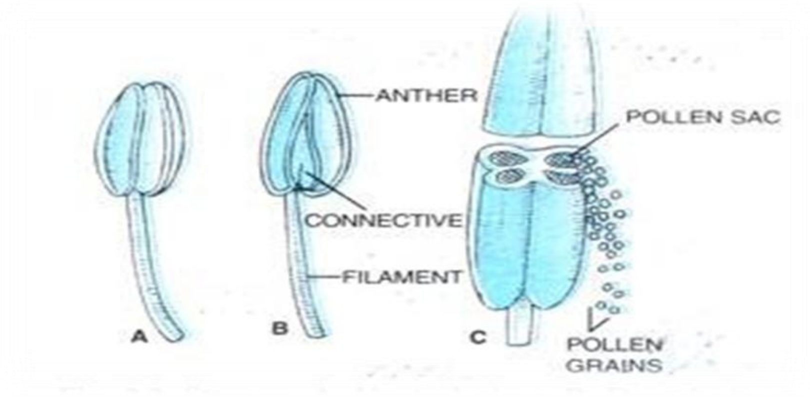
10.1.2.6. Megasporogenesis

There are plants in which several megaspore mother cells appear in a single ovule, but usually only a single mother cell develops in each nucleus. Generally the sporogenous cell develops directly from a hypodermal nucellar cell. This cell is distinguishable from the neighboring cells by its size, the size of its nucleus and the density of its cytoplasm.

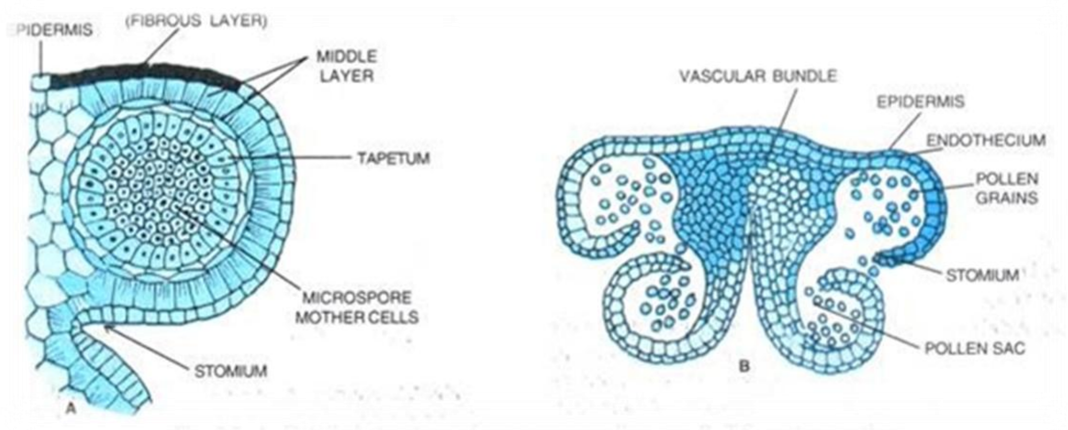
The megaspore mother cell undergoes a meiotic division which in most plants is accompanied by the formation of a separate wall on each of the four megaspores. The megaspores are arranged in one row, and generally the three closest to the micropyle degenerate and the remaining one enlarges.

10.1.3. Male Reproductive Organs

Stamens are the male reproductive parts of flowers. A stamen consists of an anther (which produces pollen) and a filament. The pollen consists of the male reproductive cells; they fertilize ovules.



Stamen: A. Ventral View**; B.** Dorsal View**; C.** Three dimensional cut section of Anther (Enlarged).



A. Detailed structure of one young pollen sac**;**

B. T.S. of a mature anther.

10.1.3.1. Stamens

- Stamens in a flower consist of two parts, the long narrow stalk like filament and upper broader knob-like bi-lobed anther.
- The proximal end of the filament is attached to the thalamus or petal of the flower. The number and length of stamens vary in different species.

