1) THE CELL WALL

*** Definition:** — In plant, almost all cells (except the reproductive cells like gametes, zoospores etc.) are provided with a rigid wall, called cell wall. The protoplast is enclosed within the cell wall.

Presence of cell wall differentiate plant cells from animal cells. The cell wall was discovered in the 17 th century by Robert Hook.

* Gross structure of the cell wall (microscopic structure):

On the basis of development and structure, three parts are generally recognised in the cell wall such as: (i) middle lamella,
(ii) primary wall,
and (iii) secondary wall.

(i) Middle lamella: — The intercellular substance which is present between two cells is known as middle lamella. It is the first partition wall between two newly originated cells. The middle lamella is amorphous and optically inactive i.e. isotropic.

(ii) Primary wall: — Next to the middle lamella a soft and delicate wall is present, known as primary wall. The primary wall is usually single layered, thin, very elastic and capable of great extension and anisotropic. It grows both in surface as well as in thickness.

(iii) **Secondary wall:**– In case of thin walled cells the cell wall is made of middle lamella and primary wall only (e.g. parenchyma). But in case of highly thick walled cells (schlerenchyma, vessels) another wall layer is formed inside the primary wall known as secondary wall. Secondary wall formation generally takes place after a cell has completed its elongation, and therefore does not extend to any considerable degree. Secondary wall is usually three-layered such as (a) the outer thin layer, (b) the thickest middle layer and (c) the inner most layer. The wall is rarely continuous over the entire surface of the primary wall. In some cases, a tertiary wall may be formed over the secondary wall.

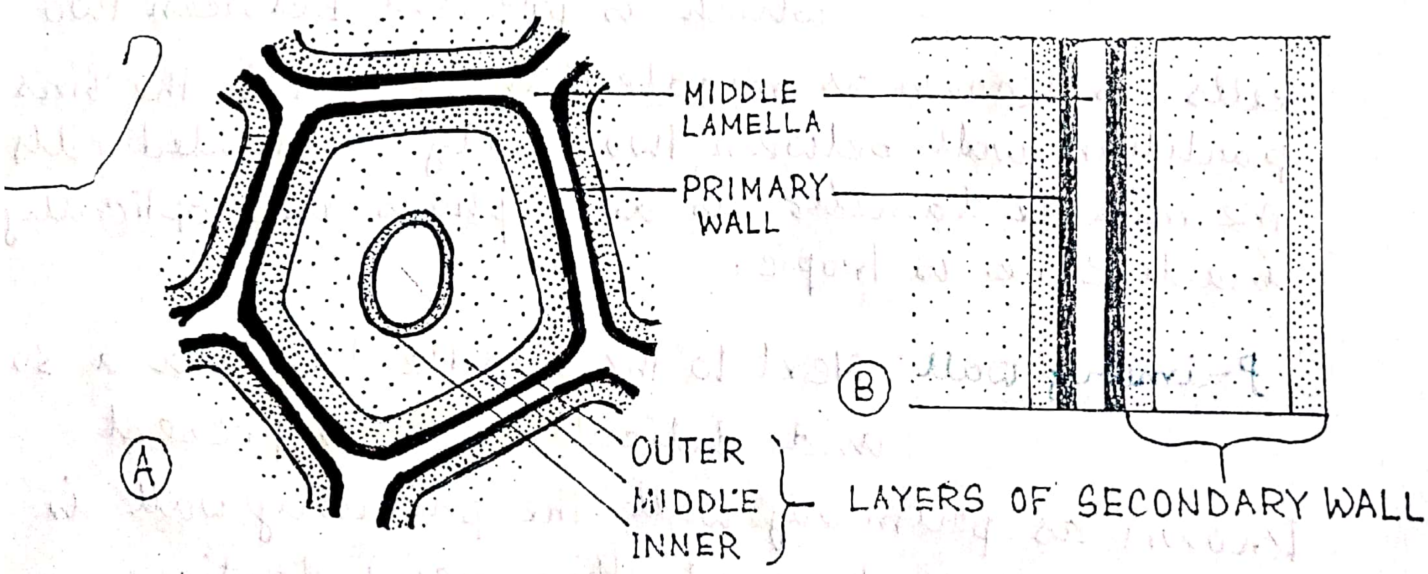


Fig: Wall-structure of a mature and lignified cell of plant.
(A)– In cross section.
(B)– In longitudinal section.

Ultrastructure of cell wall (sub-microscopic structure):-

The principal component of cell walls is Cellulose. The ultrastructure of cell wall is therefore based on cellulose. Work with electronmicroscope shows that cellulose in cell walls occurs in the form of long-chain molecules (Frey-Wyssling 1969-'76). These chain like molecules may be arranged randomly or in a more or less regular fashion. Each such cellulose molecule has a maximum width of 8 Å. Again cellulose molecules are regularly arranged in bundles and form an elementary fibril. Each bundle of elementary fibril contains 40-100 cellulose molecules in a transection, and is about 3.5 nm. wide and 3 nm. thick. Both the cellulose molecules and the elementary fibrils are ribbon-like structures. Each chain of cellulose molecules is crystalline in nature and termed as micelles or crystallites. It was observed that the number of glucose residues in cellulose molecules of fibre cell varies from 500-10,000 and the length of such molecules varies from 0.25-5 µm.

