Ministry of Higher Education and Scientific Research
University of Baghdad
College of Science
Department of Biology

Theoretical plant anatomy 2022-2023

المرحلة الثانية - الدراسة الصباحية والمسائية
الفصل الدراسي الاول

تدريسي المادة :

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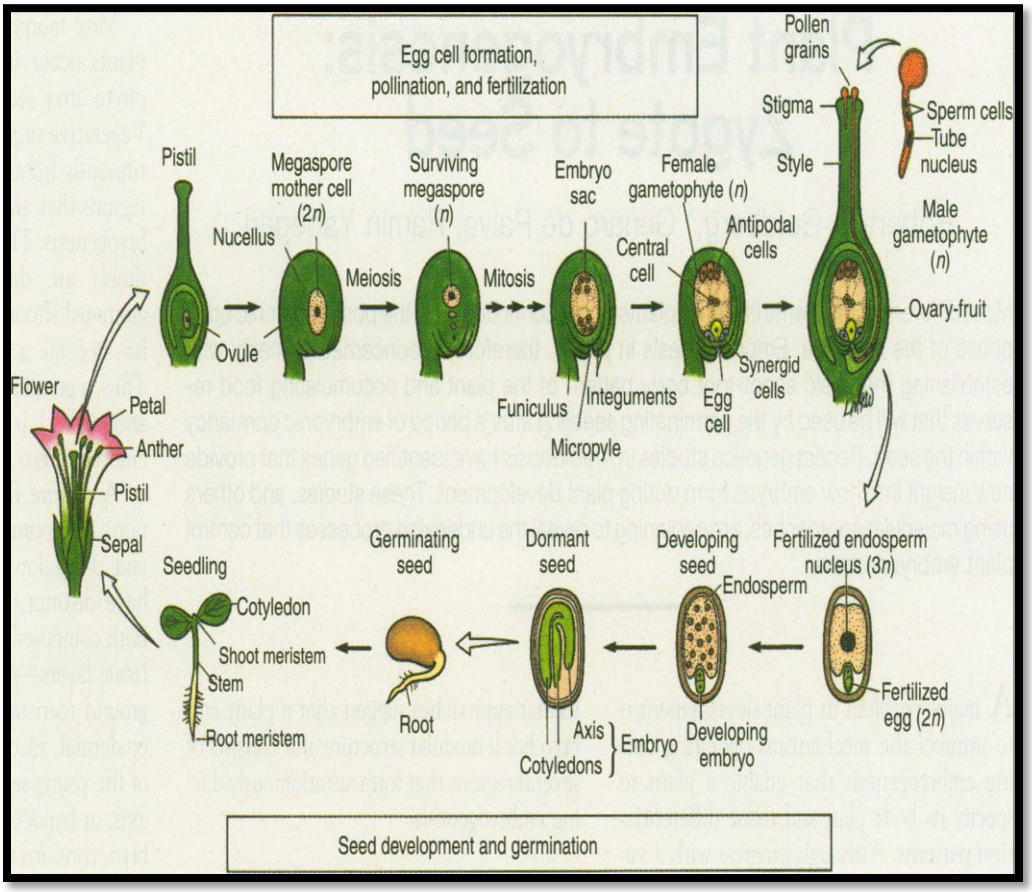
Lecture: 1

Plant anatomy

Is the study of internal structure of plant body, in general plant body composed of root system and shoot system, shoot system included vegetative and reproductive parts.

The flowering plant life cycle is divided to haploid and diploid generation. The haploid generation (gametophyte) found after mitosis and meiosis then differentiate in to either pollen grain (male gametophyte) or embryo sac (female gametophyte), each male and female gametophyte derived from specialized cell (spore mother cells) found within the reproductive organ of the flower (stamen, pistil). The diploid stage (sporophyte) started after the fertilization and formation of zygote which developed to seed then seed germination to form the seedling to mature plant with vegetative parts (root, stem, leaves) and reproductive parts, the flower which contain the reproductive parts (stamen, pistil) to started another life cycle.



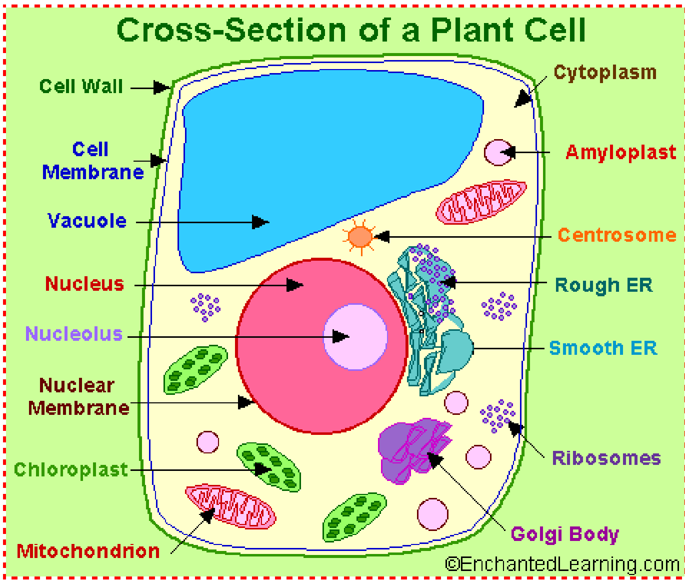
The Plant cell

Cell may be defined as a protoplast with or without a non-living envelope (cell wall) and consisting of protoplasmic components and non protoplasmic materials, cell is the unit of structure and function.

Plant cell consists of two main parts ,cell wall and protoplast

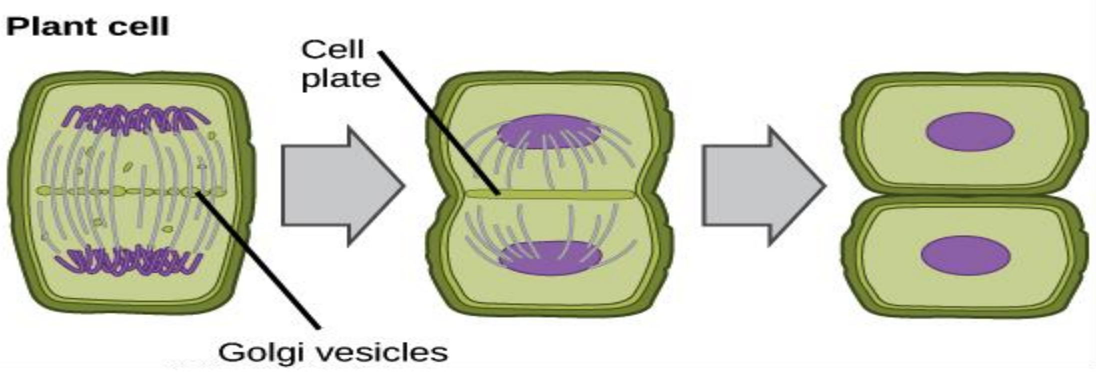
Cell wall in plant cell can be described as a thick ridged real dead wall which characterized by existence of cellulose of most plant cells but it may be absent in few plants like motile spores in algae and fungi and the reproductive cells in lower and higher plants .

Cell walls have supportive and protective functions, both as components of living cells and as remainders of non-living cells, the cell wall determines the shape of the cell and texture of the tissue.



Steps of wall formation

Cell wall is formed during the stage of cell division in late anaphase or telophase, when the chromosomes appears in the poles of the cell ,a barrel shape structure is formed in the cell called phragmoplast , followed by precipitation of Ca and Mg pectate in the center as a cell plate and grows centrifugally when the cell plate reach the cell sides it refers to middle lamella .



Simple middle lamella

In some cells the middle lamella can be recognized from other part of the wall, it consists of Ca and Mg pectate, simple middle lamella found in meristematic cells and some living cells, its characterized by its isotropic optically inactive.

Compound middle lamella

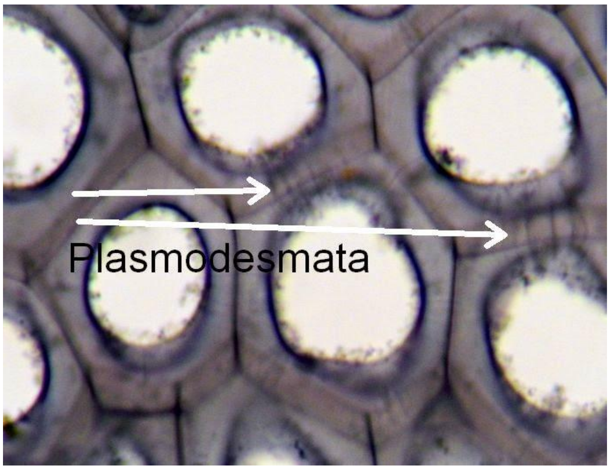
When the middle lamella fuses with some or all the primary wall or with the primary wall and some of secondary wall, so the simple middle lamella called compound middle lamella , thus :

Compound Middle Lamella may be 3-layers(2primary walls from 2 cells + middle lamella)

Or 5-layers (2primary walls+ compound middle lamella+2 secondary wall).

Compound Middle Lamella may be found in cell that become dead at maturity, as fibers and treachery elements (vessels and tracheids). Compound middle lamella is anisotropic and optically active.

The primary wall

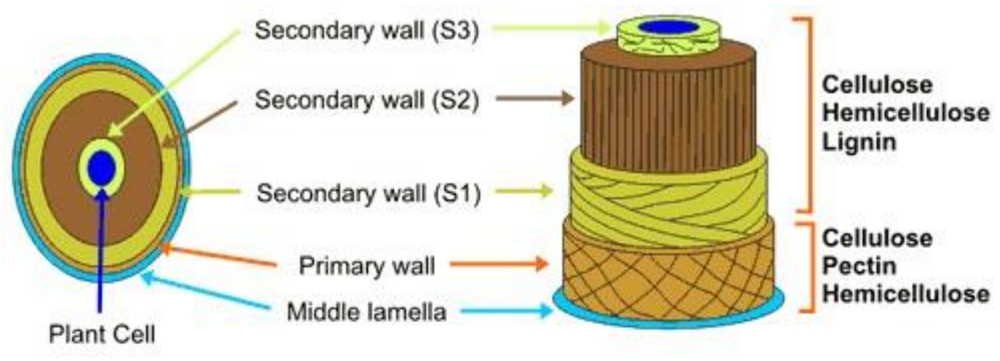


In general its thinner than secondary wall, composed from pectic substances, cellulosic microfibrils randomly arranged and noncelulosic polyscharide. Found in different living cells, the primary may become thick as in collenchyma cells in stems, and endosperms of some seeds - thickening because of increase in amount of cellulose and non-cellulosic components and water as in collenchyma tissue or as a results of storage function as in endosperm of Palme seed. The primary wall contains primary pit fields and plasmodesmata and usually has pectic substance.

The secondary cell wall

The secondary cell wall is a structure found in many plant cells, located between the primary cell wall and the plasma membrane. The cell starts producing the secondary cell wall after the primary cell wall is complete and

the cell has stopped expanding. Secondary cell walls provide additional protection to cells and rigidity and strength to the larger plant. These walls are constructed of layered sheaths of cellulose microfibrils, The inclusion of lignin makes the secondary cell wall less flexible and less permeable to water than the primary cell wall. The secondary cell wall consists primarily of cellulose with polysaccharides, lignin, and glycoprotein, while Pectins is absent from the secondary wall, and unlike primary walls, no structural proteins or enzymes have been identified. Because of the low permeability through the secondary cell wall, cellular transport is carried out through openings in the wall called pits.



Lecture 2:

The Pits

are thin portions of the cell wall that adjacent cells can communicate or exchange fluid through.

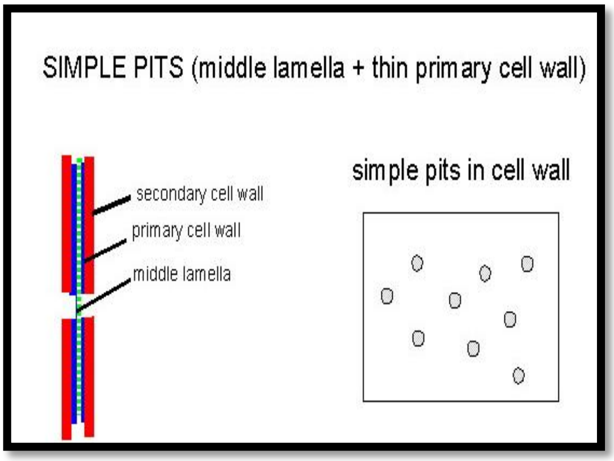
Pit: are depressions or cavities present throughout the wall.

Pits are characteristic of secondary cell walls. Pits are composed of three parts: pit chamber, pit aperture, and pit membrane. **pit chamber** is hollow area where the secondary layers of the cell wall are absent**. pit aperture** is the opening that joins the pit with the cell cavity. **pit membrane** is primary cell wall and middle lamella.

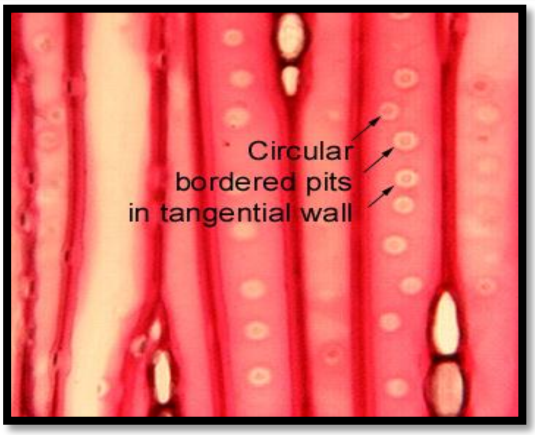
Types of pits

1-primary pit field : An area of greatly reduced thickness in the primary wall of a plant cell, often penetrated by plasmodesmata, which connect the cytoplasm of adjacent cells, Its function is conduction of water , materials dissolved in water and also conduction of impulse.

2-Simple pit : A pit pair in which the diameter of the pit chamber and the diameter of the pit aperture are equal in secondary walls present in fibers, xylem parenchyma, tracheary element, Elder pith (*Sambcus*)



3-Bordered pits: A pit pair in which the pit chamber is over-arched by the cell wall, creating a larger pit chamber and smaller pit aperture. they are characterized of wall tracheids .Its contains parts:



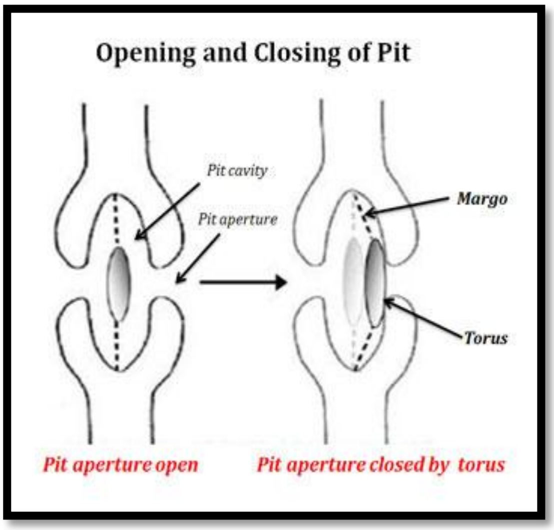
a-pit aperture

b-pit border

c-pit chamber

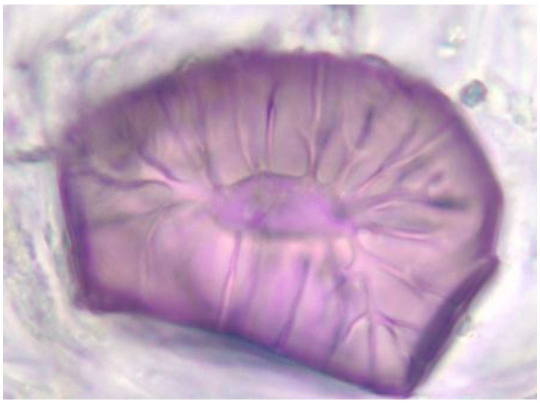
d-pit membrane

e-torus : a swollen part of pit membrane which consist of materials (middle lamella and some of primary wall) it is present in the bordered pit of the following plants: Coniferales, Gentiles, Gingoales.