10.1.3.1.1. Structure of Anthers

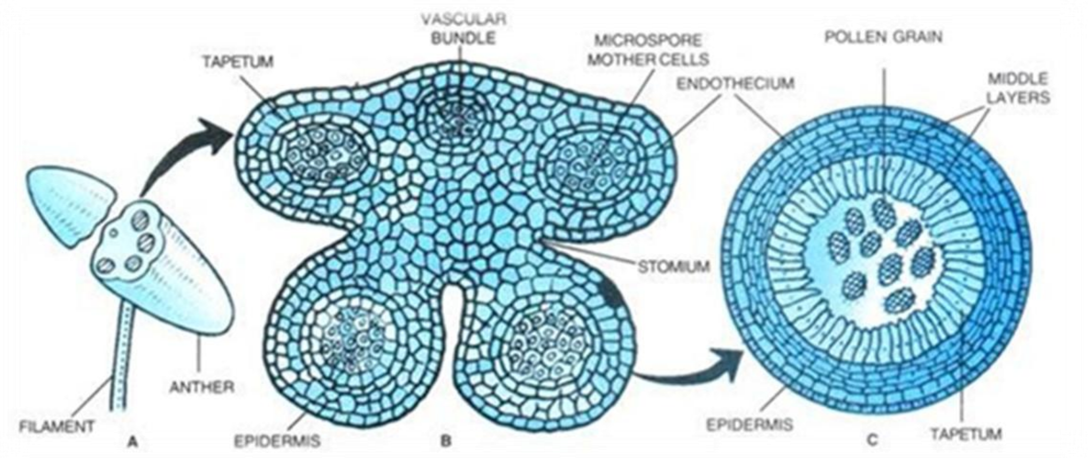
- Anthers are typically tetra sporangiate i.e. 4-microsporangia. It has a column of sterile tissue called connective in the center of the two anther lobes. Each lobe has two micro sporangia.
- Each microsporangium is separated by a strip of sterile tissue. At maturity separation between the two sporangia in one lobe breaks down.
- The anther later assumes a four-lobed shape. The hypodermal cells become prominent and constitute the archeosporium.

10.1.3.1.2. Composition of Anther wall

- Epidermis (function: protective, stimulates the tapetum).
- Followed by the endothecium-2-3 layers (function; dehiscence of anthers at maturity).
- A single-layered tapetum attains maximum development at tetrad sage of microsporogenesis. Surrounds the sporogenous tissue.

10.1.3.1.3. Structure of microsporangium (pollen sac)

Young anther while it is still in flower bud in T.S. reveals the presence of outermost epidermis. The outermost wall layer lying just below the epidermis is called endothecium or fibrous layer because wall (two radial and inner) develop fibrous thickenings on them except at the junctions of two pollen sacs. Below the endothecium, there are 1-3 middle layers of parenchyma cells.



T.S. of anther showing stomium and pollen grains

10.1.3.1.4. Tapetum

The cells of innermost wall layer are radially elongated and rich in protoplasmic contents. This layer is called tapetum. The tapetum forms the nutritive tissue nourishing the developing microspores. The cells of tapetum may be multinucleate or may have large polyploidy nucleus. The tapetal cells provide nourishment to young microspore mother cells either by forming a plasmodium (amoeboid or invasive type) or through diffusion (parietal or secretory type).

The pollen sac wall encloses a number of archeosporial cells that further forms microspore mother cells (microsporocytes). In the beginning microspore mother cells are polygonal and closely packed, but as the anther enlarges, the pollen sac becomes spacious and gets loosely arranged. A few microspore mother cells become non-functional and are finally absorbed by developing microspores.

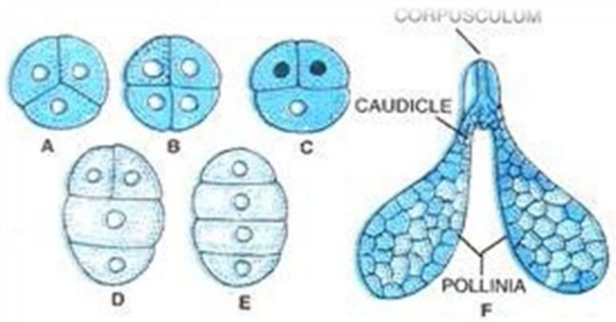
10.1.3.2. Microsporogenesis

During microsporogenesis the nucleus of each microspore mother cell undergoes meiosis and gives rise to four haploid nuclei (microspore tetrad). These four nuclei are arranged in a tetrahedral manner forming tetrahedral tetrad. The four microspores separate from each other, and each develops a characteristic shape or form which differs in different species of plants.