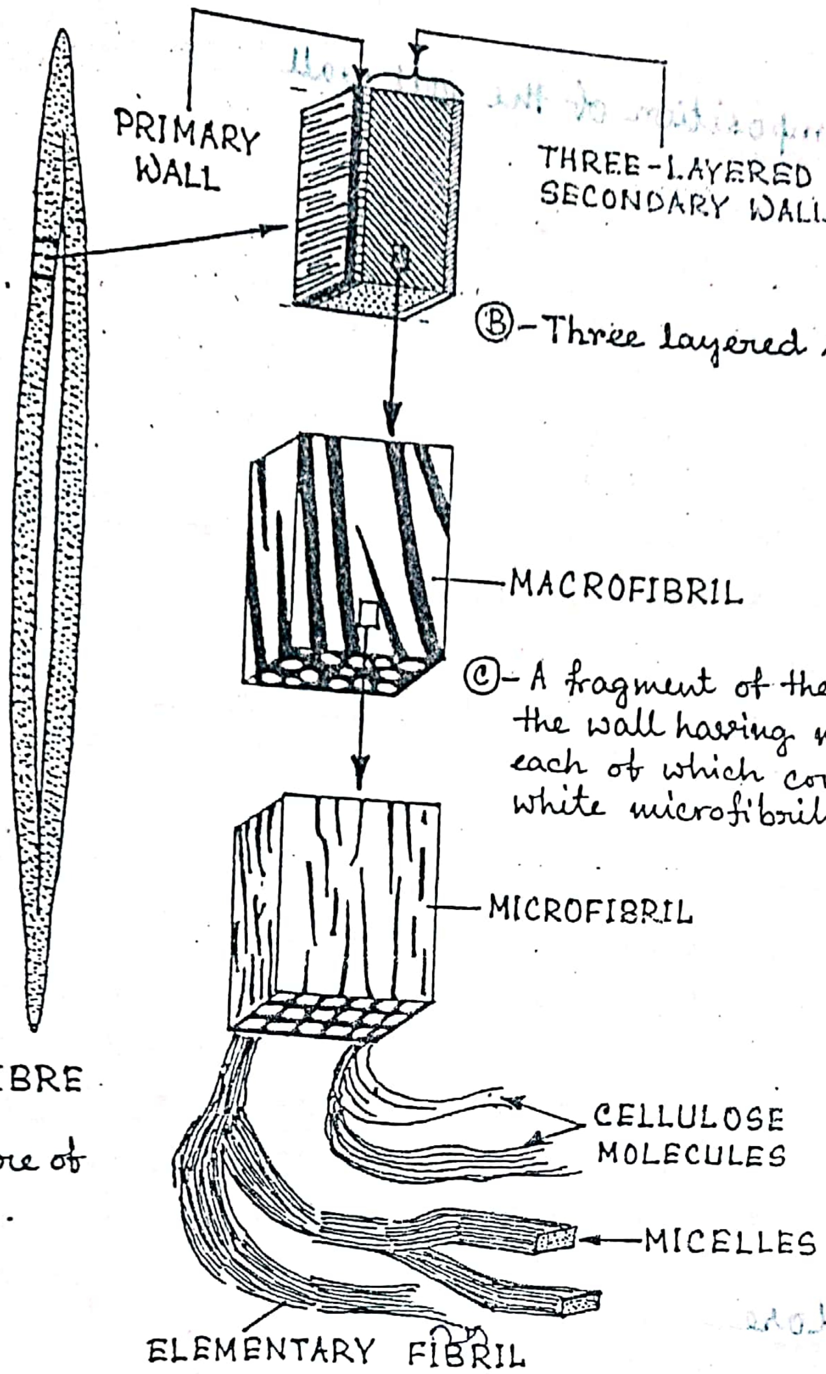
→ paragraph

The elementary fibrils are again arranged in bundles, each such bundle is called microfibril which is 250 Å wide and contains 2000 cellulose molecules. Microfibrils are combined into macrofibrils, each of which is 0.4 µ wide and contains 500,000 cellulose molecules

The spaces (micro capillary spaces) between the randomly arranged molecules in the microfibril are filled up with water, pectic substances, hemicellulose, lignin, cutin, suberin etc.

The microfibrils are arranged variously in cell walls. In the secondary walls they are arranged more or less regularly. In the primary wall they are arranged in transverse direction to the longitudinal axis.

Fig ⟹

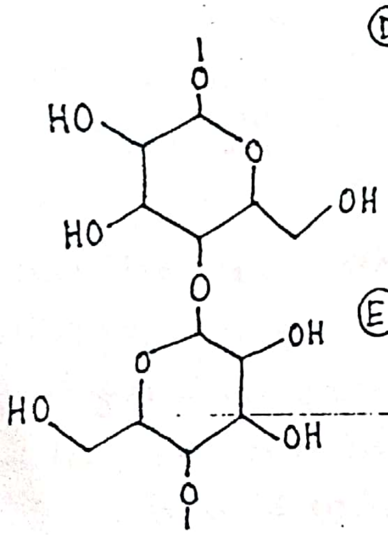


Ⓐ– Structure of a fibre.

Ⓑ– Three layered secondary wall.

Ⓒ– A fragment of the middle layer of the wall having macrofibrils (white), each of which consists of numerous white microfibrils.

Ⓓ– Microfibrils are composed of bundles of cellulose molecules, partly arranged into three dimensional network of crossed bars i.e. micelles.