4-Ramiform pit :Occur in cells with thick secondary wall,

They appear in the form of canals which are usually branched as in barchysclerieds.

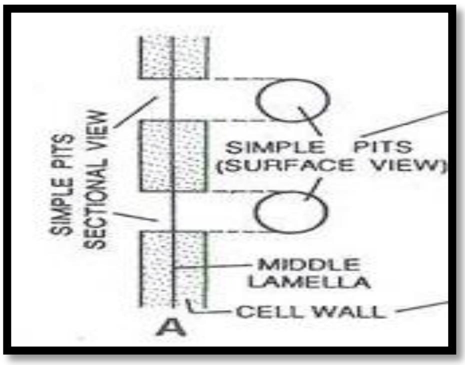


Pit pairing

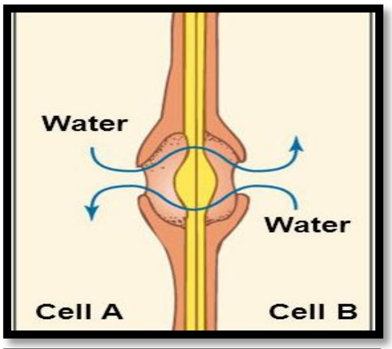
Each pit has a complementary pit opposite of it in the neighboring cell , usually a pit on one side of the wall pairs with another pit of same type or different type on the other side of the wall.

Types of pit pairs

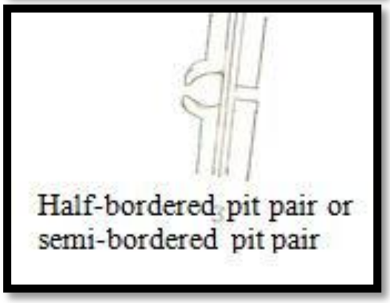
1-Simple pit pair: A simple pit in one side of the wall associated with another simple pit on the other side of the wall.



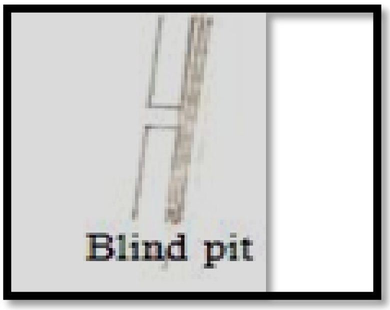
2-Bordered pit pair : A bordered pit in one side of the wall is associated with another bordered pit



3-Semi-bordered pit pair: A bordered pit of the wall associated with simple pit on the other side of the wall ‹found in the wall separating tracheary elements from xylem parenchyma

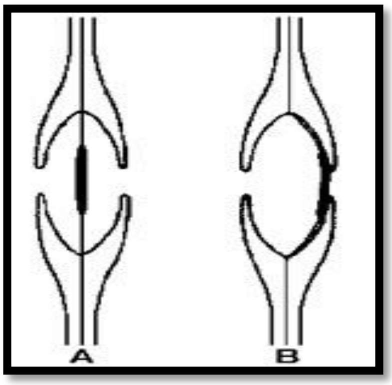


4-Blind pit : A pit on one side of the wall not associated with another pit on other side of the wall , found in walls of parenchyma adjacent to intercellular space and also found in wall separating tracheary element from the fiber.



5-Unilaterally compound pitting : pitting in plant cell walls in which one large pit occurs opposite two or more small pits in an adjacent cell.

6- Aspirated pit : bordered pit pairs having torus in which the torus is displaced to closed one of the pit aperture. So , the aspirated pit in **non functional** because the tours is thick and prevents movement of dissolved materials in water.



Lecture 3:

Plant cell contents

Living components of cell plants

1) **Cytoplasm:** The substance except nucleus surrounded by the plasma lemma of cell is known as cytoplasm.
2) **Endoplasmic reticulum:**

Cytoplasm contains an extensive network of membrane enclosed spaces; these spaces along with the membranes enclosing them are known as endoplasmic reticulum (ER). **Functions:**

1) It provides structural base for protein, lipid and phospholipids synthesis.

2) It sorts proteins according to their destination.

3) It provides a control passage for the export of mRNA molecules from nucleus to rough endoplasmic reticulum.

3-Ribosomes:

Ribosomes are particles of about 200 A° diameter; they are composed of RNA and protein. Generally ribosomes are attached to the outer surfaces of ER membranes. This converts smooth ER elements into rough ER. **Function:** Ribosomes are essential for protein synthesis, as mRNA can support protein synthesis only when they are attached to ribosomes.

Ribosomes may be exist :

1-free in cytoplasm.

2-Associated with the endoplasmic reticulum.

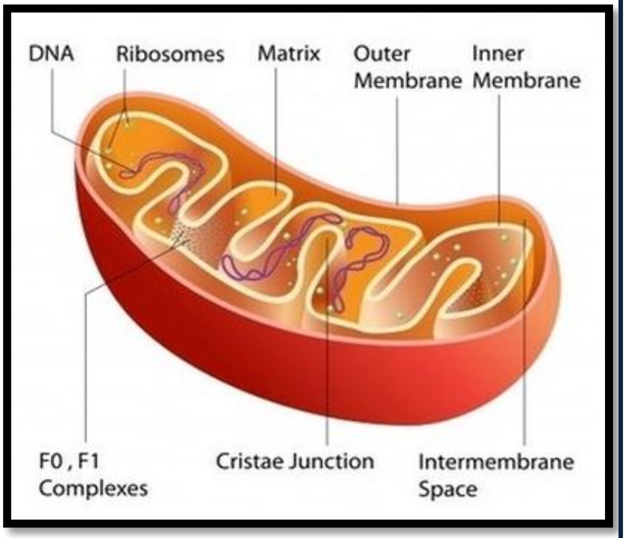
3-In some organelles in plastids and mitochondria.

4- **Golgi body (golgi apparatus) = Dictyosomes**

Golgi bodies originate from ER elements its present in both plant and animal cells . **Function:** major function of Golgi bodies is protein sorting , secretion . in plant cells they play important role in the formation of the cell wall.

5- Lysosomes: formed by budding of golgi bodies and they contain hydrolytic enzymes. Function: The function of lysosomes is to digest (lyses) the food particles ingested by a cell and also to cause autolysis of cells, if required.

6-Mitochondria: an organelles surrounded by double membrane the inner membrane is folded to form the cristae, mitochondria is characteristics of Eukaryotes (plant and animals) and its contain DNA . **Function:** The main function of mitochondria is the oxidation of carbohydrates, amino acids and fatty acids and the production of ATP.



7-**Plastids :** living organelles surrounded by a double membrane, ATP generated from ADP by photophsphorylation and have capable of division, It contains DNA and RNA ,enzymes, proteins and lipids, plastids are lacking in prokaryotes and present in some plant cells but lacking in fungi and animals cells. In meristematic cells plastids are present in the form of protoplastids.

Types of plastids

1-Leucoplast: Colorless plastids includes amyloplast (store starch) and elaioplast (store oil).

2-Chloroplast (green plastids) its function is photosynthesis.

3-Chromoplasts.its primary function is carotenoides accumulation.

8-**Nucleus:**

It is a denser, rounded or spherical protoplasmic body enclosed in the protoplasm. Its shape and size differs greatly according to size of cell. It is composed of following organelles

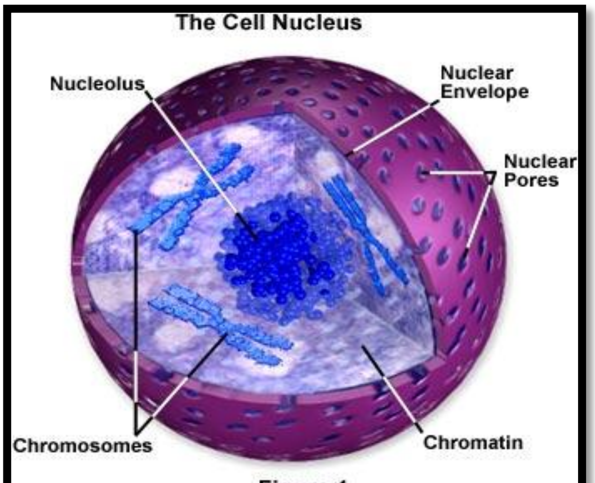


Figure 1

1) **Nuclear Membrane**
2) **Nucleoplasm**
3) **Chromatin network**
4) **Nucleolus**

Functions of nucleus:

1. It is responsible for life.

2. It is controlling centre of all the vital activities of the cell.

3. It takes direct part in growth and cell division.

4. It contains chromosomes and genes (hereditary material).

Non-living components

included crystals, starch grains, aleuronic grains and vacuoles.

1- Starch grain : considered as a stored materials, plastid which synthesize and store starch is called Amyloplast .

Starch grains classified according to the following bases:

a- Shape and position of the hilum (hilum is the center of the starch grain).
b- The number of hila.
c- Size and shape of starch grain.
d- Starch stratification (layers).

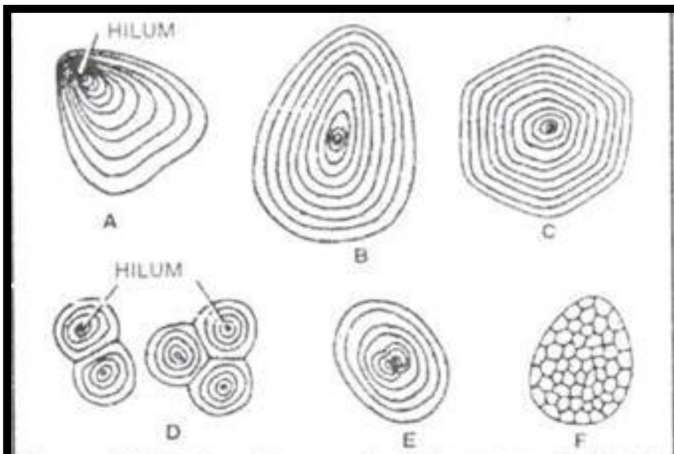


Figure 3.48 Different types of starch grains. **A.** Simple eccentric starch grain of potato, **B.** Concentric starch grain of wheat, **C.** Concentric starch grain of maize, **D.** Compound starch grain of banana, **E.** Semicompound starch grain of potato, **F.** Compound starch grain of oat.

Position of hilum may be central or eccentric .

According to Numbers of hila starch grains classified to:

1-Simple starch grain having one hilum.

2-Compound starch grain have two hila.

3-Semi-compound starch grain having 2 or more number of hila separated by incomplete septum.

2-Aleurone grains: grins contain protein as stored materials .

Aleuronic grains may be differ in their structure according to which plant belong .These grains may be simple or may contain inclusions of globoids and crystalloids of protein. found in many seeds ,embryonic cells and endosperms.

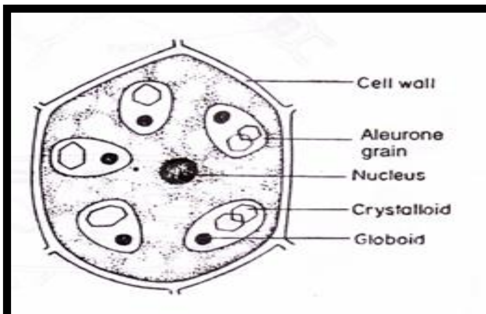
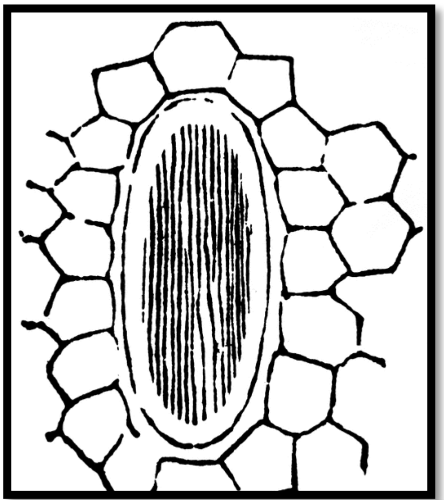


Fig. 3.7 : Cell showing *Aleurone* grains of Casterbean (*Ricinus* sp.)

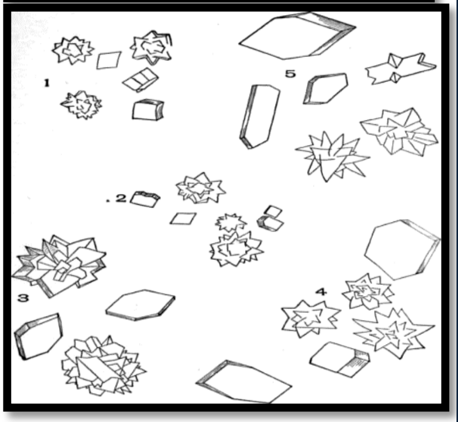
3-Crystals

Non-living components produced in the cells as waste products , most crystals are composed of Ca-oxalate (Oxalic acid is highly poisoning).

Types of crystals



1-Raphid crystals are needle-shaped crystals of calcium oxalate as the monohydrate or calcium carbonate , found in more than 200 families of plants (*Mirabilis* and banana). Both ends are needle-like, but raphides tend to be blunt at one end and sharp at the other.



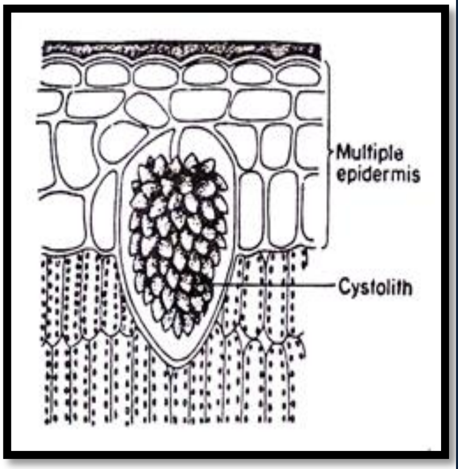
2-Druses crystals

crystals are aggregated into roundish stellate bodies within the idioblasts. These are called sphaeraphides or druses.(like star).

Ex. *Tilia*.

3-Prismatic crystals : There are solitary of rhombohedrons or octahedrons crystalline forms.

Ex. in onion scaly leaf.



4-cystolith crystals: **(**calcium carbonate crystals). botanical term for outgrowths of the epidermal cell wall, usually composed of calcium carbonate, formed in a cellulose matrix in special cells called lithocysts, generally in the leaf of plants. ex. Cucurbitaceac and Moraceae family as in *Ficus* leaf.

4-Vacuoles: a cavities within the cytoplasm filled with a liquid .vacuoles are vary in shape and size in relation to the stage of development and metabolic state of the cell.

Its function is store food and waste materials of the cell, regulates osmotic pressure of the cell.(shrink or turgid) and gives support to young organisms.