10.1.3.2.1. Structure of microspore (Pollen grain)

Pollen grains develop from the diploid microspore mother cells in pollen sacs of anthers. Typically, pollen grain is a haploid, unicellular body with a single nucleus. Pollen grains are generally spherical measuring about 25-30 micrometers in diameter. The outer surface of microspores may have spines, ridges or furrows which may vary in other ways in different species.

There may be oval, ellipsoidal, triangular, lobed or even crescent-shaped pollen grains. The cytoplasm is surrounded by a two layered wall. The outer layer **exine** is thick and sculptured or smooth. It is cuticularised and the cutin is of special type called **sporopollenin** which is resistant to chemical and biological decomposition.



Kinds of Microspore tetrads in angiosperms.
A—Tetrahedral tetrad; B—Isobilateral tetrad;
C—Decussate tetrad; D—F shaped tetrad; E—Linear
tetrad; F—Pollinium of Ak or *Calotropis*.

In insect pollinated pollen grains, the exine is covered by a yellowish, viscous and sticky substance called pollen kit.

Pollen grains are well preserved as fossils because of the presence of sporopollenin. At certain places the exine remains thin. The thin areas are known as **germ pores**, when they are circular in outline and germ furrows when they are elongated. The cytoplasm is rich in starch and unsaturated oils.

Uninucleate protoplast becomes 2-3 celled at the later stages of development. The branch of study of pollen grains is called **palynology**. In *Calotropis* and orchids, the pollen of each anther lobe forms a characteristic mass called **pollinium**. Each pollinium is provided with a stalk called **caudicle** and a sticky base called disc or **corpusculum.**

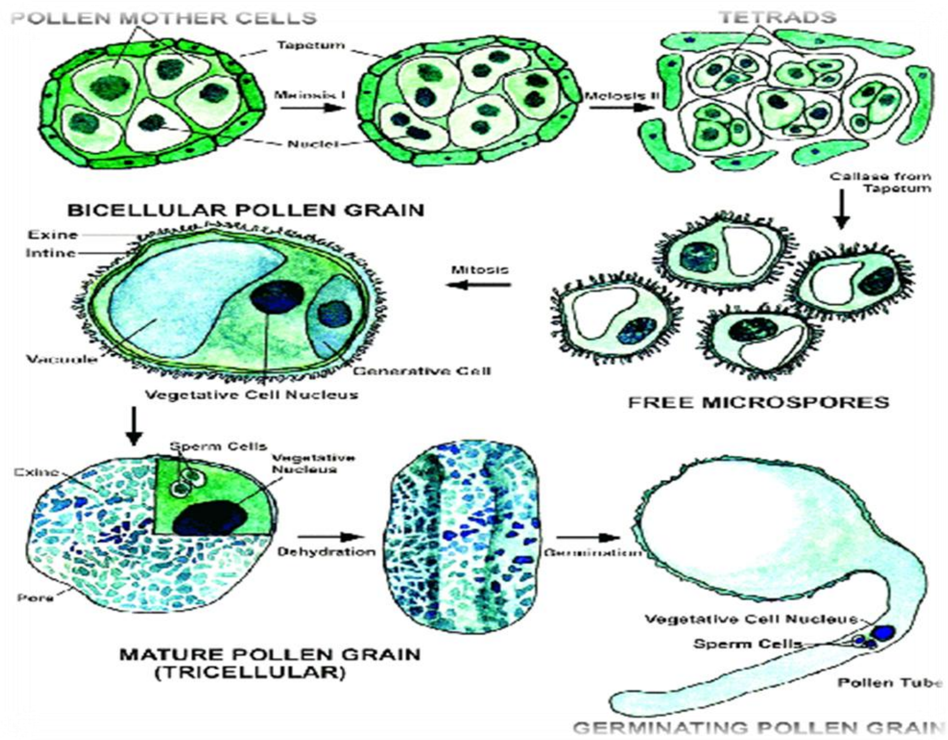
Reproductive cells produce by reproductive organ