Ⓔ–

Fig: Diagramatic representation of the ultrastructure of the cell wall.

* Chemical composition of the cell wall :-

Carbohydrate cellulose is the basic and most common compound in plant cell walls. Hemicellulose and pectic compounds are also the common carbohydrate constituents of the wall. The fatty compounds, suberin, waxes etc. occur in varying proportions in the walls of many types of cells. Various other organic compounds and mineral substances may also be present. Water is another important and variable component of cell walls. A group of proteins containing hydroxyproline may be present in the primary walls of various tissues.

(1) **Cellulose** — It is a relatively hydrophilic crystalline compound having the formula $(C_6H_{15}O_5)n$. The molecules of cellulose are chain- or ribbon-like structures with 1,000 or more of the glucose residues connected together by oxygen bridges with β-1,4-glucosidic bonds. The length of each chain varies greatly and may be upto 4 μ. (Frey-Wyssling, 1959).

Hemicellulose — These are like cellulose; they are built up not of glucose molecules, but of those of other sugars. Xylans, mannans, galactans, glucans etc. are examples of some of the individual members of hemicellulose.

Pectic substances — These substances occur in cell walls in three forms such as protopectic, pectin and pectic acid. Pectic substances belong to the polyuronids i.e. polymers composed mainly of uronic acid. Pectic compounds are amorphous, colloidal, plastic and highly hydrophilic.

Gums and mucilages are also regarded as compound carbohydrates of the cell walls. The mucilages occur in some mucillaginous and gelatinous types of cell walls of many aquatic plant bodies.

Lignin is another most important composition of the cell wall. It is a polymer made up of units of phenylpropane derivatives. Physically lignin is rigid. Lignin may be present in the middle lamella, the primary wall and the secondary wall.

Mineral substances like silica, calcium-carbonate etc. and various organic compounds like resins, tannins, fatty substances, volatile oils, acids, crystalline pigments etc. may impregnate walls.

Cutin, suberin and waxes are most important fatty substances present in the walls. Suberin and cutin are highly polymerised compounds composed of fatty acids. Cutin forms a continuous layer termed cuticle on the surface of epidermis of aerial plant parts. Suberin occurs with cellulose in cork cells of the periderm. Waxes are present in the surface of cuticle in various forms.

* Functions of cell wall :—

i) Cell wall protects the living protoplasm from external injury.

ii) It also gives definite shape to the cell and texture to the tissue.

iii) Cell walls provide mechanical strength to the cell.

iv) Being permeable, the cell wall allows water and mineral salts to pass through it.

v) Cell walls play an important role in some physiological activities such as absorption, transpiration, translocation, secretion etc. (Frey-Wyssling, 1959).

vi) Cell walls also connect the living protoplasts of adjacent cells through plasmodesmata.

* Plasmodesmata :—

Formation of secondary wall materials on the primary wall does not take place uniformly, instead some thin areas are left out — those thin areas are called pit-fields. Thin and delicate strands or fibrils of cytoplasm called plasmodesmata (singular - plasmodesma), pass through such pit-fields of the cell wall at intervals, thus connecting the living protoplasts of adjacent cells. Plasmodesmata usually occur in groups.

Plasmodesmata may be ~~quite~~ numerous.

e.g. — meristematic cells may have plasmodesmata between 1000-10,0000.

Practically, plasmodesmata are narrow channels through the cell wall, they are bounded by plasmalemma and containing cytoplasm and often a desmotubule. Desmotubules are derivatives of endoplasmic reticulum. Plasmodesmata are upto 60 nm. in diameter, normally organelles can not pass through them.

Plasmodesmata can be observed in the endosperm of certain species like Phoenix, Diospyros, Strychnos etc.

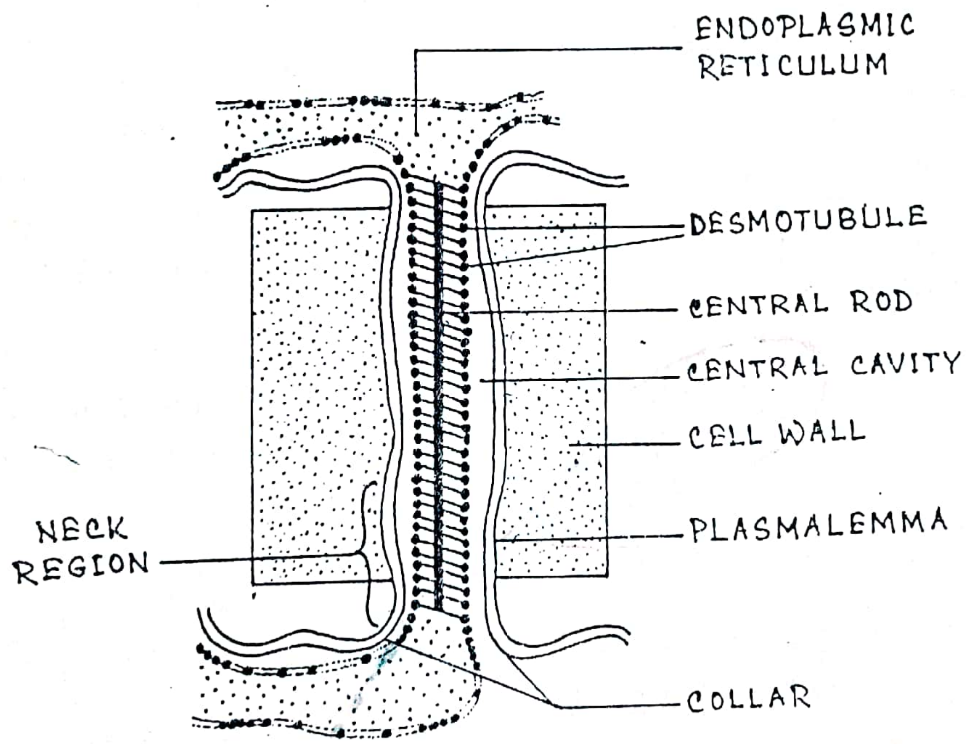


Fig: Diagram of a plasmodesmata as seen under electron microscope (in t.s.).