Lecture: 4

Tissue

tissue: a group of cells of similar shape and size which all have the same function. ex: mesophyll and vascular tissue.

organs: a group of cells of tissue forming part of an organism with a special function. plant organs usually have several different kinds of tissue ex: a leaf, stem.

Classification of tissues

According to the ability of cell division. Tissues can divided to:

1-meristematic tissue 2-permanenet tissue

1-Meristematic tissue

meristem is the tissue in most plants containing undifferentiated cells (meristematic cells), found in zones of the plant where growth can take place. Meristematic cells give rise to various organs of a plant and are responsible for growth.

Characteristics of Meristematic Tissue:

1. They are composed of immature cells.

2. lacking the intercellular spaces.

3. Cells are oval, rounded or polygonal in shape.

4. Cells are always living and thin walled.

5. Cells are rich in cytoplasm with minute vacuoles.

6. Cell is diploid and shows mitotic cell division.

7. Cell is lacking the reserve food materials, ER and plastids.

Functions of Meristematic Tissue:

1. Meristems are actively dividing tissues of the plant.

2. They are responsible for primary (elongation) and secondary (thickness) growth of the plant.

3. All new organs and their growth occur by the division of meristematic tissue.

4. Secondary tissues such as, wood, cork are also formed due to activity of meristematic tissue.

Classification of meristematic tissue

1-According to its position in plant body

a-Apical meristems.

b-Lateral meristems.

c-Intercalary meristems.

2-According to their origin

a-Primary meristem(during the primary growth of the plant body.

b-Secondary meristem(during the secondary growth).

Vascular cambium → Secondary xylem, Secondary phloem

Cork cambium → Periderm

Periderm consists of → Cork, Cork cambium, Phelloderm

3-According to their function: The tissue produced from them, all plants contain a meristematic tissue called promeristem which found in shoot apex and root tip and this meristem derived from a meristematic cell in the embryo

Apical meristem

The shoot apex: The shoot apical meristem is the terminal meristem of the shoot which is the continuing embryonic region of the plant. It continuously gives rise to new cells and tissues from which new organs are formed. It is self determining and autonomous organizing centre of the plant The following are most important theories concerning the shoot apex:

1-**Single apical cell theory**

Presence of a single tetrahedral apical cell in the shoot apex of most vascular and lower plants prompted Nageli (1878) to postulate the apical cell theory. According to this theory a single apical cell is the structural and functional unit of apical meristem and it governs the whole process of growth.
Such a single apical cell occurs in algae and majority of bryophytes and pteridophytes. A single apical cell was also believed to be present in seed plants.

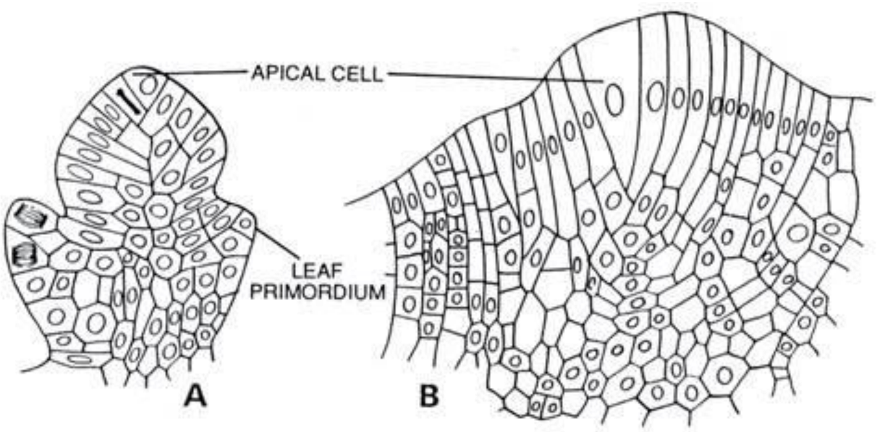
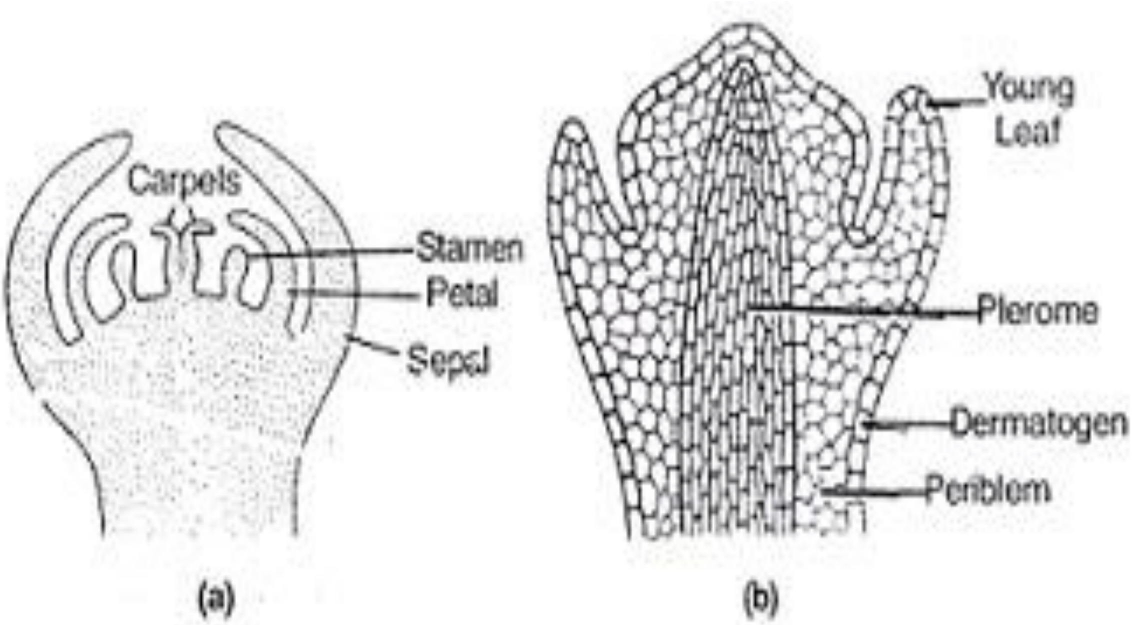


Fig. 36.1. Apical meristems. A, shoot apex with apical cell of *Equisetum* shoot; B, shoot apex of *Pteridium*.

2-Histogen theory (Hanstien theory)

It was proposed by Hanstein (1870). According to this theory, the shoot apical meristem consists of three distinct meristematic zones or layers (or histogens).
(a) **Dermatogen:** Outermost layer and it forms epidermis and epidermal tissue system.
(b) **Periblem:** It is the middle layer which gives rise to cortex and

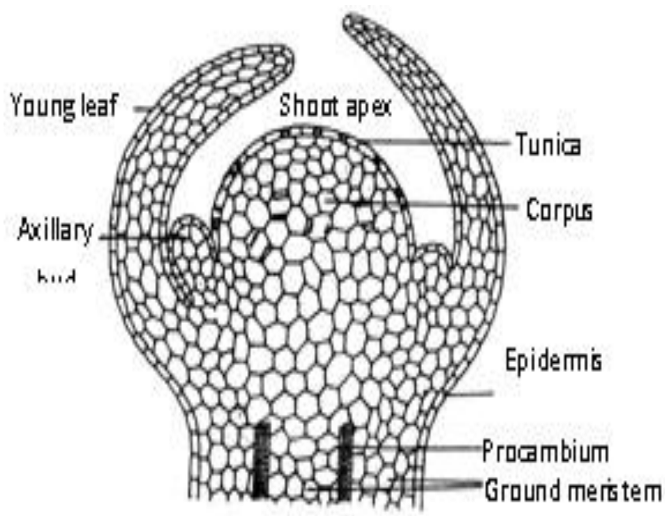
endodermis.
(c) **Plerome:** The innermost layer forms pith and stele.
(d)Clyptrogene: The inner most layer of root cap.



(al Reproductive apex (Diagrammatic)
(b) Vegetative shoot apex showing histogens

3-Promeristem theory
In this theory the shoot apex and also root apex posses a least differentiated region , located at apex of the shoot .
The promeristem region is differentiated into3 primary meristems:
1-Protoderm: formed the epidermis in stem .
2-Procambium: formed primary phloem and primary xylem.
3-Ground meristem: formed the cortex and the pith.

4-Tunica corpus theory (Schmidt theory 1924)
This theory was proposed by Schmidt (1924). According to this theory, the shoot apex consists of two distinct zones.



(a) **Tunica:** It is mostly single layered and forms epidermis. The cells of tunica are smaller than corpus. The tunica shows only anticlinal division and it is responsible for surface growth.

(b) **Corpus:** It represents the central core with larger cells. Corpus shows divisions in all planes and it is responsible for volume growth.

5-Cytohistologic zonation (growth of zones theory)

Widely accepted cytohistological zonation, it was introduced by Foster (1943) for some Gymnosperms, e.g. *Ginkgo biloba*, wherein he recognized four zones. This zonation is based not only on planes of division, but also on cytological and histological differentiation and degree of meristematic activity of component cell complexes. The different zones recognized were as:

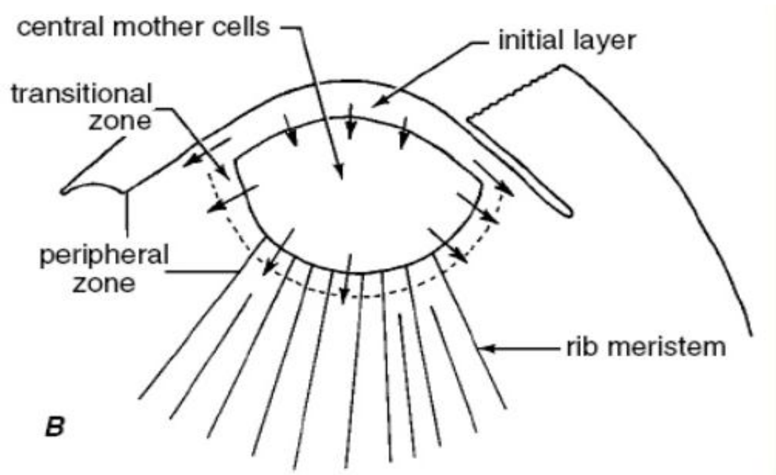
1- Apical initial zone –terminating the axis

2-Central mother zone (inner zone)- appears directly below the distal zone; usually becomes the pith

3- Peripheral zone or outer zone (flank meristem) –shows the smallest dimensions and densest cytoplasm; most meristematic Transition zone –like a cambium; actively dividing derivatives of the distal zone

4-Rib meristem located under the central mother cells and responsible for the formation of pith.

. Cyto-histologic zonations based on: – Planes of division – Degree of meristematic activity – Cytological and histological differentiation Shown in the apex of Gymnosperms



6-Theory of waiting meristem

Proposed by Buvent 1952 and it involves that

1-At that shoot apex there is a meristematic region called waiting meristem.

2-No cell division occurs in the waiting meristem as long as the apex in the vegetative state .

3-As soon as the vegetative apex starts to become converted into reproductive apex, the cell in waiting meristem becomes active abd being to divide.

Root apex

The root apex shows different growth patterns , as comparative with shoot apex, the root apex have some differences :

Theories of root apex

1-Single apical initial apex

Ex. lower vascular plant as in *Equisetum*, derivative are formed from 4 sides and in all directions.

2-One apical zone

The cells of this zone divide and give rise to epidermis , cortex ,central cylinder ,root cap ,ex. *Allium cepa* , *Viciafaba* .

3- Two set of initial

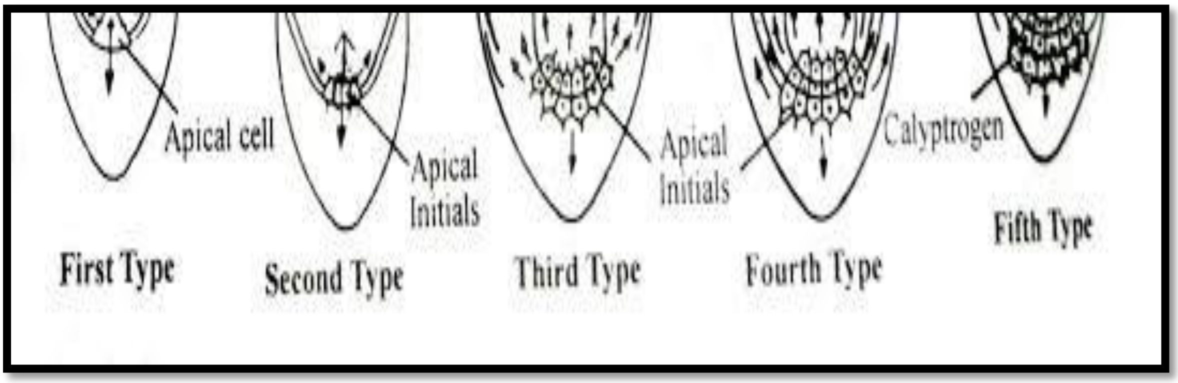
In some gymnosperms and some dicots .

4- Three initial zones.

Ex. *Zea mays* .

5- Four initial zone.

Ex. Some higher monocots and some hydrophytes.



Differences between Shoot and Root Apical Meristem

Shoot Apical Meristem	Root Apical Meristem
Terminal in position.	Sub-terminal in position due to the presence of root cap.
Conical (dome-shaped).	Cup-shaped (roughly hemispherical) due to the presence of quiescent centre.
No quiescent centre.	Quiescent centre in most of the root apices.
Protected by young (juvenile) leaves.	Protected by root cap.
Lateral appendages produced.	Lateral appendages not produced.
Branch-primordia appear in the axils of leaves.	Branch-primordia formed far behind the root-apices.
Exogenous origin of branches.	Endogenous origin of branches.
Activity altered during reproductive phase.	No alteration in activity.
The most favoured theory to explain the organisation is tunica-corpus theory.	The most favoured theory to explain the organisation is histogen theory.

Differentiation

Is the process in which cells of the root and the shoot apical meristems and the cambium mature to perform specific functions. In this process, lots of structural changes occur in the cells. The process of cell *differentiation* occurs during cell growth.

De-differentiation

Dedifferentiation refers to a cellular process in which a differentiated cell loses its special form or function, or reverts to an earlier developmental stage.(The term *dedifferentiated* is used to describe a mature cell that returns to a less mature state and performs a more generalized function.)

Re-differentiation

A process by which a group of once differentiated cells return to their original s pecialized form.

The differentiated cells can once again lose the capacity to divide and mature to perform specific functions. This is called Re differentiation.

Lecture:5

Permanent tissue

the meristematic cells gradually divide and get differentiated to form permanent tissue, which are composed of such cells in which growth has stopped either completely or for the time being. the cells of these tissues may be living or dead, thin walled or thick walled, sometime they again become meristematic partially or wholly.

The primary meristematic tissues form the primary permanent tissues and the secondary or lateral meristems or cambial layers form the secondary permanent tissue.

In Dicots and Gymnosperms the cambium is present, while in most of the monocots cambium is absent and therefore there is no secondary growth.

All the permanent tissue can be categorized in tow main groups according to complexity .

1-simple tissues this one included

* Epidermis tissue

**parenchyma tissue.

** *collenchyma tissue.

**** sclerenchyma tissue.

2-complex tissue included:

*xylem tissue.

**phloem tissue.

Simple tissue

These are composed of similar cells and have homogenous nature.