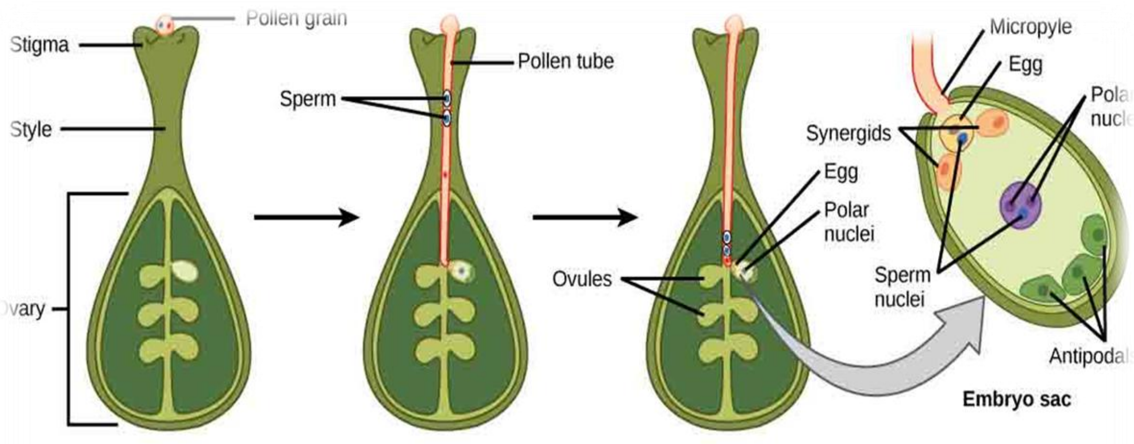
- Sporophyte dominant
- Gametophyte much suppressed

10.1.4. Male Gametophyte

i. It is derived from a pollen grain or microspore.
ii. It does not remain permanently embedded inside the microsporangium.
iii. It has two phases of growth— pre-pollination and post-pollination.
iv. Only pre-pollination growth occurs inside the microsporangium. The remaining occurs over the female reproductive organs.
v. The male gametophyte comes out of the confines of the pollen grain by forming a pollen tube.
vi. The male gametophyte is only 3-celled.

All the cells of the male gametophyte are functional. The tube cell is required to carry the two male gametes, both of which take part in fertilization. The remains of male gametophyte disintegrate after fertilization.





The pollen grain adheres to the stigma, which contains two cells: a generative cell and a tube cell.

The pollen tube cell grows into the style. The generative cell travels inside the pollen tube. It divides to form two sperm.

The pollen tube penetrates an opening in the ovule called a micropyle.

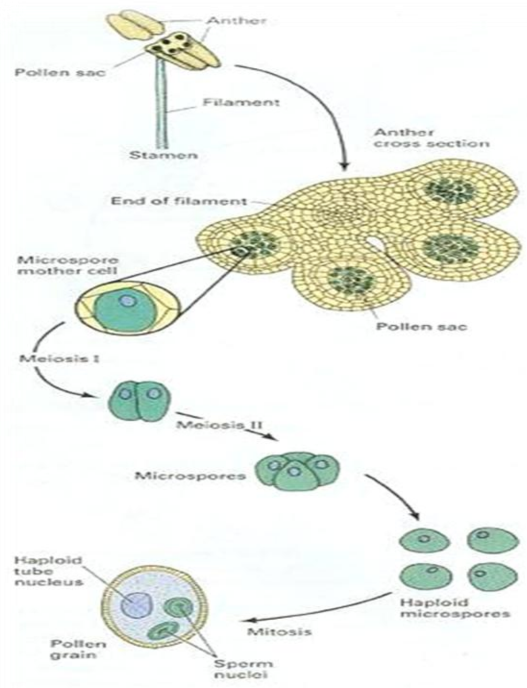
One of the sperm fertilizes the egg to form the diploid zygote. The other sperm fertilizes two polar nuclei to form the triploid endosperm which will become a food source for the growing embryo.