Function of plasmodesmata:—

1. Plasmodesmata are mainly concerned with the translocation of food specially in storage tissue like endosperm.

2. Plasmodesmata are concerned with the conduction of external and internal stimuli through plant tissue.

3. In some cases they establish union of isolated protoplasts of the plant body into a single protoplasmic structure.

4. Sometimes they are regarded as channels for the movement of viruses from cell to cell. (Esau, 1965).

5. It has been thought that most plant hormones move through the plasmodesmata (Carr, 1976).

III Economic importance of Plant Cell Wall:

Besides protective functions, cell wall reveals some important economic aspects —

1. Jute is a bast fibre obtained from the secondary phloem of Corchorus sp. (Tiliaceae).
2. Resin, tannin, volatile oil are present in the cell wall structure mostly.
3. The wood obtained from the plant is hard and rigid due to presence of the cell wall deposition Like- Lignin, cutin, Suberin etc..
4. The primary walls of the endosperm are very thick and serve as a source of reserve carbohydrate
5. Secondary walls are non-Living at maturity, yield cotton fibres from hairy coverings of the seed of Grossypium herbaceum.
6. Calcium carbonate crystals are present in the epidermal cell walls of leaves of Ficus elastica (rubber plant). produce the latex.

PIT

Pit :- Pits are unthickened areas in the secondary walls of the plant cells. They, therefore, appeares depressions. Pit generally occur in pair on the wall of two adjacent cells. A pit has a cavity, pit chamber, & pit membrane. The pit membrane consist of Primary wall and middle lamella.

▲ Fundamentally Pit or pit pair consist of three parts :-

- Pit cavity :- The space or the cavity formed by the break in the secondary wall is called pit cavity or Pit chamber.

- Pit aperture :- The openining of the pit cavity on the inner-side of the cell wall is called pit aperture.

- Pit membrane or closing membrane :- It is the thin wall composed of the layers of primary cell wall together with the middle lamella between two adjacently lying cells.

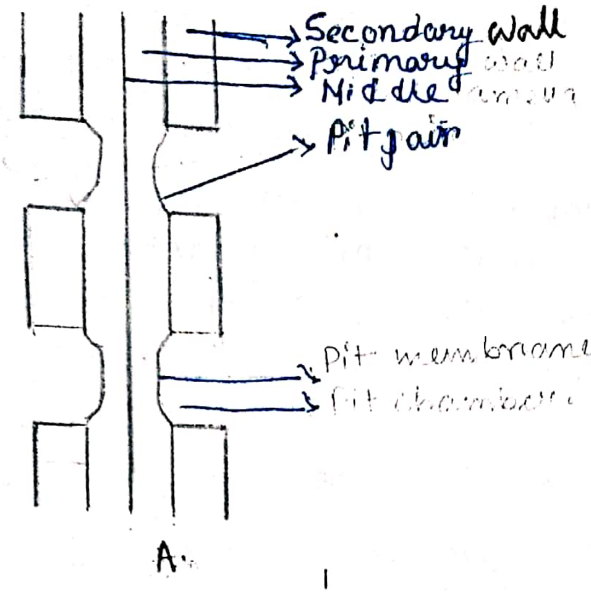
Types of Pits :-

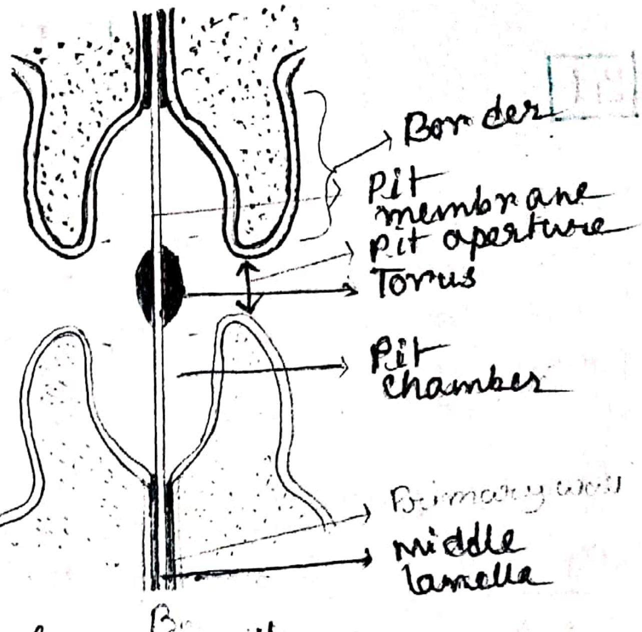
Two main types of Pits are recognised in cells with secondary walls.