Epidermis

The **epidermis** (from the Greek meaning "over-skin") is a single layer of cells that covers the leaves, flowers, roots and stems and other parts of plants.

It is the primary tissue system or the dermal tissue system in the primary state development ,it is protective tissue .

In old stems and roots the epidermis is replaced by the periderm, exception evergreen leaves and some monocots. It is consists of cells that remain living at maturity. The cells of epidermis may converts to meristematic tissue (de-differentiation) ex. Cork cambium.

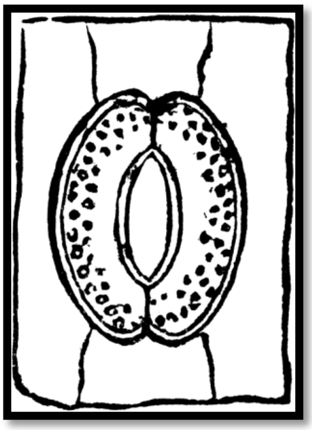
The epidermis of aerial plants is characterized by the presence of cuticle and stomata. The epidermis lack intercellular spaces and its duration one year.
Epidermis may be uniseriate (simple) as In Compositae , or multiseriate (multiple) as in Moraceae (Ficus) and Malvaceae and Palmae. The numbers of layers varies between 2-16 layers and it originated as a simple epidermis which undergoes a periclinal division .

Simple epidermis → Periclinal division → Multiple epidermis
The number of layers .

Cuticularization
Process of cuticle formation by deposition of cutin as a continuous layer
On the outer periclinal wall of epidermal cells of aerial organs.

Cutinization
The impregnation of cutin through the wall.

Epidermal cell types :
The epidermal tissue includes several differentiated cell types.
1-Ordinary epidermal cells
Living cells, least differentiation and least specialized , lack chloroplast, Exception shade plants, ptridophytes , hydrophytes (water plant) .
2-Guard cells
Kidneys shape ,highly specialized cells, pair of guard cells surrounds each stoma on the leaf surface , have chloroplast , occur in aerial parts, its function is regulates the exchange of gases in photosynthesis ,respiration and transpiration .



3-Subsidary cells
Specialized epidermal cells associated with guard cells and are lacking in some plants as in *Vicia faba* . The arrangement of subsidiary cells and guard cells is refer to stomatal complaex .

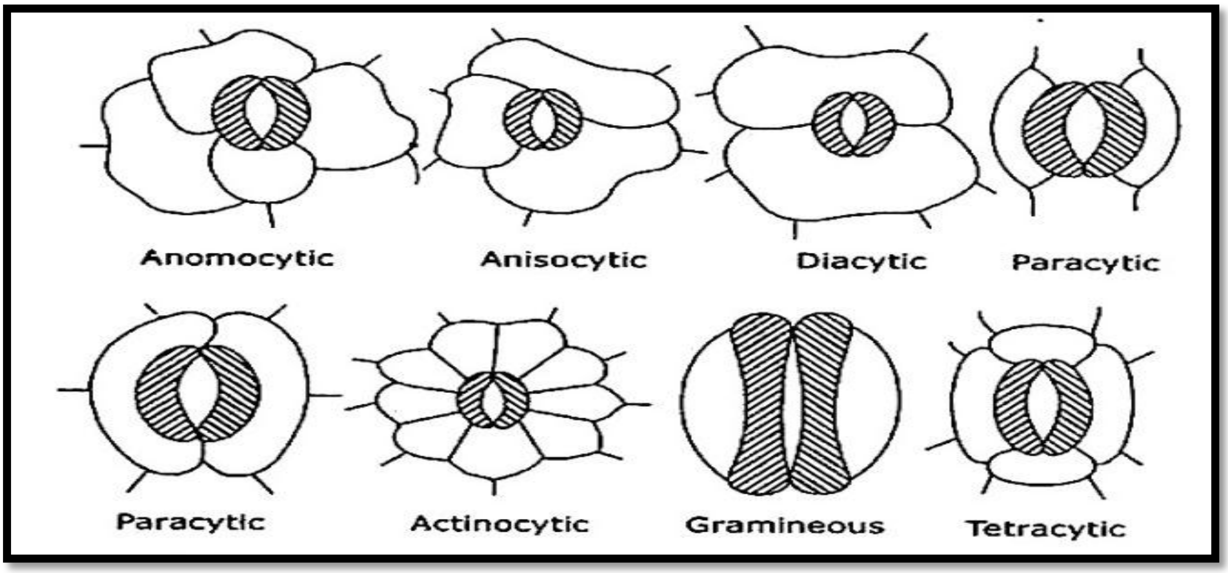
Types of stomatal complex :
a-Anomocytic type : Lacking subsidiary cells as in *Vicia* .
b- Anisocytic type : Presence of 3-subsidary cells which differ in size as in *Raphanus*

c- Diacytic type :Stoma remains surrounded by a pair of subsidiary cells as in *Dianthus* .

d- Actinocytic type : stoma where at least five subsidiary cells surround a stoma (*actinocytic* = star-celled) as in *Rosa* .

e- Paracytic type : In this *type*, the stoma remains surrounded by two subsidiary or accessory cells which are parallel to the long axis of the pore and guard cells, as in *Ricinus communis* .

f-Gramineae type : In this type the stomata surrounded by two guard cell like bones , as in *Hordeum*.



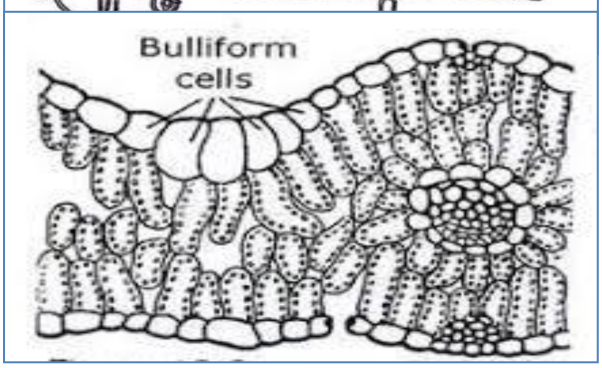
4-Epidermal hairs (Trichomes)

Epidermal cells may be unicellular or multicellular, Uniseriate or muliseriate, branched or un-branched , glandular or non-glandular.

5-Motor cells (bulliform cells)

are large, bubble-shaped epidermal cells that occur in groups on the upper surface of the leaves of many monocots. These cells are present on the adaxial or the upper surface of the leaf. They are generally present near the mid vein. These cells are large, empty and colorless.

Function : Folding and un-folding of leaves in mature plants due to change in moisture and storage of water.

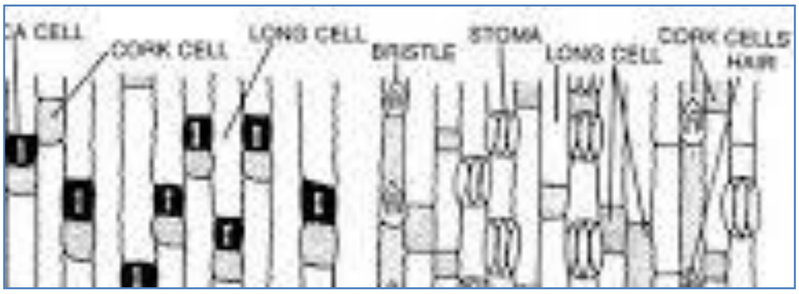


6-Lithocytes

special cell contains in general the special crystal which is Cystolith, found in Moraceae and urticaceae family.

7- Silica and cork cells

The epidermis of grasses often have two types of cells: long cells and short cells. The short cells themselves often occur in pairs, one being a silica cell (with a granule of silica in it), the other being a cork cell (with suberin in its walls).



8- Epidermal fibers

Fibers like cells , result from sclerification of some cells (deposition of lignin in the wall).

9-Myrosin cells

Myrosin cells accumulate myrosinases in their vacuoles, in family Cruciferae.

10-Secreatory cells

Epidermal cells associated with the secretion of some substances.

Lecture: 6

Parenchyma tissue

Is the most common unspecialized morphologically and physiologically simple tissue.

1- origin:

As regard their origin the parenchyma tissue of the primary body (that is the parenchyma of the cortex, pith, mesophyll of leaves, and flower-parts) get differentiated from the ground meristem.

The parenchyma associated with the primary and secondary vascular tissues is formed by procambium and vascular cambium respectively.

procambium - form parenchyma associated with the primary vascular tissue.

vascular cambium - form parenchyma associated with the secondary vascular tissue during secondary growth.

they also arise from the phellogen (cork cambium) as secondary cortex or phelloderm .

2- Distribution

parenchyma cells may be associated with other types of cells in morphologically heterogeneous tissue. Generally they occur in the pith and cortex of stems and roots ,the photosynthetic tissue, mesophyll of leaves. the fleshy part of succulent fruit ,the endosperm of seed etc .

They also occur in tissues like xylem and phloem as vascular rays (xylem ray & phloem ray). Beside these tissues, certain specific tissues are also parenchymatous in nature like sclereids, laticiferous tissues, sieve tubes, and certain glandular tissues .

3- Structure :

(i) shape: The parenchyma cells are usually iso-diametric or polyhedral in shape or with -14- sided tetrakaidecahedron . Many kinds of parenchyma become elongated as Prosenchyma cells (elongated cell with tapering ends). Parenchyma mesophyll tissues are variously lobed (as in spongy parenchyma), long or short prismatic (as in palisade parenchyma), folded, stellate and armed.. In *Pinus* mesophyll parenchyma are folded with internal ridges . In ordinary parenchyma, cells are homogenous with small spaces or non. (fig. 1)

(ii) cell-wall: Parenchyma cells have usually thin wall composed of cellulose with primary pit field.

In storage organs parenchyma walls may be considerably thick due to deposition of hemicelluloses or as a result of storage function ex. in the endosperm of seeds of date palm (*phoenix dactyllifera*). (fig. 1)

(iii) cell-arrangement: Mature parenchyma cells are either closely packed with short intercellular spaces as a food storage tissue of seeds endosperm which does not have large spaces and may be absent also, while storage parenchyma of fleshy fruits bear larges and numbers intercellular spaces.

(iv): cell-contents: the cell contents are widely variable and are intimately related to the activities of the cell, e.x. photosynthetic cell contain numerous chloroplasts and starch, non-chlorophyllous parenchymatous-cells are highly vacuolated and contain leucoplasts, also in many parenchyma cells accumulate tannine, as phenol derivatives and store mineral substance.

(v): Nucleus: generally the parenchyma cell are uni-nucleate and nucleus may be either in center or near the wall of the cell .

4- Function:

Parenchyma cell are centers of many essential physiological activities like:-

1- **photosynthesis** (tissue called Chlorenchyma) as a result of living protoplast present .
2- **upward and downward conduction** of water and dissolved food materials by Parenchyma cells of xylem and phloem in form of traches and sieve elements respectively.
3- These cells are also helpful in **wound healing and regeneration**.
4- Parenchyma with thin cellulose wall can also serve as **supporting tissue.**
5- Cutinized parenchyma of epidermis are **protective in function**.
6- Parenchyma of cambial cell divide and **form secondary tissue**.
7- Parenchyma cells of meristems are helpful in **formation of adventitious root and buds.**
8- Parenchyma cells which **store air** (aerenchyma) give buoyancy to the aquatic plants to float easily in or on the water.
9- In succulent plants these cells **store water and mucilaginous substances.**
10- **storage function** as in the endosperm of seeds of date palm (*phoenix dactyllifera*) which has a thick primary cell wall (thick

walled storage parenchyma) and *Ricinus* seed endosperm which store aleurone grains and has a thin primary cell wall (thin walled storage parenchyma) (fig 1)

Specialized parenchymatous cells

Parenchyma cells of mesophyll tissue of leaves and green stems of xerophytic plants (succulent plants) contain chlorophyll pigments, These are known as Chlorenchyma cells are photosynthetic in function.

Parenchyma of aquatic plants have large and abundant intercellular spaces. As a result they often becomes star-like or stellate in shape, These are called as aerenchyma. The air spaces give buoyancy to the plants.

Specialized parenchymatous cells which produce and store tannis, oils, and crystals, or calicium oxalate are known as idioblasts.

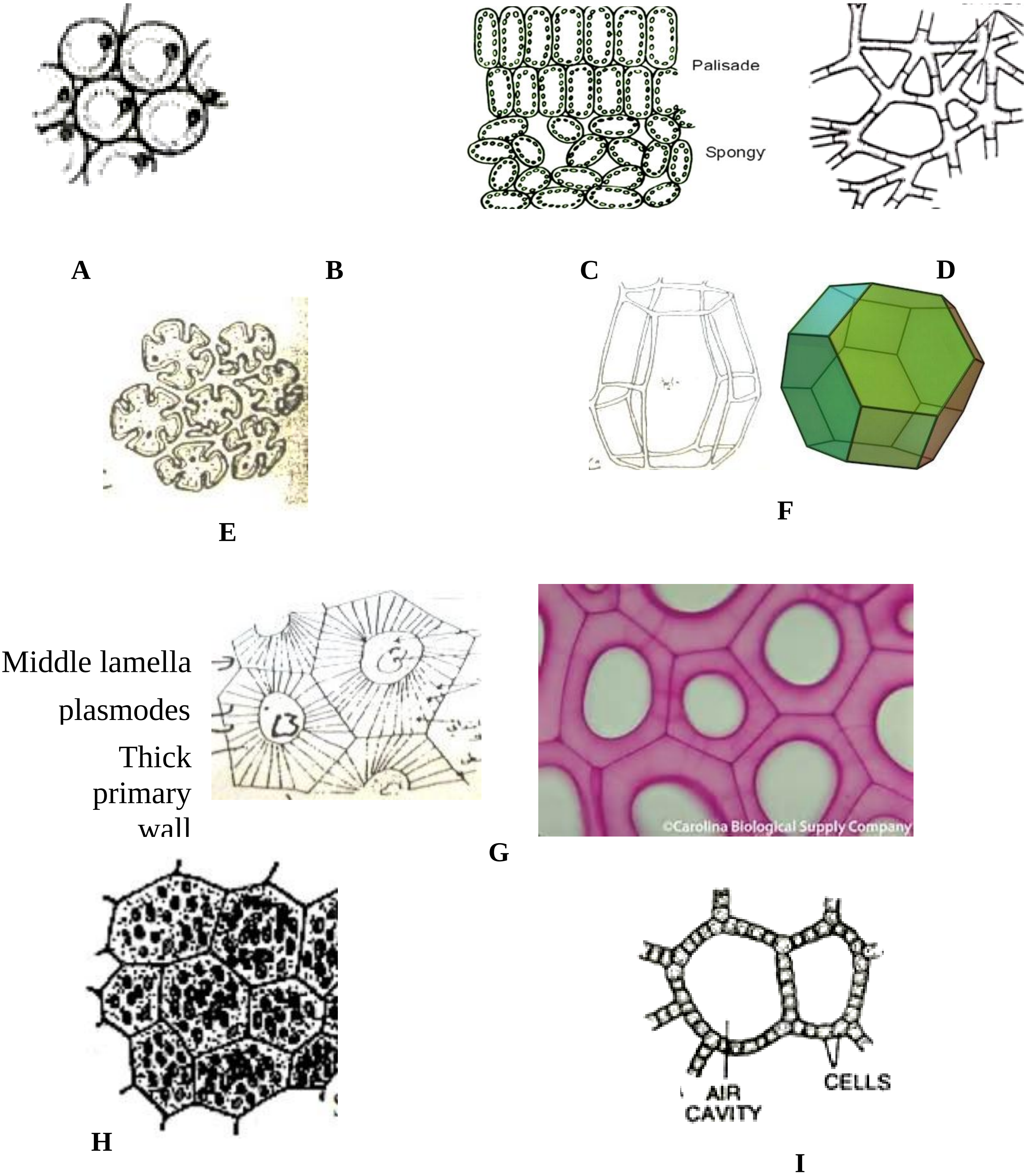


Fig. 1: A: ordinary parenchyma, B: prosenchyma, c: prismatic & lobed, D: stellate (*Canna indica)*, E: folded, F: polyhedral (tetrakaidecahedron), G: thick walled storage parenchyma in *Diospyrus*, H: Thin walled storage parenchyma, I: aerenchyma.