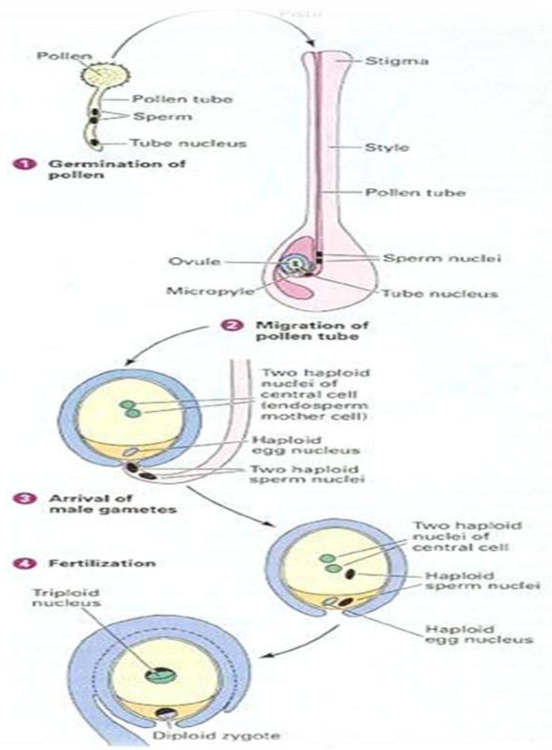
10.1.5. Female Gametophyte

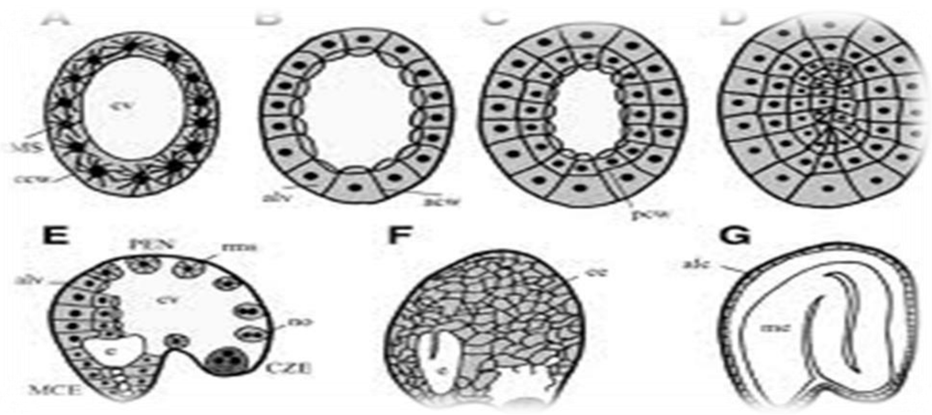
i. It is derived from a megaspore.
ii. The female gametophyte remains permanently embedded in the mega sporangium or nucellus.
iii. All the cells are formed in a single phase of growth.
iv. The whole growth occurs inside the mega sporangium.
v. The female gametophyte remains surrounded by the membrane of the megaspore.
vi. The female gametophyte is 7-celled.
vii. The antipodal cells do not seem to perform any function except absorption of nourishment from nucleolus in certain cases. Out of two synergies only one is required for receiving the pollen tube.
viii. After fertilization two new structures are produced both of which show active growth.

10.1.6. Difference between Microsporogenesis and Megasporogenesis

Microsporogenesis	Megasporogenesis
• It is a meiotic formation of haploid microspores from diploid microspore mother cell.	• It is a meiotic formation of haploid megaspore from diploid megaspore mother cell.
• The arrangement of microspores is generally tetrahedral.	• The arrangement of megaspore in a tetrad is commonly linear.
• All the four microspores of spore tetrad are functional.	• Only one megaspore of a spore tetra remains functional, other three degenerate.