(1) Simple Pits
(2) Bordered Pits

(1) **Simple pits** :- These are round or oval thin areas in front views. The diameter of the pit cavity is equal through out its entire depth or it may be wider or narrower towards the pit aperture, the simple pit approaches the structure typical of a bordered pit. The thickened side walls (of the secondary wall) lie at right angles to the pit membrane. No border or rim is found. In place where the secondary wall is very thick, the pit cavity has the form of canal.

Simple pit may break into two or more cavities and look like branched canal, called ramiform pits or branched simple pits.





A. Diagram showing the str. of simple pit
B. Diagram showing the str. of bordered pits.

3) **Bordered pits** :- The bordered pits are more complex and more variable in structure than simple pits. In this type, pits are provided with a rim or border. The secondary wall develops over the pit cavity i.e. pit chamber to form an over arching roof (Pit border) with narrow pore (pit aperture) in its center. The pit aperture may be circular, lenticular, or linear. If the secondary wall is very thick, a canal called pit canal formed between the cell lumen and pit chamber. The two openings are distinguished in the pit canal such as (i) inner aperture, which lies towards the cell lumen, (ii) Outer aperture, which lies towards the cell wall.

The pit membrane is composed of two thin layers of primary wall and middle lamella. In some cases the central portion of the pit ~~chamber~~ membrane is thickened, which is of a primary nature, this disc-shaped thickening called torus (diameter larger than pit aperture). Thin part of the membrane surrounding the torus, called margo. (Frey-Wyssling 1959)

The pit membrane is flexible and under certain conditions the torus occurs in a lateral position, appressed to one or the other pit aperture of the pit pair, called aspirated pit pair.

Bordered pits generally occur in the elements of xylem, e.g vessels, tracheids, fibres etc.

If two pits of the pair are simple, called simple pit pair, if two pits are bordered. called bordered pit-pairs.

Sometimes a type in between simple and bordered pit, known as a half bordered pit pair.

Vestured pits

Vestured pits :- In some dicotyledons thin, simple or branched sculpturing of various shape are formed on the secondary wall or around the pit aperture, called vestured pits or sieve pits. These pit appears as porous or net like in top views.

It is found in tracheary elements of the secondary wood of Cucurbitaceae, Myrtaceae, Leguminosae etc (dicotyledonous families).

Function:- Through the pit substances move from cell to cell. In living cells the plasmodesmata remain in the region of the pit membrane.

Simple Pits	Bordered pits.
① No border or rim is found.	① Border or rim is found
② Secondary wall does not over the pit cavity.	② Secondary wall develops over the pit cavity.
③ inner and outer aperture is absent.	③ Inner and outer aperture is present.
④ torus is absent.	④ torus is present.
⑤ Found in libriform fibre, sclereids, xylem parenchyma.	⑤ Found in elements of xylem vessels, tracheids, fibres etc.

⟨3⟩ STOMATA (singular. – Stoma)

* **Definition:** The continuity of the epidermis is interrupted by minute pores or openings called stomata.

Stomata occur on most of the green aerial plant parts, specially on leaves and young stems, roots lack stomata.

* **Structure:** A stoma consists of a pore bounded by two specialised epidermal cells called guard cells, which by their changes in shape bring about closing and opening of stoma. The pore of the stoma is the stomatal aperture through which gaseous exchange takes place.

The guard cells together with the stomatal aperture i.e. pore between them constitute the stoma proper.

The epidermal cells adjoining the guard cells often differ morphologically from the rest of the typical epidermal cells, such cells are called subsidiary or accessory cells. The whole str. i.e. stoma together with the subsidiary cells is termed as stomatal complex.

In many dicots, the guard cells are semi-lunar, crescent shaped cells, attached to each other by their curved ends and forming a silt-like opening. But in many monocots, guard cells are dumbbell shaped having a thick wall and narrow pore.

The guards cells contains distinct single nucleus, mitochondria, elements of E.R., golgi bodies, vacuoles and chloroplastids.

Just beneath each stoma, a prominent cavity or intercellular spaces known as sub-stomatal chamber is present, which communicates to the exterior by stomatal pore.

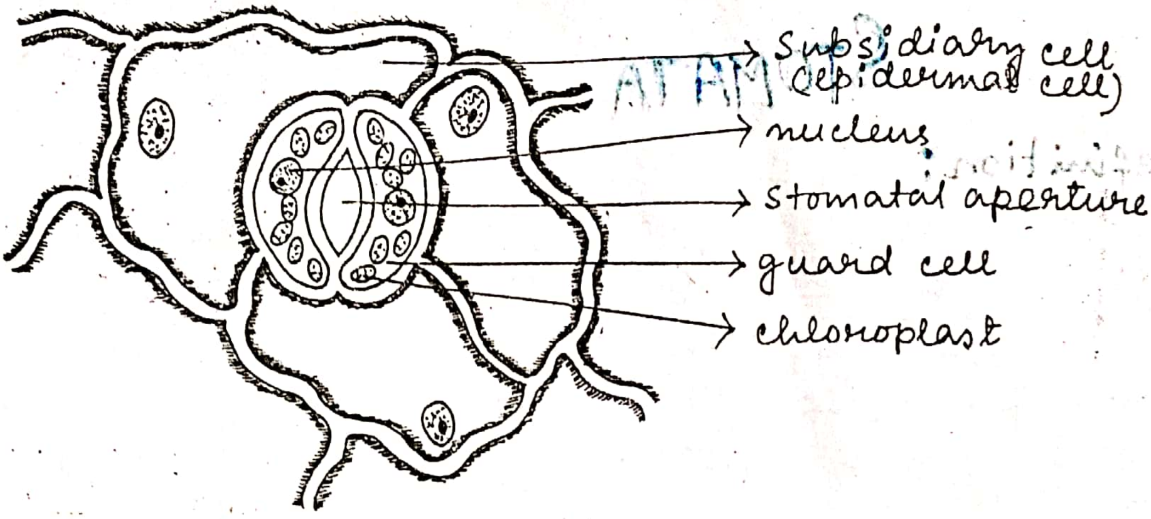


Fig: Structure of stoma in surface view.