Collenchyma tissue

These are living tissue composed of more or less elongated cells with thick primary non-lignified wall.

1- Origin

The derivative of apical meristems are differentiates in to protoderm, procambium and ground meristem. And collenchyma originated from ground meristem.

2- Structure

Collenchyma cells are not much variable in structure;

- Cell shape: these cells are considerably elongated with oblique, slightly rounded or tapering ends, the shorter Collenchyma cells are prismatic like many parenchyma cells, and they are usually polygonal in cross section.
- Cell wall: the most distinctive feature of collenchyma cells is the nature of cell walls, which are un-evenly thickened, and according to the manner of deposition of secondary cell wall materials (cellulose impregnated with pectin), three types of collenchyma have been recognized: (fig: 2)

(a) Angular collenchyma: Here the deposition is localized to the junction between the cells, and the cells are irregularly and compactly arranged with little or no intercellular spaces; as in *Solanum lycopersicum, Datura, Morus, Vitis and Ficus.*

(note: the degree of deposition varies in different plant species)

(b) Lamellar (plate - like): Here the thickening occurs chiefly on the tangential walls , e.x: *Sambucus*. Due to thickening the cells appear like plates, bands or lamellar.

(c) Lacunar (Tubular): Here the cells are with large intercellular spaces, and the thickening occurs on the walls facing the intercellular spaces e.x: in ***salvia***, ***malva*** etc.

The cell wall of all the types of collenchyma is composed of cellulose and pectin with high percentage of water, and the thickening to a great extent is determined by the environmental factors.

3- cell contents:

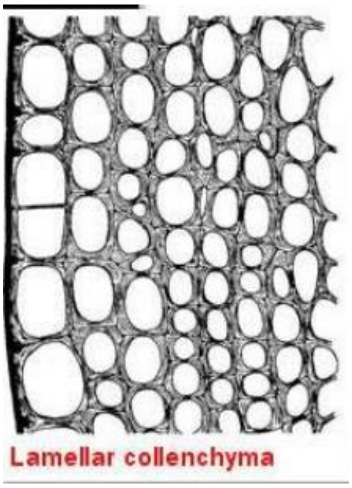
The cells of collenchyma tissue are living with vacuolated protoplast. chloroplast may also be present. They are always uni-nucleate. The structures of collenchyma is sometimes modified for doing specific functions. These tissues have a considerable tensile strength with flexibility and plasticity Thus the older tissues are harder than the younger ones.

4- Distribution:

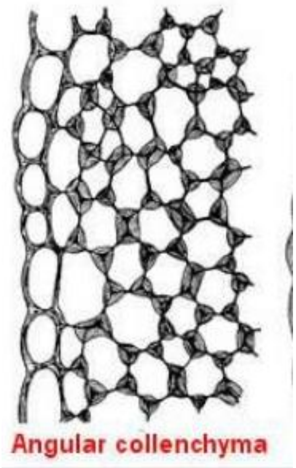
collenchyma is found in arial plant parts below the epidermis in herbaceous dicots plants. They occur either as **homogeneous layer** e.x: in sunflower *Helianthemum* or in **patches** ex: in ribs of *cucurbita* stem. In leaves they are present on **both sides of the veins** or **along the margins** . This tissue is normally absent in underground stems, roots and stems and leaves of monocots .

5-Function

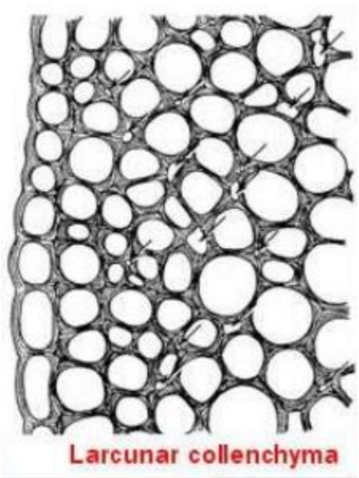
1. It is effective mechanical tissue and give support to the growing organs.
2. It gives tensile strength to the growing organs during their development.
3. It protects the vascular bundle of leaves by forming cap or bundle sheath like structure.
4. If chloroplasts are present then it may perform little photosynthetic function also.



A- Lamellar collenchyma in *Sambucus* stem, thickening mainly on tangential walls.



B- Angular collenchyma in *Cucurbita* stem, thickening in the angles.



C- Lacunar collenchyma in *Lactuca* stem, show numerous inter cellular spaces (indicated by arrows) and the most prominent thickening located

Lecture: 7

Sclerenchyma

It is also a simple tissue mainly adapted for mechanical function. A sclerenchyma tissue is considerably thick walled and lignified with simple pits in the walls, sclerenchyma cells show much variations in form, structure, origin and development, and the different types of cells are placed into two group:

1- fibers

2- sclereids.

1- Fibers: fibers are very much elongated, usually with pointed needle like ends, and dead in nature.

Classification: fibers are divided in to two large groups

- xylary fibers or wood fibers (intraxylary fibers) which sub divided in to two main groups

1-. fiber tracheid

2- libriform fibers.

- extraxylary fibers, which contain phloem fibers besides the fibers found in cortical and pericycle, these last two types of fibers included fibers placed outer of the primary phloem in dicot stems and also the fibers placed hypodermal in some monocot stems originated from ground meristems.

Structure:

- Extraxylary fibers or phloem fibers are long spindle- like with acute or acuminate or blunt ends. Generally primary extraxylary fibers are longer than the secondary. The cell wall of fibers is quiet thick with simple or slightly bordered pits. Few extraxylary fibers bear lignified walls (monocots) and others are non-lignified. At maturity these fibers lose protoplasm and become dead.
- Intraxylary fibers or Wood fibers or xylem fibers: Have strongly lignified secondary walls. They vary in size, shape, thickness of wall, and frequency of pitting, the pits may be small round or slit like in appearance. Sometime the secondary wall is so much thickened and lignified that the central lumen is almost obliterated. Some fibers may bear gelatinous sheath. The tracheids fibers and libriform fibers both are septate fibers also show overlapping or interlocking nature at their ends.

Distribution:

Fibers occur as groups or as sheets or as cylinders in the cortical and vascular region (in xylem and phloem) or as bundle sheath or bundle cap.

In stem of Dicots fibers occur in the outermost parts of the primary phloem as bundle cap fibers or perivascular fibers besides phloem fibers and xylem fibers ex: in *Linum* and *Nerium.*

In Monocot stems fibers have been observed as bundle sheath and hypodermal fibers ex:. in *Zea mays.*

The primary and secondary xylem and phloem tissues of roots also bear fibers.

Gymnosperms usually have no fibers in primary phloem but may have them in secondary phloem.

Functions:

These are the most important type of mechanical cells their great strength, flexibility and elasticity serve to enable plant organs to develop resistance against gravitational tension and strains.

Economic fibers:

Flax, hemp, jute and ramie fibers are obtained from phloem and are used for preparing carpets, ropes etc.

The commercial fibers are separated in to hard and soft fibers, the hard fibers are obtained from monocots stems and leaves with heavy lignified walls ex:. *Musa textilis,* while the soft fibers obtained from dicots ex: *Cannabis sativa.*

2- Sclereids

Origin:

Sclereids have different origins ex:

- Some sclereides developed from the derivatives of peocambial and cambial cells.
- Stone cells embedded in cork originate from phellogen (cork cambium)
- Macrosclereids of seed coat are protodermal in origin.

Structure:

The secondary walls of the sclereids vary in thickness and are typically lignified. In many sclereides the lumens are almost filled with massive wall deposits and secondary walls show ramiform canal like pits, and normally become dead with maturity.

Some Sclereid may get branched during their developmental period.

Classification: (fig 3)

Sclereids are classified on the basis of their size, shape, nature of cell wall and mode of deposition of secondary cell wall materials:

1- **Brachysclereids (stone cells):** these are isodiametric, short, resemble parenchyma cells and occur in cortex, pith of the stem and flesh of fruits as in fruits of *Pyrus communis* (Pear).

2- **Macrosclereids**: these are rod shaped elongated cells form palisade like epidermal layer on the seed coat in species of *Phaseolus* and *Pisum* (Pea) etc.

3- **Osterosclereids (bone shaped sclereids**): these are bone like in shape, columnar cells enlarged at the ends. They occur in the leaves of some dicots and seed coat of Pea.

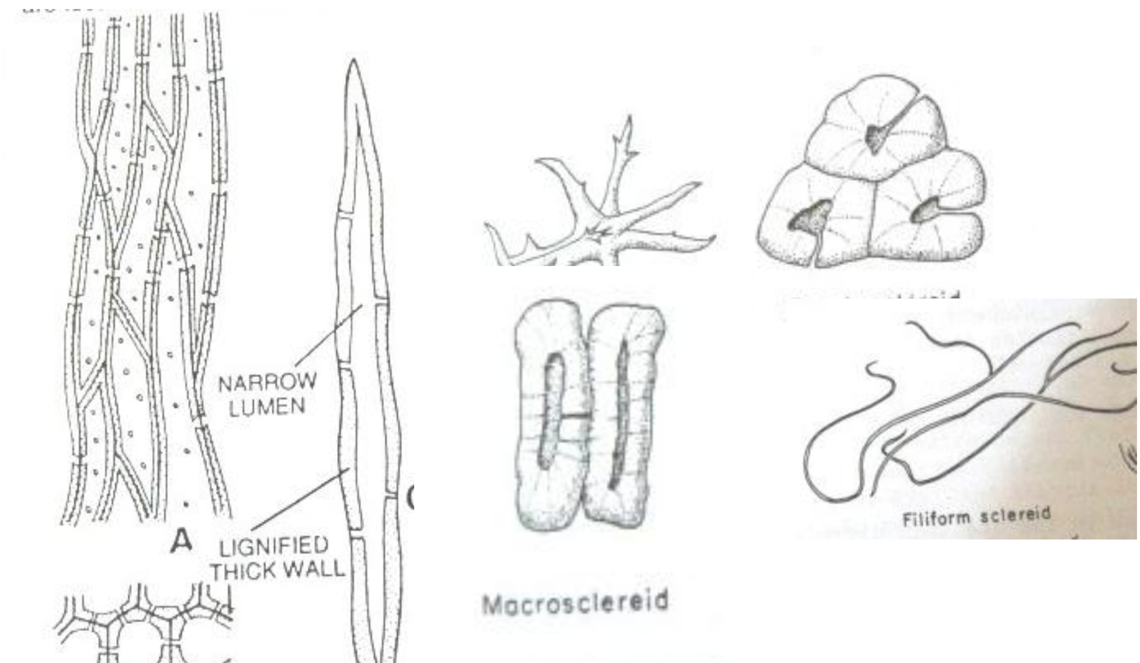
4- **Astrosclereids (Star shaped sclereids):** these are star or stellate shaped and occur in the leaves of some dicots such as *Nympheae* (water lily)

5- **Trichoseclereids (filiform sclereids):** these are long, slender and hair like as L or Y shaped, they occur in leaves mesophyll of Olive plant.

Function:

1- give firmness to the parts where they are present.

2- sclereids because of their lignifications in the secondary wall give mechanical support to a particular part by producing a hard texture ex: seed coats, endocarp of fruits etc.



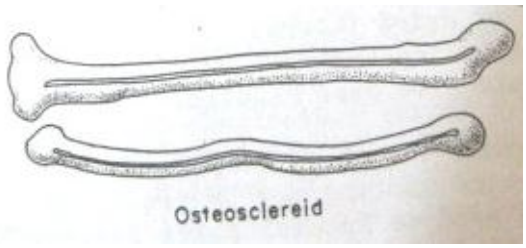


Fig. 3: fibers & sclereids.
A: longitudinal section in overlapping fibers. B: cross section in fibers. C: longitudinal section in fiber

Lecture: 7

The vascular tissue system

The vascular tissue system is a continuous system of tissues that conduct water, minerals and food, this system consist of two complex tissues: xylem and phloem**.** Xylem bring water and minerals nutrients from the root to the rest of the plant, while phloem move sugar and other organic nutrient from the leaves to the rest of plant, in other words phloem carries the food produced by photosynthesis. The elements of xylem and phloem originate from the procambium of apical meristem or vascular cambium through the primary and secondary growth respectively.

The contents transported by xylem and phloem are known as sap, so that the plant are divided in to two groups :

1- Plants including xylem and phloem called as Vascular plants (Trachophyta)

2- Plants without xylem and phloem called as non vascular plants.

Xylem tissue

Xylem tissue has four elements such as tracheids, vessels xylem fibers and xylem parenchyma.

1- Tracheids (fig. 4)

They are long cells with tapered ends and appear either circular or polygonal in transverse section, with secondary walls which deposit in different manners as annular, spiral, scalariform, reticulate, or pitted.

The xylem of all Vascular plants contain tracheids while they consider typically the only type of water conducting cells in Ferns, Conifers, and most other non-flowering plants (Gymnosperms).

Tracheids align with each other to form a continuous water conducting system, the secondary cell wall of tracheid has thinner region called pits in which only the primary wall is present. Pits in adjacent tracheids are usually aligned allowing water and minerals to flow from one tracheid to another one below or next to it. In some plants pits are often bordered by bulges (border) in the secondary cell walls which strengthen the opening and also make it narrow to slowing down the flow. In Conifers and some primitive Angiosperms the middle of the pit membrane is a thicker area called a torus that acts like a valve. And if the membrane move to the side the torus block the pit opening thereby slowing or stopped the flow.

(fig. 4) shows how the pit membrane consisting of porous primary cell wall and the thin middle lamella regulates the flow though bordered pits.

Function of tracheids

Du to present of central lumen and thick, hard elastic and highly lignified wall they are well adapted for transport of water and solutes from root to stem and leaves. They also give a slight mechanical support.

2- Vessels (fig.4)

In addition to tracheids the xylem of most flowering plants and a few Gymnosperms contains other eater conducting cells called Vessel which consist of numerous vessel elements which transport water and minerals more rapidly than tracheids.

Vessels element are dead at maturity with secondary cell wall like tracheids, forming hallow tubes but vessel elements are generally wider shorter and less tapering than tracheids. They have the largest diameter of all conducting cells up to 100 micrometers (μm) compared with 10 μm of tracheids and can carry about 10 times as much water and minerals as tracheids.

Vessel elements lose some or most of their cell wall at each end leaving perforation plates that allow water to flow through while still providing support. In this way vessel elements are jointed to form a continuous pipe or vessel. Vessel elements also have pits which allow lateral flow from vessel to vessel.

The secondary wall layers are deposited as in tracheids in different manner as Annular, spiral, scalariform, reticulate and pitted.(Fig. 2)

Vessel function

The vessels due to present of thick lignified walls are much adapted for easy transport of water and solutes from roots to stem and also give mechanical support.