Stages of Zygote development

10.1.7. Double Fertilization

The pollen tube enters the ovule through the micropyle and ruptures.

- One sperm cell fuses with the egg forming the diploid zygote.
- The other sperm cell fuses with the polar nuclei forming the endosperm nucleus. Most angiosperms have two polar nuclei so the endosperm is triploid (3n).
- The tube nucleus disintegrates

10.1.8. Development of Endosperm

Endosperm is the nutritive tissue formed as a result of triple fusion in the angiosperms. Endosperm is generally triploid meant for nourishing the embryo. Endosperm formation starts prior to embryo formation. The formation of endosperm starts with degeneration of the unclear tissue.

10.1.9. Types of endosperm

Based on the mode of development there are three types of endosperms:

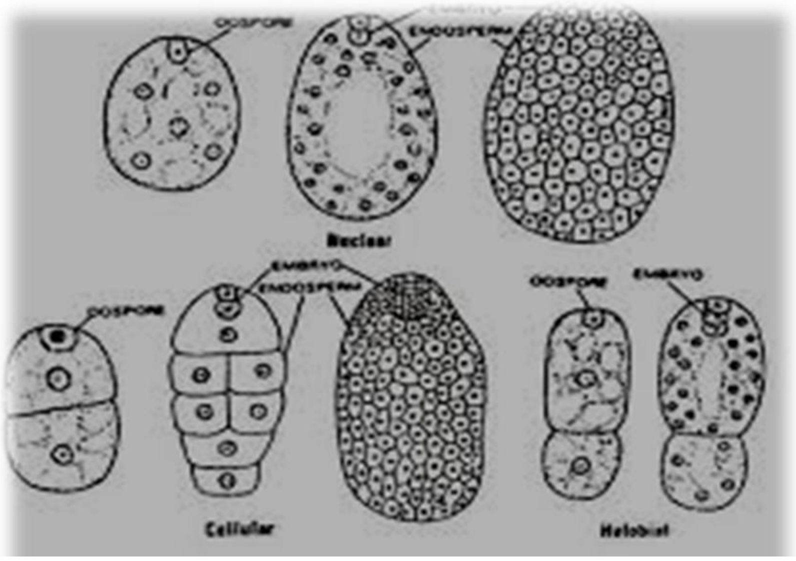
- Nuclear
- Cellular
- Helobial

➢ **Nuclear endosperm**

Primary endosperm nucleus divides repeatedly to form a large number of free nuclei. No cell plate formation takes place at this stage. A central vacuole appears later.

➢ **Cellular endosperm**

In cellular endosperm wall formation occurs immediately after division of the primary endosperm nucleus. Subsequent divisions also are accompanied by cell plate formation. As a result, the endosperm becomes cellular from the beginning. Example- Balsam, Petunia.



Types of Endosperm

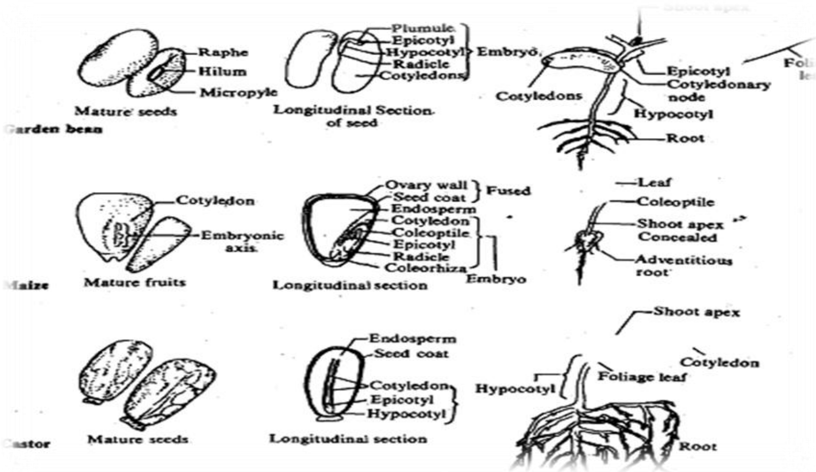


Diagram showing development of embryo of monocot plants

- **Helobial endosperm**

First division of the primary endosperm nucleus is cellular i.e. wall formation takes place following the first division. However, inside each of these newly formed cells, free nuclear divisions occur. But finally, the endosperm becomes cellular following the pattern of development of nuclear endosperms. Hence, helobial endosperm is the combination of cellular and nuclear endosperms.