* Types of Stomata :

(1) IN DICOTYLEDON

→ On the basis of the arrangement of subsidiary cell neighbouring the guard cells, Metcalfe and Chalk (1950) have classified four stomatal type among dicotyledons, viz —

Ranunculus

(i) Type A : Anomocytic or irregular celled type — Here actual subsidiary cells are absent, each stomata is irregularly surrounded by a certain number of cells which do not differ in size and shape from other epidermal cells. This type is also known as Ranunculus type.

⇒ Found in Cucurbita sp., Ranunculus sp.

Cruciferous

(ii) Type B : Anisocytic or unequal celled type — Here each stoma is surrounded by three subsidiary cells, one cell being considerably smaller or larger than the other two. This type is known as Cruciferous type.

⇒ Found in Solanum sp., Brassica sp.

(iii) Type C : Paracytic or parallel-celled type —

Rubiaceous

Here each stoma is accompanied on either side by one or more subsidiary cells, the longitudinal axis of which are parallel to that of the guard cells and pore. This type is also known as Rubiaceous type.

⇒ Found in Gardenia sp., Phaseolus sp.

(iv) Type D : Diacytic or cross-celled type —

Type

Caryophyllaceous

Here each stoma is surrounded by two subsidiar cells and their common wall is at right angles to the longitudinal axis of the guard cells. ~~Typ~~ This type is also known as Caryophyllaceous type.

⇒ Found in Dianthus sp., Hygrophila sp.

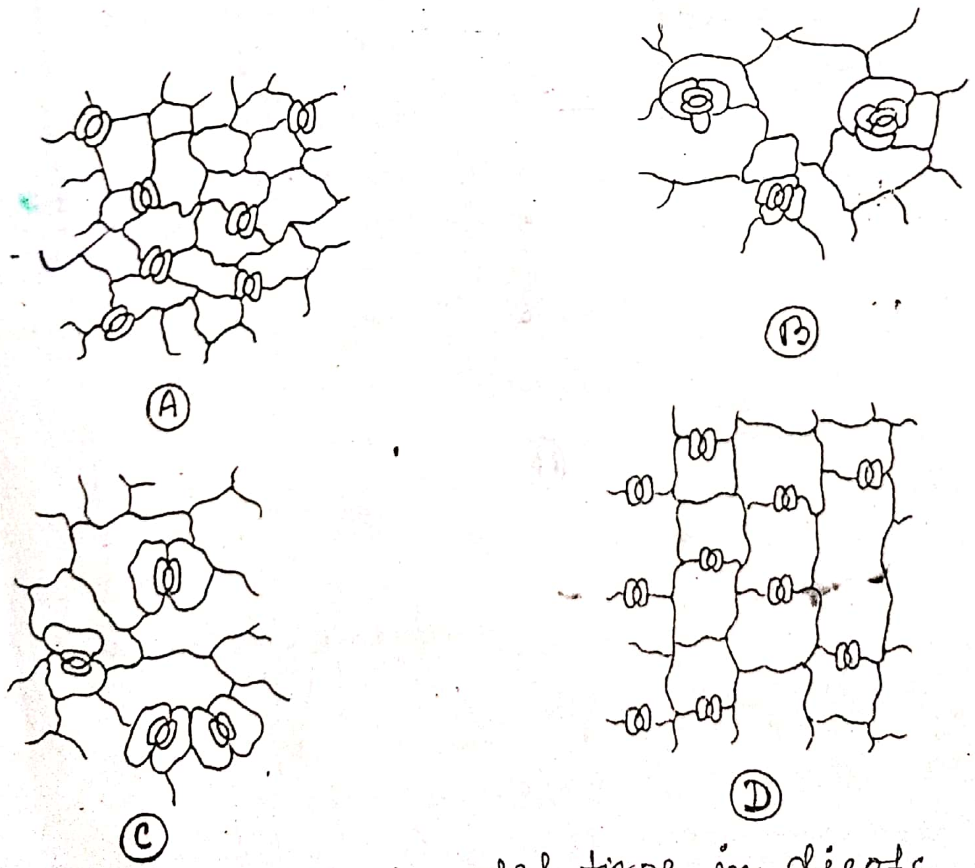


Fig: Different stomatal type in dicots.
(A) – Anomocytic type ; (B) – Anisocytic type
(C) – Paracytic type ; (D) – Diacytic type

In monocotyledon

Stebbins and Khush (1961) have classified the stomatal complex of monocotyledonous leaves into following types —

(i) **Type 1:** In this type, guard cells are surrounded by 4-6 subsidiary cells.

⇒ Found in *Commelina* sp., *Rhoeo* sp.

(ii) **Type 2:** Here guard cells are surrounded by 4-6 subsidiary cells of which 2 are smaller and rounded than the rest and are situated at the ends of guard cell.