According to similarity in function of tracheids and vessels so that there is a general term is using as tracheary elements.

3- Xylem fibers

Sclerenchymatous fibers associated with xylem are known as xylem fibers, which are long, slender, pointed and dead cells. Two main types of xylem fibers are reported from primary and secondary xylem tissue.

- Fiber tracheids
- Libriform fibers

4- Xylem parenchyma

Living parenchyma associated with xylem are called as xylem parenchyma, which is store food reserve in form of starch, fat, tannins, crystals and various other substances may also occur in these cells.

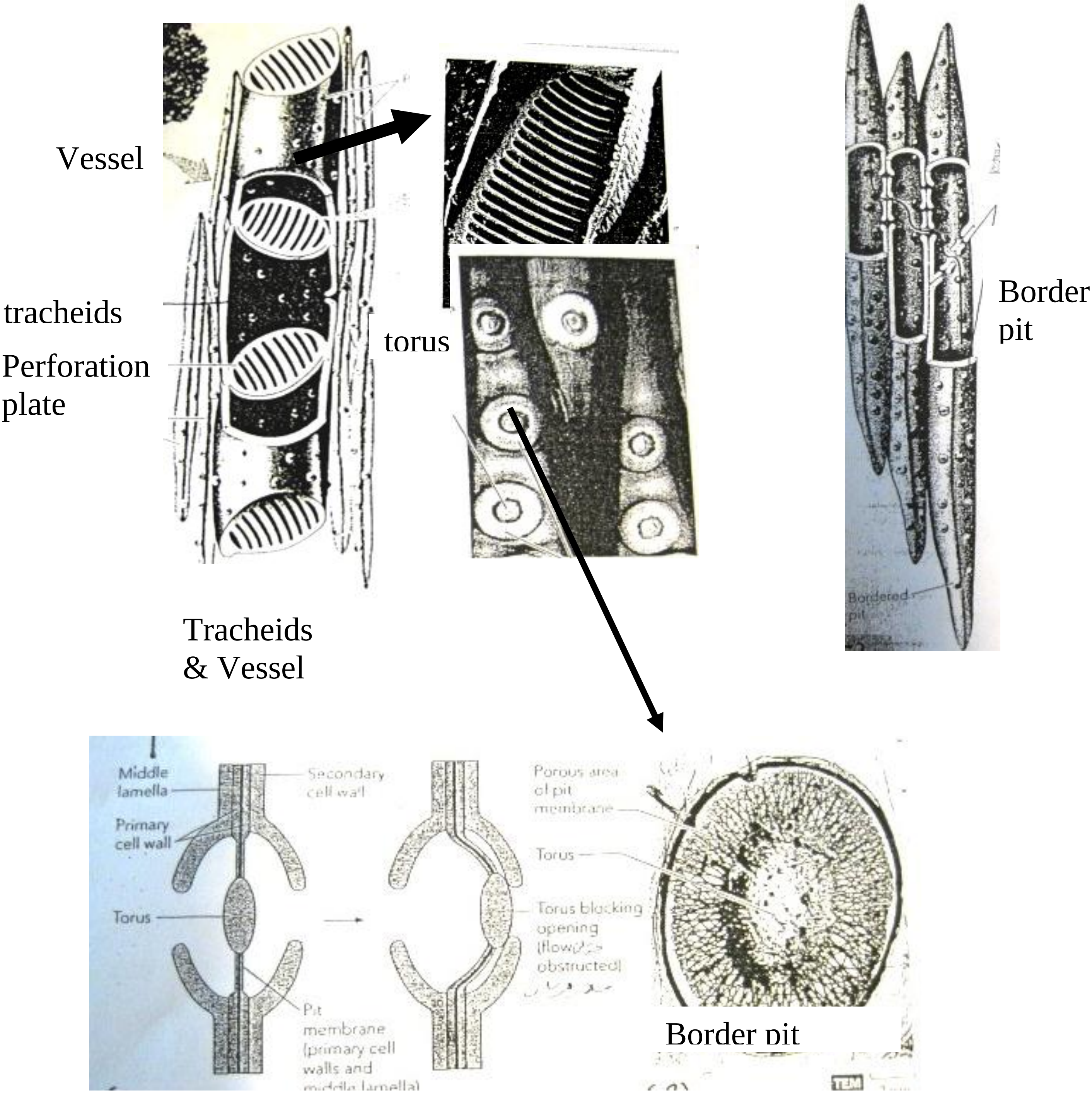


Fig.4: tracheids & vessel, details of border pits & border pit membrane

Lecture: 8

Phloem tissue (Food conducting tissue)

It is another complex vascular tissue which transports food, its originate from procambium through primary growth and from vascular cambium through secondary growth, phloem tissue composed of

- sieve elements (sieve cell , sieve tube)
- Companion cells
- Phloem parenchyma
- Phloem fibers

1- **Sieve elements**: these are of two types :

- Sieve cell: the less specialized and more primitive type of food conducting cell, which is found in non-flowering vascular plants (lower plants and Gymnosperms) such as Ferns and Conifers.

  Rows of sieve cells function much like sieve tube members, but the ends of sieve cells lack sieve plates, this difference is somewhat like the difference between the overlapping tracheids and the continuous tube of vessel elements. Sieve cells lack an nucleus when they are mature, each sieve cell has an associated cell named Albuminous cell, which has a nucleus and appears to serve the same function as the companion cell does for a sieve tube member.
- Sieve tube: The more specialized type of food conducting cell, found in Angiosperms (flowering plants), and its long tube like, slender bodies composed from several sieve tube members arranged in longitudinal series where the end walls are perforated in sieve like manner, these are called as sieve plates, through which cytoplasmic connections are established between adjacent cells. The perforation in sieve plate are called as sieve area which is found in inclined position, and according to the properties of sieve area there are two types of sieve plate:

  1- Simple sieve plate: which has one sieve area.

  2- Compound sieve plate: which has several sieve areas arranged in scalariform, reticulate or other manners.

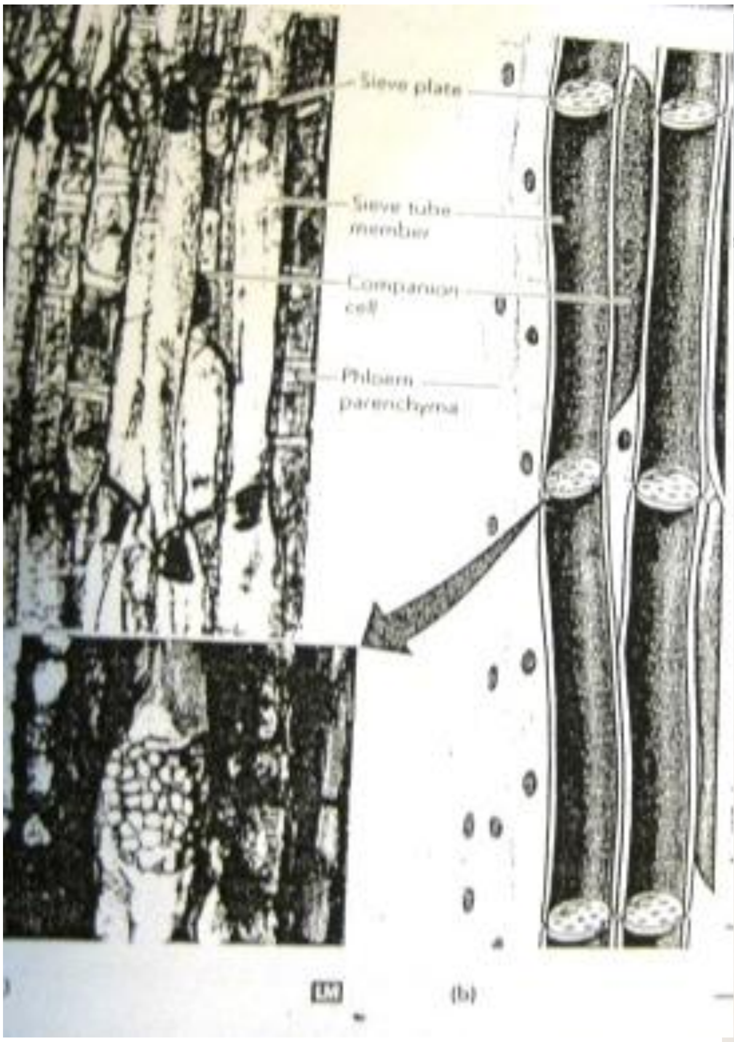
The origin: the sieve elements originate from the same meristematic cells from which companion cells originate.

The Function: The main function of sieve elements is the longitudinal transmission of prepared food materials, proteins and carbohydrate from the leaves to the storage organs.

2-**Companion cells**: these are specialized parenchymatous cells which are closely associated with sieve elements in origin, position, function and development, these cells occur only in angiosperms, and they are formed by the same meristematic cell which form sieve elements. (fig. 3)

3-**Phloem parenchyma**: The phloem tissue contains variable number of parenchyma cells, The main function of these parenchyma is to store organic food materials and other substances like starch, fats. Resins, etc.

4- Phloem fibers: These fibers occur both in primary and secondary phloem and have much commercial importance in used for the manufacturing of clothes, ropes etc.



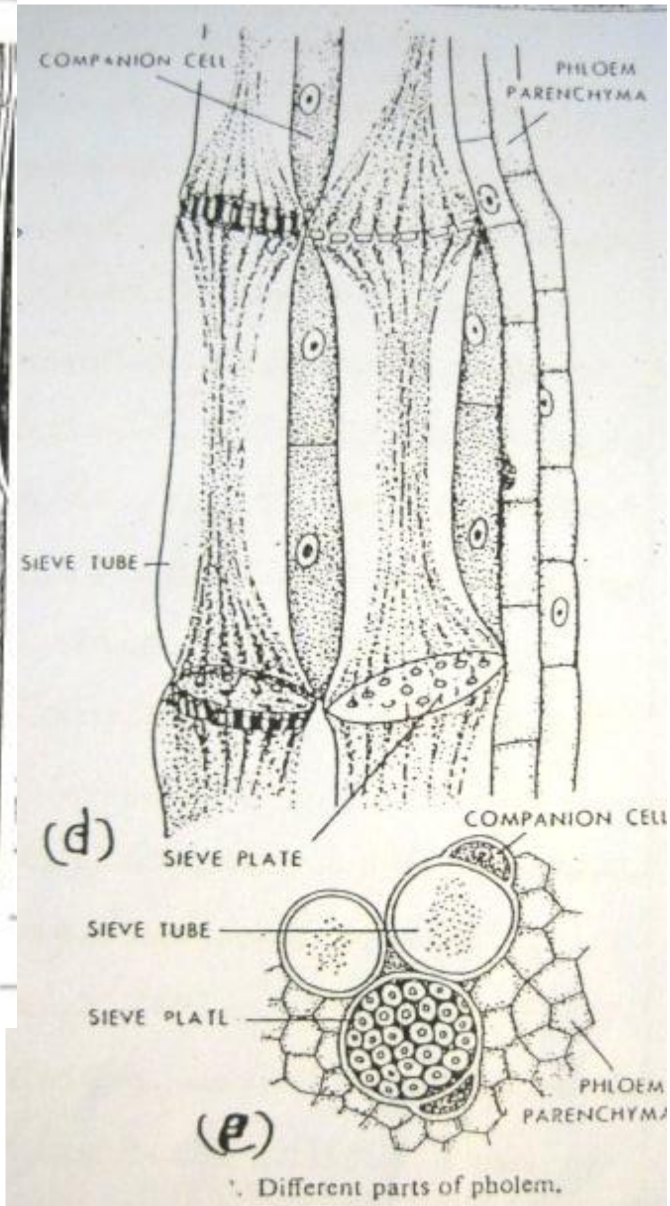


Fig5: Phloem tissue cells

Lecture:9

The primary structure of plants

Plant body in primary growth contains tissues originated from meristems derivative from apical meristems (protoderm , procambium, ground meristems). The vascular tissue (xylem and phloem) in primary growth is composed of primary xylem and primary phloem.

1- **Primary xylem**: its composed of two types of cells :

- **Protoxylem**: these are first formed xylem tissue which appears at beginning of vascular differentiation and occupy particular position in the primary vascular system of plant organ, its consist of tracheids, vessels and parenchyma while the fibers being usually absent. in stem it occurs near the pith while in root its located farthest from the center. The primary cell wall of its cells are of cellulose while secondary materials are deposited in form of annular and spiral thickenings. The protoxylem elements are narrower than the metaxylem.
- **Metaxylem :** it's the lately formed xylem after the plant organ completed their elongation, and consist of tracheids, vessels, parenchyma and fibers. Its more complex than protoxylem and possesses more of wider tracheary element with pitted thickening of secondary cell wall

2- **primary phloem** = It is composed of two types of tissue :

- **proto phloem**: The first phloem formed is called as proto phloem which develops directly from procambium. It is composed of sieve – elements only (sieve- tubes in angiosperms and sieve- cells in gymnosperms and pteridophytes) and the companion cells are scarce or lacking.
- **Metaphloem** : The metaphloem elements are differentiated after growth in length of the organs is completed. It is composed of sieve elements, parenchyma and fibers. The sieve elements are longer and widen with more distinct sieve areas, companion cells are typically present in metaphloem.

Not: In stems, the xylem occurs towards the centre and phloem towards the periphery. In root , both these tissues are arranged in alternate manner. In leaves phloem is toward the lower epidermis and xylem is towards the upper epidermis.

The Secondary structures of plants.

The secondary growth in plants takes place by the vascular cambium in stellar region and by cork cambium into extra stellar region. The cork cambium forms the secondary cortex and cork and vascular cambium forms the secondary xylem and secondary phloem. The secondary xylem and secondary phloem tissues differ from primary tissues in having additional structures. They form a complete ring around the central core.

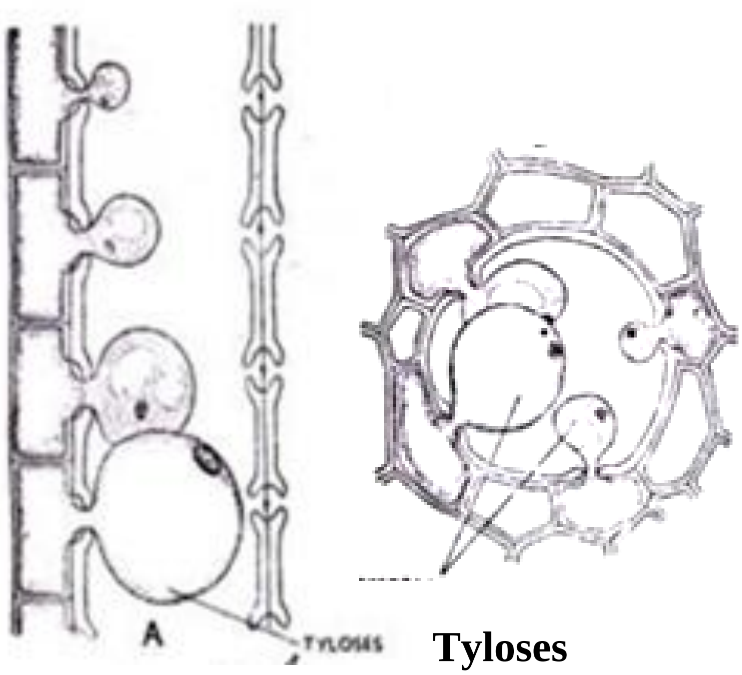
Tyloses

It is an outgrowths from parenchyma cells happened in many plants when developed protrusion that enter tracheary cells when these become in active or the xylem tissue is injured.