10.1.10. Development of Seed

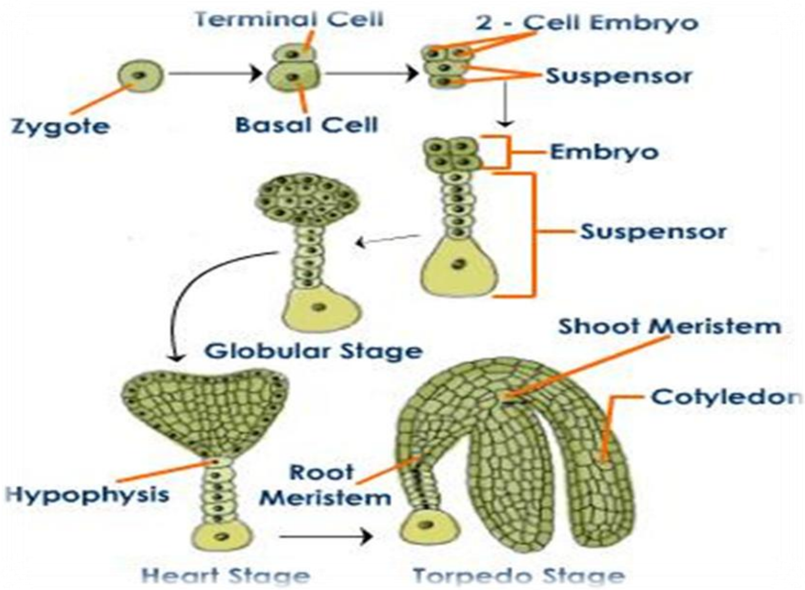
The seed is the mature, fertilized ovule. After fertilization, the haploid cells of the embryo sac disintegrate. The maternally derived diploid cells of the ovule develop into the hard, water-resistant outer covering of the seed, called the testa, or seed coat. The diploid zygote develops into the embryo, and the triploid endosperm cells multiply and provide nutrition.

The testa usually shows a scar called the **hilum** where the ovule was originally attached to the funicle. In some seeds a ridge along the testa called the **raphe** shows where the funicle originally was pressed against the ovule. The micropyle of the ovule usually survives as a small pore in the seed coat that allows passage of water during germination of the seed.

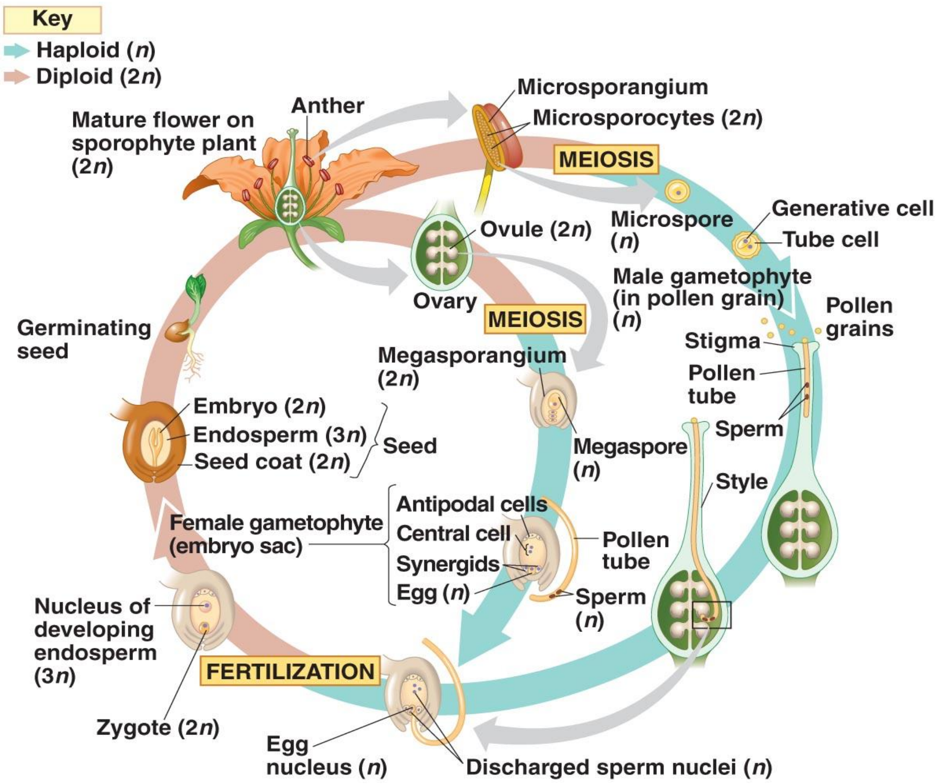
In some species, the funicle develops into a larger structure on the seed called an aril, which is often brightly colored, juicy, and contains sugars that are consumed by animals that may also disperse the seed (as in nutmeg, arrowroot, oxalis, and castor bean). This is distinct from the fruit, which forms from the ovary itself.