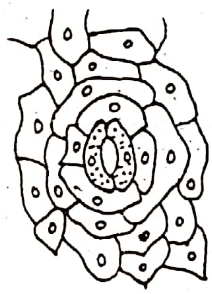
⇒ Found in *Pandanus* sp.

(iii) **Type 3:** In this type, guard cells are surrounded laterally by 2 subsidiary cells, one on each side.

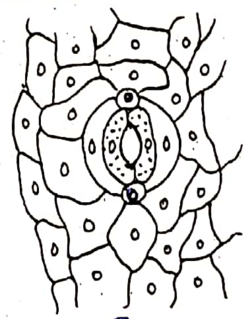
⇒ Found in *Alisma* sp., *Oryza* sp.

(iv) **Type 4:** In this type guard cells are not surrounded by any subsidiary cells.

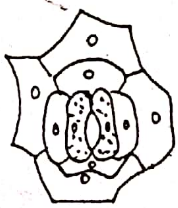
⇒ Found in *Vanda* sp., *Iris* sp.



(A)



(B)



(C)

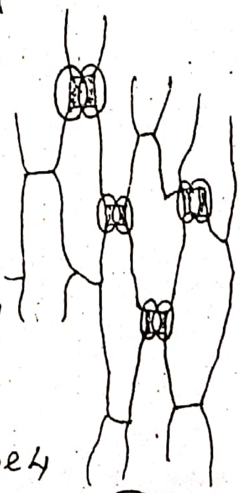


Fig: Different stomatal types in monocots.

(A) - Type 1 (*Commelina* type); (D) - Type 4 (*Iris* type) (D)
(B) - Type 2 (*Pandanus* type);
(C) - Type 3 (*Alisma* type);

Functions of Stomata:

① To take part in gaseous exchange between plant organs and atmosphere during respiration and photosynthesis.

② To eliminate excess of water absorbed by root system by the process transpiration.

③ To carry out photosynthesis in the guard cells owing to the presence of chloroplastids.

Ontogeny of Stomata (Origin):

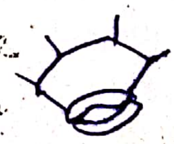
The stomata originate from the protoderm. Protodermal cells divides unequally into two cells - of these two cells, the smaller one acts as the mother cell or the precursor of guard cells. Subsidiary cells developed from protoderm cells lying close to stoma mother cell.

Pant (1965) on the basis of ontogeny, has classified stomata into the following types —

ⓐ **Mesogenous** — Here subsidiary cells have a common origin with the guard cells, i.e. both are developing from same meristemoid.

ⓑ **Perigenous** — Here subsidiary cells do not have a common origin with guard cells, instead subsidiary cells are formed by cells lying around the meristemoid that divides to form guard cells.

ⓒ **Mesoperigenous** — Here, at least one of the subsidiary cells has a common origin with the guard cells, but others do not have common origin.



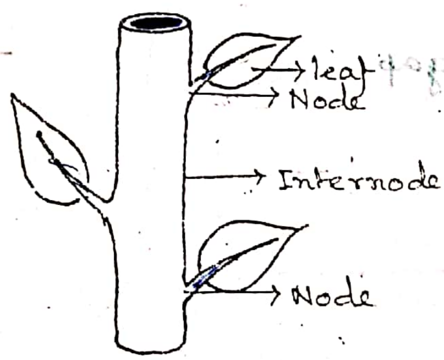
· Rannanculus

Scanned with CamScanner

NODAL ANATOMY

The stem together with its leaves and branches forms a continuous structure, known as 'shoot'. So, the vascular strands of stem and its lateral organs (leaves and branches) are interconnected to supply water and nutrients to all parts of the shoot.

A node is the point of attachment of the leaf on the stem. Here we discuss how the stelar vascular tissues of the stem break and enter into the lateral organs in the nodal positions.



STEM

1.

(A) Leaf Trace and Leaf Gap :—

The vascular strands of leaves and stem are connected. It is evident that at each node one or more vascular strands enter the leaf from the stele of the stem. Such prolongation of stelar vascular tissues into the leaf is called leaf trace or foliar trace. The terminal part of the leaf trace is made of both xylem and phloem, and the basal part is made of xylem only.

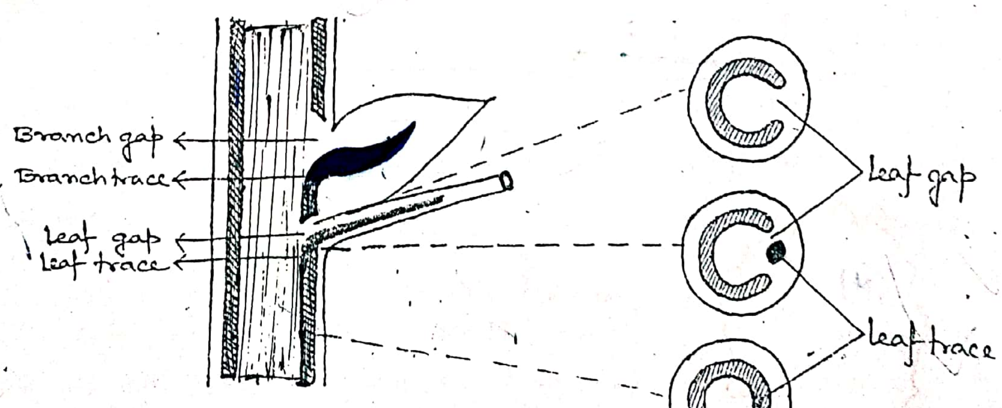
(*) (In the nodal region where a leaf trace bends away from the centre of the stem towards the leaf base, a parenchymatous region continuous with the pith occupy the interfascicular region known as leaf gap. A leaf gap is thus a parenchymatous region in the vascular cylinder of the stem located opposite and upper part of a leaf trace. The continuity of circular vascular cylinder is interrupted by leaf gap.)