Tyloses development occurs through the pits, and it is sometime being so numerous as in *Quercus* that they completely fill the lumen of the tracheid or vessel element. The nucleus of the originating parenchyma cell and part of the cytoplasm appear in the tyloses.

The tylosoid

In *Pinus* the epithelial cells surrounding the resin ducts (specialized intercellular spaces) are thin walled parenchyma and remain active for several years. In some genera produce little resin eventually a resin ducts may be become closed by enlarging epithelial cells to form structure like tyloses are called tylosoids, and they differ from Tyloses in that they don't grow through pits.



Tyloses

Fig 6: A: longitudinal section showed vessel filled with Tyloses as shows continuity between Lumina of Tyloses and parenchyma cells, with nucleus have migrated from parenchyma to Tyloses, B: transverse section showed vessel filled with Tyloses.

Annual rings (Growth layers)

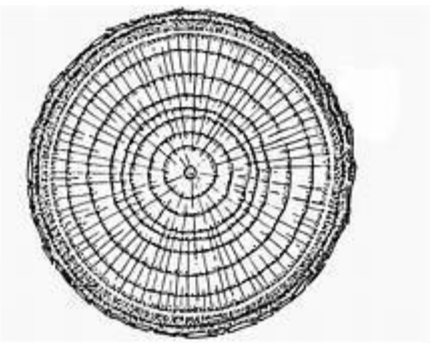
A layer of wood (secondary xylem) that forms in the stems and roots of woody plants growing in temperate areas or tropical areas with rainy and dry seasons. Usually one ring forms per year.

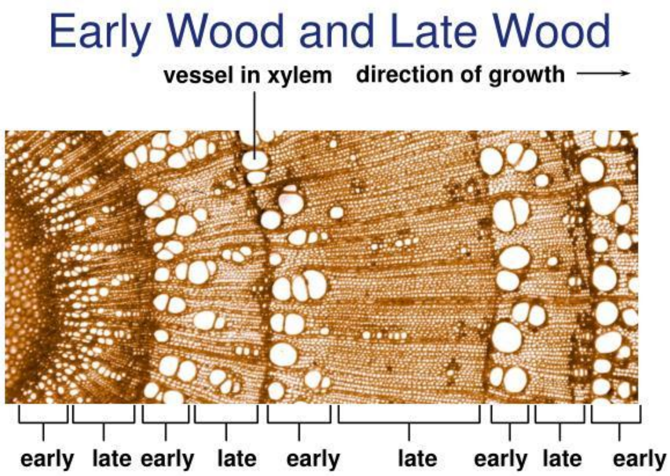
Growth rings are visible because of the distinction between early wood produced in spring and late wood produced in late summer, In spring and early summer as the days grow longer with abundant moisture and light the vascular cambium produces large cells with relatively thin secondary cells walls. In later summer as days grow shorter and cooler the vascular cambium produces smaller cells with thicker walls.

The dividing line between the late summer wood of one year and the spring wood of the following year is visible as the line between growth ring.

In most regions of the world trees produce one growth ring per calendar year however the seasonal growth is interrupted adverse climatic conditions, diseases or other agents and it later resumed a second growth layer will be visible in the wood added during one season, such an additional layer is called a false annual ring and the annual growth increment consisting of two or more growth rings is termed a multiple annual ring.

The width of a growth ring may reveal something about the season that produced it, a thick ring results from a season with good growing conditions while a thin ring indicates the opposite, and the trees age can be determined by counting the growth rings. Growth rings can reveal not only a trees age but also details about climate changes and human history, for example a pattern of 20 thin growth rings and 2 fat ones may indicate that a dry spells of 20 years followed by 2 years of heavy rain fall.





B Early and late wood in an ash tree. Early wood forms during wet springs. Late wood indicates that a tree did not waste energy making large-diameter xylem cells for water uptake during a dry summer or drought.

Heart wood and sap wood

You may have noticed that some trees have wood with two different colors. Heart wood the older wood in center of the trunk is typically a brownish-red color, and microscopic examination of heart wood reveals that its vessels and tracheids are plugged with pigments, tannins, gums, resins and other materials which have a function of antibacterial and antifungal substances that help protect the heart wood from rot and fungi, therefore heart wood no longer functions in conduction. Hear wood id denser than sap wood and provides structural support for trees, and there is some evidence that heart wood is resistant to decay. While the functional secondary xylem is the sap wood which is the younger, lighter colored wood, closed to the bark and actively conducts water and minerals.

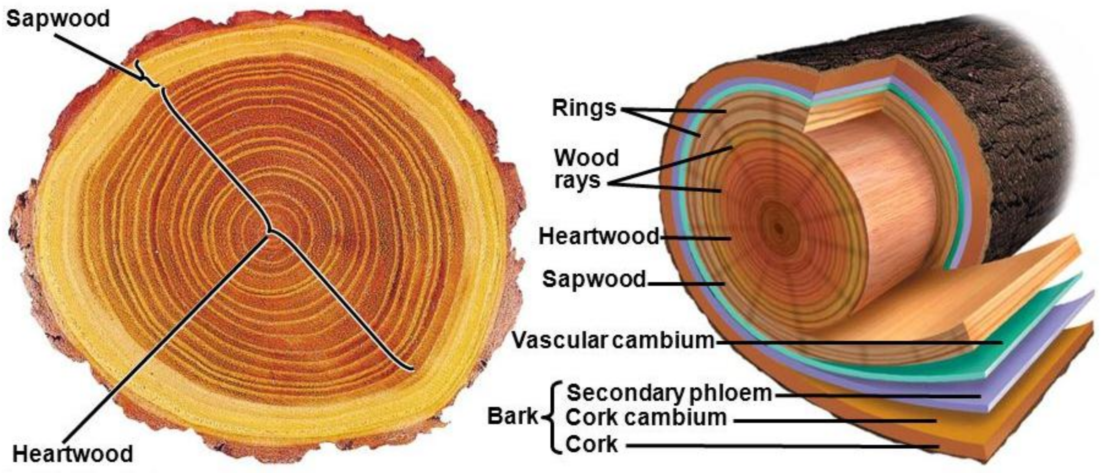


Fig 8: heart wood and sap wood

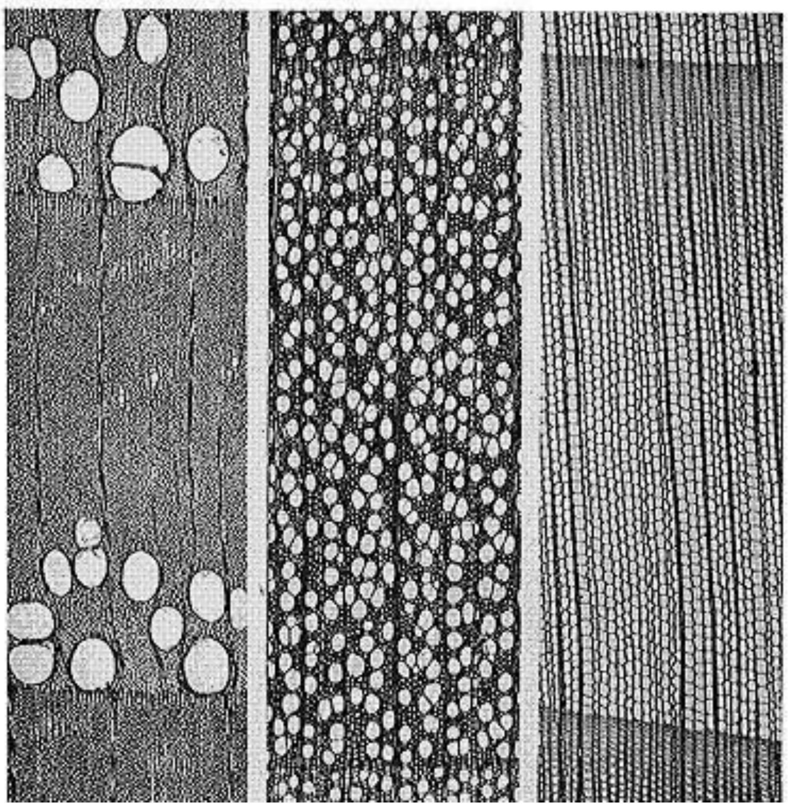
Diffuse porous wood and ring porous wood

According to the distribution of vessels, there are three types of wood, diffuse porous wood, ring porous wood, and non porous wood. (the word porous to the appearance of the vessels in transverse sections, they seem like holes or pores in the section of the wood)

The arrangement of vessels in dicotyledonous wood show two main patterns, when the vessels have essentially equal diameters and are uniformly distributed through a growth ring, the wood is called **diffuse porous**.

Wood with vessels of un equal diameters and with the largest vessels localized in the early wood (spring wood) and smaller ones localized in late wood (summer wood) are called **ring porous** as a result of the ring like arrangement of the large vessels in transverse section of the xylem such as in *Fraxinus* and certain species of *Quercus*. between these two extremes various intergrades occur, moreover in a given species the distribution of vessels may vary in relation to environmental condition and may changed with increasing age of the tree.

Gymnosperms described as **non porous wood** because the its woods are lacking of the vessels.



C B A

Fig 9: types of woods, A: non-porous wood of Gymnosperms, B: diffuse porous wood, C: ring porous wood

The periderm

Periderm is a protective tissue of secondary origin. It replaces the epidermis when the axis is increased in girth and the epidermis is destroyed.

Periderm formation is a common phenomenon in stem and roots of Dicotyledons and Gymenosperms that increase in thickness by secondary growth structurally the periderm consist of three parts:

1- the phellogen (cork cambium)

2- Cork produced by phellogen toward the outside

3- phelloderm, a tissue that resembles cortical parenchyma and consist the inner derivatives of phellogen.

The Bark

Bark is applied most commonly to all tissues outside the vascular cambium of the stem or root, in either a primary or secondary state of growth. It is also used more specifically to designate the tissue that accumulates on the surface of the plant axis as a result of phellogen activity.

Bark has two distinct region :

1- inner bark: consist of living secondary phloem and living phelloderm produced by the most recently formed cork cambium.

2- outer bark: consists of dead secondary phloem plus periderm from earlier cork cambium.

Bark the outer most layers gradually crack and peel off in patterns that vary from species to species.

fig 10: inner and outer bark

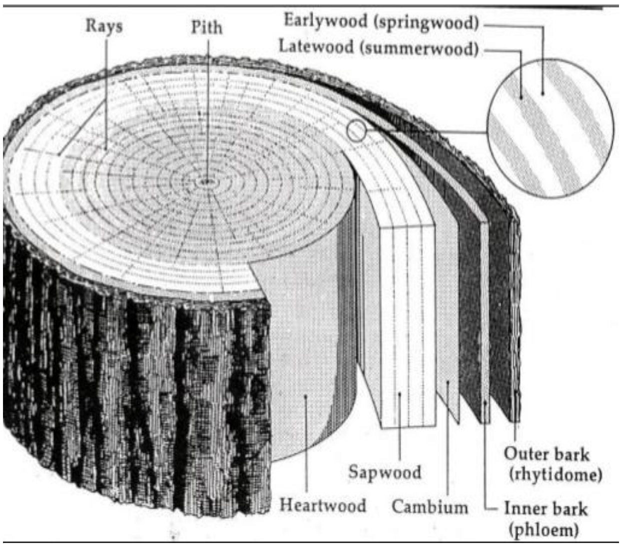


Fig 11: some variation in bark A: thick, checkered bark in Silver birch *Betula pendula*, B: smooth bark in Birch *Betula albosinensis,* C: thin, rough bark in Madrone *Arbutus menziessii*

Lenticels

The suberin in the cell walls of cork cells blocks the passage of oxygen into the stem or root. However, stem and roots have lenticels, which are small openings in the outer bork where the cork layer is thin and there is enough space between cells to allow for exchange of gases. As new cork cambium arises, new lenticels develop that are aligned with the outer lenticels, providing a continuous pathway for oxygen

In trees with smooth bark lenticels are easily observable usually appearing as short streaks, slits or raised dots on the surface of twigs, branches, trunks and roots. In addition to appearing in stems and roots lenticels can be seen as spots and streak on the surface of some fruits, such as apples and pear. (Fig. 7&8).

Lenticel: A porous swelling in a woody stem that develops when the epidermis is replaced by periderm , facilitates the exchange of gases between the stem's interior and the atmosphere.

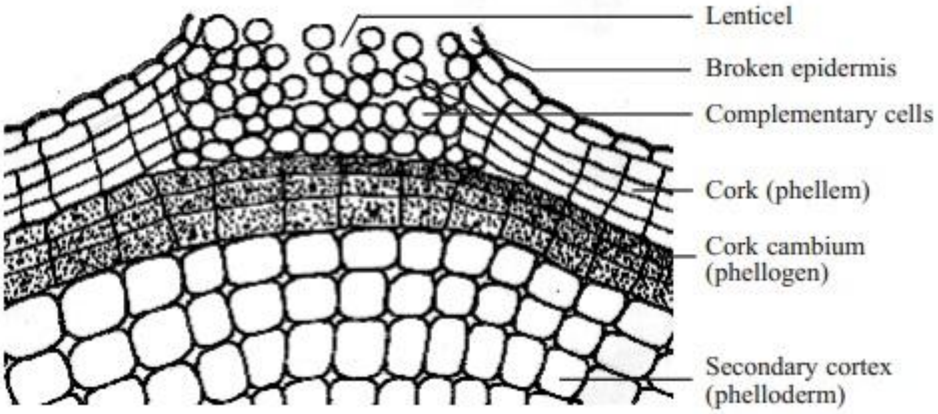


Fig. Structure of a lenticel

Lecture:10

Anatomy of Dicot stem (ex: young stem of sunflower *Helianthus)*

In a transverse section the stem appears circular or slightly wavy in outline, the tissues are arranged as follows:

1- Epidermis

It is the outer most uniseriate layer composed of parenchymatous cells which are tubular in shape, flattened tangentially and attached end to end along their radial walls without inter cellular space. In young stem chloroplasts may be observed, and covered by cuticle material, which is check the loss of water. Stomata are present and also a large numbers of multicellular hairs are also present.

2- Cortex

It lies below the epidermis and is differentiated in to following zones:

a- Hypodermis

this layer is immediately below the epidermis and is composed of 3 to 4 layers of thick collenchymatous cells. The corners or angles are thickened due to deposition of pectin or cellulose. The cells are living and may contain few chloroplasts.

This layers forms a continuous band of external cortex which provides mechanical support to the peripheral portion of the stem.

b- General cortex

it consist of thin walled, large oval or rounded living parenchymatous cells, having conspicuous intercellular spaces. The cells of this layers may contain some chloroplasts, so they may function as assimilatory cells and they also serve for storage of food.

C- endodermis

It is the inner most layer of the cortex and separates the cortex from stele. The cells are somewhat barrel shaped, compactly arranged having no intercellular spaces and are parenchymatous. They contain numerous starch grains, the layer is therefore referred to as a starch sheath. The radial and the inner walls are thickened due to deposition of lignin forming casparian strips which is a characteristic feature of endodermis.