10.1.10.1. Development of Monocot embryo

The oospore divides to form a proembryo which is a filament consisting of three cells, a large **Basal cell,** a **middle cell** and a **terminal cell.** The basal cell is present towards micropylar end. It enlarges in size forming most of the suspensor. The middle cell divides repeatedly by a series of transverse and vertical division to produce several superposed tiers of cells which produce in succession next to the basal cell a few Suspensor cells, radical (root tip), hypocotyl and plumule. The terminal cell divides repeatedly to produce a single cotyledon which is terminal in monocots.



Development of dicot embryo



Diagrammatic representation of Life cycle of Angiosperms

The development described above represent development in one of the most primitive monocot family i.e. Allismaceae.

10.1.10.2. Development of Dicot embryo

The oospore elongates and divides transversely into a Suspensor Cell (towards micropylar end) and an embryo Cell directed towards the cavity of the embryo sac. The embryo cell enlarges and become spherical in outline. It divides by a a vertical division into four cells.

Two further divisions, one vertical and the other at right angles to the first one result in the formation of an Octant (8-cell embryo). This 8-celled stage of the embryo is called proembryo. The four octants next to the suspensor are the **hypobasal** or **posterior octants** while the four octants toward the chalazal end are **epibasal** or **anterior octants.**

The epibasal octant give rise to **plumule** and the **cotyledons** whereas the hypobasal octants from the **hypocotyls (rot end of the embryo)** except for its tip. Now all the eight cells of the octant periodically form an Outer and inner layers of cells. The cells of outer layer divide in anticline manner, forming a peripheral layer, the dermatogens from which epidermis is formed.

The cells of inner layer divide longitudinally and transversely forming the **periblem** (ground tissue) beneath the dermatogens and **plerome** (vascular tissue) in the centre.

The dermatogens are incomplete at the root end of the embryo, because the apex of the root ids formed from hypophysis of the suspensor. the hypophysis divide transversely, all the cell next to the embryo completes the periblem and the other undergoes two longitudinally divisions at right angles to each other forming a plate of four cells. Each of these four cells divide, the upper ties completes the dermatogens and the lower ties form root cap. As the growth progresses the free end of the embryo becomes Heart shaped and lobed.

Each lobe is cotyledon primordium. The plumule and the epicotyls is produced in the depression between the two cotyledons. The plumule in dicots is terminal. The cells of the lower end of the embryo forms hypocotyls carrying radical at it tip the suspensor cell divides transversely and produce 6-10 celled filaments, the suspensor pushes the embryo into the endosperm. The uppermost or distal cell of the suspensor is large and act as **Haustorium**, while the lowermost cell of the suspensor next to embryonic cell is known as hypophysis which by further division give rise to the radicle (embryonic root).

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