The number of leaf traces and the number of leaf gaps are different in different plants; and even may vary in the same species. The gap is often called 'lacuna'; consequently the nodes of plants are known as unilacunar with single trace, trilacunar with three traces etc.

(B). Branch trace and branch gap :—

The extension of vascular strand of the stem into the lateral branches is known as branch trace or ramular trace. Thus all parts of the stem and its appendages are connected by primary vascular system. A branch trace is located above the leaf trace.

(An interruption occurs in the vascular cylinder around and above the point of departure of the trace. This opening or break, through which continuity of the pith and cortex is established is called branch gap. Branch gaps are larger and more extended than leaf gaps.



L.S through a node showing B/G, B/T, L/G, L/T.

T.S

Concept of Apoplast and Symplast

What is Apoplast?

Apoplast is the space outside the plasma membrane consisting of intercellular spaces where the material diffuses freely. It does not involve protoplasm in the plant tissues but involves the non-living parts of the plant such as cell wall and intercellular spaces.

Apoplast Pathway

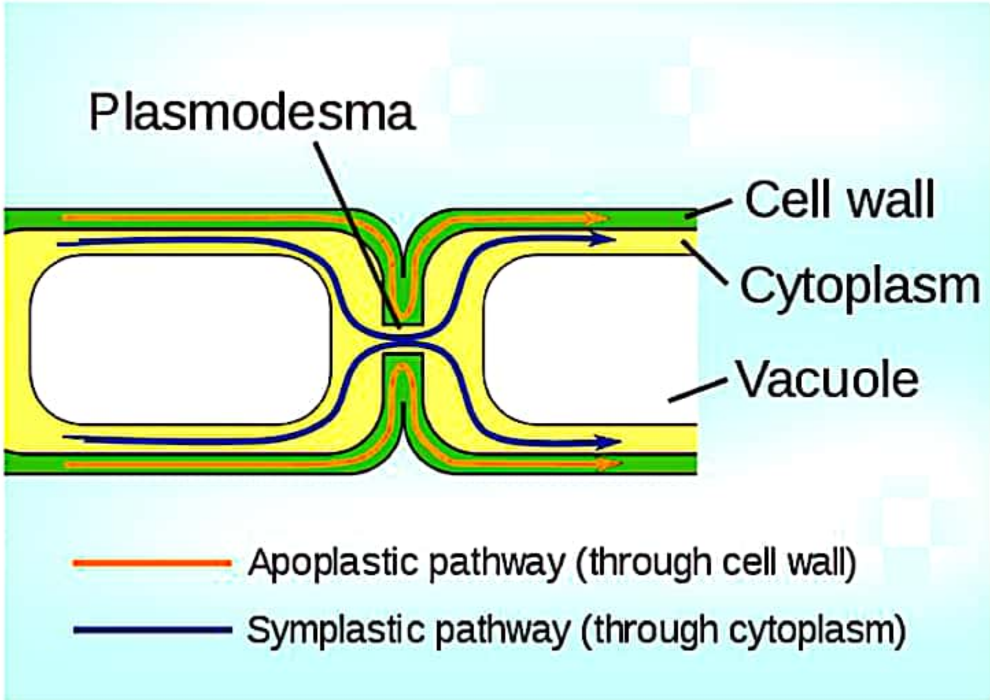
In the apoplast pathway, water is transported from root hair to xylem through the cell wall of intervening cells. The apoplastic route is blocked by a Casparian strip of endodermal cells. Hence, the symplastic route is utilized to deliver water and ions over the cortex. Since apoplast is made up of non-living components, the apoplastic route is least affected by the metabolic state of the root.

What is Symplast?

Symplast consists of cytoplasm network of every plant cell interconnected by plasmodesmata. Symplast does not involve intercellular spaces and cell wall and therefore considered as the complete living component of the plant tissue.

Symplast Pathway

The pathways of ion and water created by symplast are known as the symplastic pathway. This pathway offers resistance to the flow of water since the selective plasma membrane of the root cells handles the intake of ion and water. Moreover, symplasty is affected by metabolic states of the root. The symplastic route occurs beyond the endodermis in plants with secondary growth.



Difference between Apoplast and Symplast

The major difference between apoplast and symplast is as follows:

Criteria	Apoplast	Symplast
1.Parts	Consist of intercellular spaces and cell wall.	Consist of protoplasm.
2.Living and Nonliving parts	Consists of non-living parts.	Consists of living parts.
3.The rate of Pathways	Apoplastic pathway is fast.	Symplastic pathway is slower than the apoplastic pathway.
4.Metabolic State	No effect on water movement.	Metabolic states interfere with the flow of water in the symplastic pathway.
5.Transportation	More ion and water are transported through the apoplastic pathway in the cortex.	Water and ion are mainly delivered through the symplastic pathway beyond cortex.