3- Stele

It is consist of the following:

a- pericycle

it lies below the endodermis and is composed partly of parenchyma cells and partly of sclerenchymatous tissues. The schlerenchyma are form bundle cap which is localized outside the phloem and separated the vascular bundle from the cortex, it is hard bast so it give mechanical support to the plant parts.

b- Vascular bundles

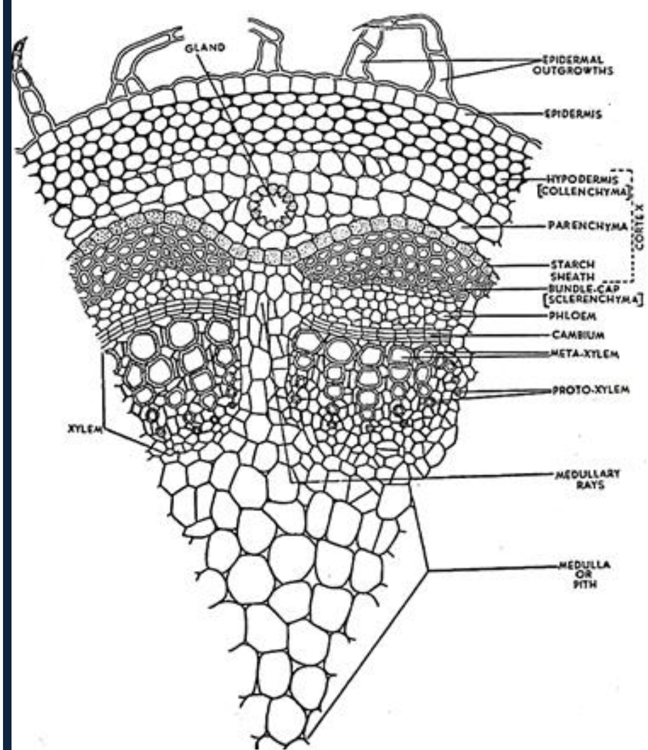
these are conjoint collateral open, wedge shaped and arranged in a ring around the central pith. (The size of the bundles varies in different species). Each bundle has a patch of xylem towards the center, a patch of phloem towards the periphery and strip of cambium is between them.

c- Pith

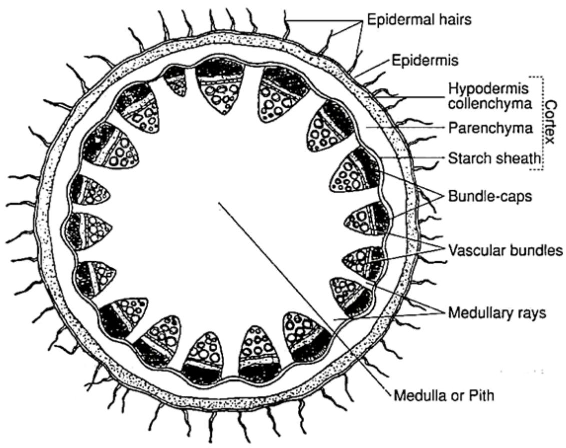
the center of the stem is known as pith or medulla, it is composed of parenchyma cells. The cells are rounded or polygonal, thin walled with conspicuous intercellular spaces, food is stored in this region.

d- Pith rays

the pith extends in between the adjacent vascular bundle to form elongated structure called as pith rays or medullary rays. The cells are thin walled parenchymatous cells, and polygonal or radially elongated. The pith rays store the food materials and also help in internal translocation of water and other substances.



جزء مكبر من حزمة وعائية (نبات زهرة الشمس)



مقطع متعرض لساق نبات زهرة الشمس

Anatomy of monocot stem

In monocot stems there is no secondary growth. The stems bear only primary permanent structures which are formed due to the activity of the apical meristem only. We are discussing here the anatomy of *Zea mays* stem. It can be distinguished in the following region.

1- Epidermis :

It is single outermost layer composed of small thin walled somewhat barrel-shaped parenchymatous cells which are tightly packed without intercellular spaces. A thick-cuticle is present on the outer surface. Here and there in the epidermis few stomata are present. Usually the trichomes or hairs are lacking (Fig.12.) .

2- Cortex :

The cortex is not well differentiated into disinct regions it is composed of the following regions :

a- Hypodermis

It lies just below the epidermis comprising few layers of thick walled lignified sclerenchymatous cells without intercellular spaces (hypodermal fibers).

b-Ground tissue :

It is a continuous mass of thin-walled,parenchymatous tissues which lies below the hypodermis. The intercellular spaces are porfusely present. The cells are rounded or polygonal in shape. There is no differentiation of general cortex, endodermis, pericycle, pith and pith-rays, vascular bundles are irregularly embedded in this region.

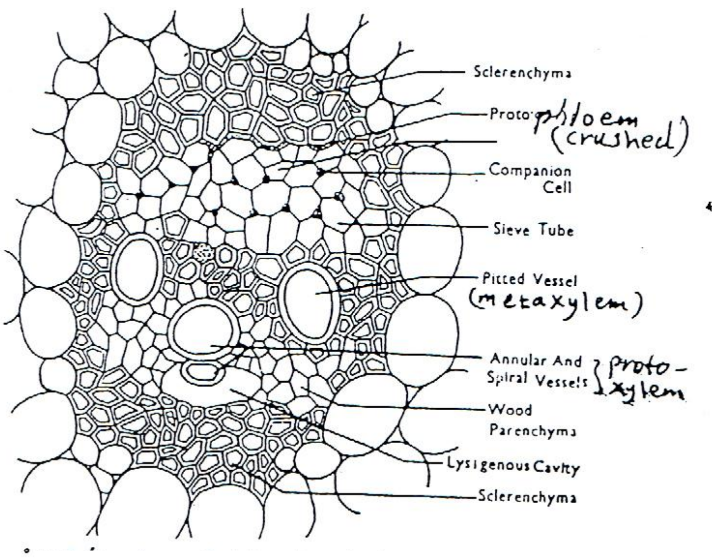
c- Vascular bundles

the vascular bundles are conjoint, collateral, and closed without cambium, irregularly scattered in the ground tissue. The bundles present in the peripheral region are smaller in size and compactly arranged while those towards the central region are larger in size and widely placed. All the vascular bundles have similar structure, it has xylem towards the center and phloem toward the periphery, it is oval in shape and surrounded by a sheath bundle sclerenchymatous cells (bundle sheath fibers) more numerous on upper and lower side. Xylem, it is Y- shaped bearing two large metaxylem vessels with wider cavities and pitted thickening at two lateral arms. The protoxylem vessels are only one or two smaller with narrow cavities and having annular or spiral thickening at the base.

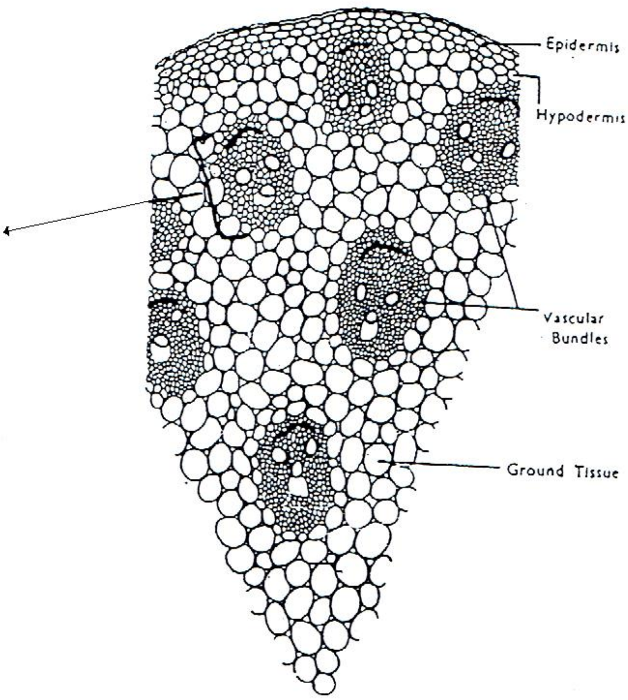
Below the protoxylem vessels there is a large water containing cavity formed lysigenously by disintegration or breaking of some cells of parenchyma tissue and rarely protoxylem vessels (Schizolysigenous inter cellular spaces).

Phloem, it lies outside the xylem and is partly present near the metaxylem vessels. It is composed of sieve elements and companion cells. In a mature bundle the protophloem cells get crushed just below the sheath so the inner portion is the metaphloem,. The sieve tube appear polygonal in shape in teansvers section having internally situated companion cells.

3- Stele **Absent**, the vascular bundles are irregularly arranged in the cortex.



حزمة وعائية مكبرة لنبات الذرة



مقطع متعرض لساق نبات الذرة

Lecture: 11

Anatomy of Dicot Root

Absorption of water and dissolved minerals from the soil is carried out by roots. Therefore, cuticle in roots is absent. The noncutinized outerlayer of the root is called as epiblema or rhizodermis.In general outline , the transverse section appears circular following tissues are visible.

1- Epiblema (rhizoclermis)

it's the outermost uniseriate layer composed of this walled , closely packet , parenchymatous cells without inter cellular spaces . unicellular root hairs are present . The cuticle and stomata are absent. The root hairs absorb water and dissolved mineral salts from the soil.

2- Cortex

Its extends from just below the epidermis up to the stele and comprises following tissues:

a- exodermis

it lies immediately below the epiblema, composed of one layer is closely packed. In some cases it is short lived and outermost cortical cells bear thin cuticle and become corky. These perform the function of protection. This layer is called as exodermis.

b- general cortex

it composed the largest layers of thin walled loosely arranged cells bear conspicuous intercellular spaces. The cells contain leucoplasts for storage of starch grains.

c- endodermis

it occurs inner to the general cortex around the stele and it is composed of barrel shaped parenchymatous cells without intercellular spaces. Usually the radial and inner tangential wall of these cells are thickened due to deposition of suberin and lignin due to deposition strip like structure are formed, these are known as casparian strips. The endodermis act as a water tight jacket around the stele (why?)

because: The cells of the endodermis lying opposite to the protoxylem elements are thin walled and known as passage cells because they allow the passage of water from root to the xylem.

3- stele

It is tetrarch as there are four xylem bundles alternating with four phloem bundles. It consists of following parts:

a- pericycle

It lies internal to the endodermis and forms a single uniseriate layer of thin walled parenchymatous cells containing a bundant protoplasm.

b- vascular bundles

these are arranged in ring but xylem and phloem are placed on different radii (pl. of radius) having equal number of patches, arranged alternately.

c- pith

it is a central small region or absent in the dicot root.

Anatomy of Monocot root

The internal structure of Monocot root comprises following parts:

1- Epiblema

It is similar to epiblema of Dicot roots.

2- Cortex

It lies inner to epiblema, it is similar in structure to that of dicots.

3- Endodermis

It lies below the cortex around the central stele

4- Stele

It is comprising following parts:

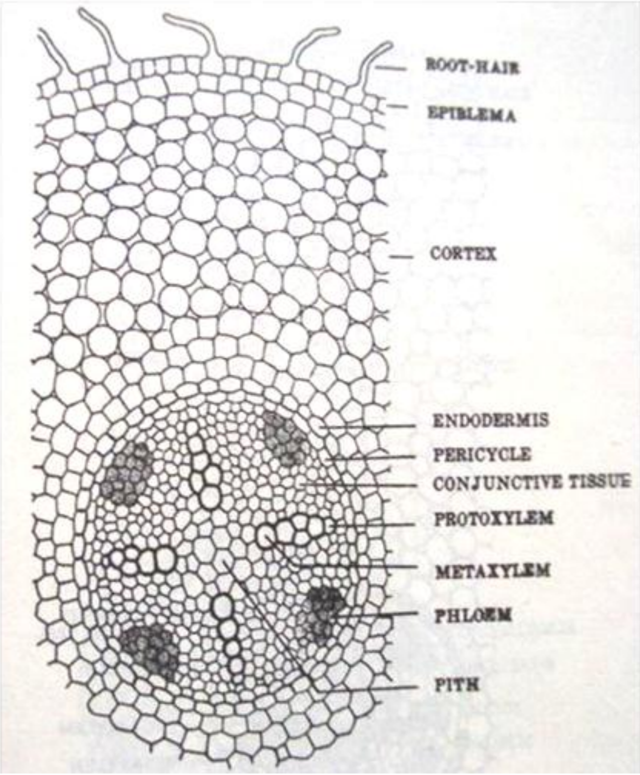
a- pericycle

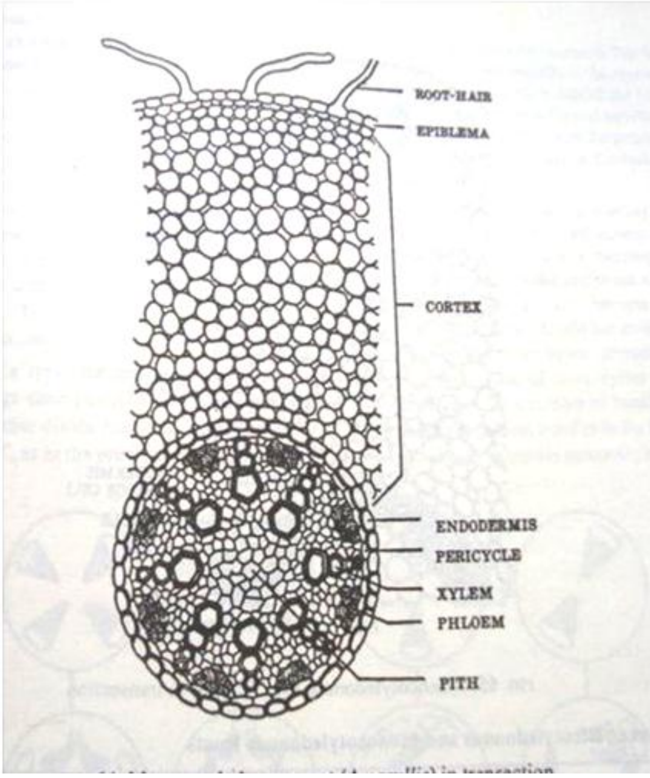
b- vascular bundles

there are a large number of radial bundles arranged in a ring around the central pith.

c- Pith

it is the central portion and widely than in Dicots roots.





Cross section in dicot root **cross section in monocot root**

Differences between anatomy of root and stem

Stem	Root
1-Stem bears multi-cellular hairs with cuticle .	1-Root has uni-cellular hairs with thin walls , without cuticle .
2-Cuticle and stomata are present in outer most epidermis .	2-Cuticle and stomata are absent in outer most epiblema .
3-Epidermis is protective in function .	3-Epiblema is absorptive in function .
4-cortex is narrow .	4-cortex is broad
5-outer most layer of cortex is hypodermis , it may be collenchymatous or sclerenchymatous and is protective in function .	5-outer most layer of cortex i.e. exodermis is some time protective in function .
6-Endodermis may or may not be distinct. It cells generally bear starch and thus the layer is known as starch-sheath .	6-Endodermis is generally distinct with thick radial walls . It form a water tight jacket around the stole .
7-passage cells are absent .	7-Passage cells are present .
8-pericycle is multi-layered composed of partly parenchymatos .	8-pericycle is single layered composed of thin walled parenchymatous cells .
9-Vascular bundles are conjoint collateral and either closed or open .	9-Vascular bundles are radial i.e. ,xylem and phloem are separate .
10-Xylem is endarch i.e. , proto-xylem is towards center .	10-xylem is exarch i.e. proto-xylem is towards periphery .
11-Lateral branches exogenous in origin .	11-Lateral branches are endogenous in origin .