Semester	Course	Hours	Credit	Sub. Code	Marks
III	CC 4	6	5	18K3B04	25 + 75 = 100

ANATOMY AND EMBRYOLOGY

UNIT-I: ANATOMY

Plant tissues - Meristematic tissues, Permanent Tissues- simple Tissues (Parenchyma, Collenchyma and Sclerenchyma) Complex Tissues (xylem and phloem),Stomata- Types of stomata.

UNIT-II

Primary structure of root, stem and leaf in Dicots and Monocots. Normal secondary growth in stem and root.

REFERENCES

1. Pandey B.P., 2005. Plant Anatomy,S.Chand& Company Ltd. New Delhi.
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UNIT-I

UNIT – I : ANATOMY

Plant Tissues

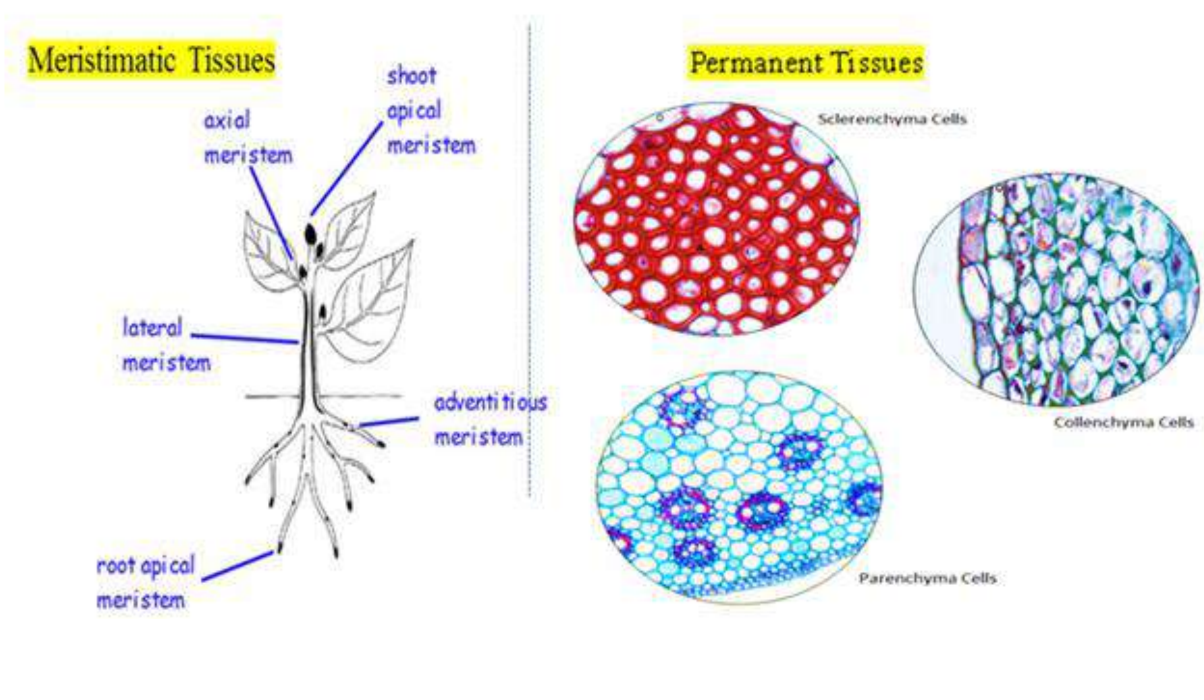
A collection of cells performing a specific function is called tissue. Plant tissues can be grouped into plant tissue systems each performing specialized functions. A plant tissue system is defined as a functional unit, connecting all organs of a plant. Plant tissue system is also grouped into various tissues based on their functions. Let's find out more.

Types of Plant Tissues

Plant tissues can be broadly classified based on the ability of the cells to divide into Merismatic tissue and Permanent tissue.

Merismatic tissues consist of a group of cells that have the ability to divide. These tissues are small, cuboidal, densely packed cells which keep dividing to form new cells. These tissues are capable of stretching, enlarging and differentiating into other types of tissues as they mature. Meristematic tissues give rise to permanent tissues. Merismatic tissues can be of three types depending on the region where they are present: Apical meristems, lateral meristems, and intercalary meristems.

Permanent tissues are derived from the merismatic tissues and have lost their ability to divide. They have attained their mature form. They are further classified into two types: Simple and complex permanent tissues.



Permanent Tissues

The permanent tissues form the major portion of the plant.

Simple Permanent tissues

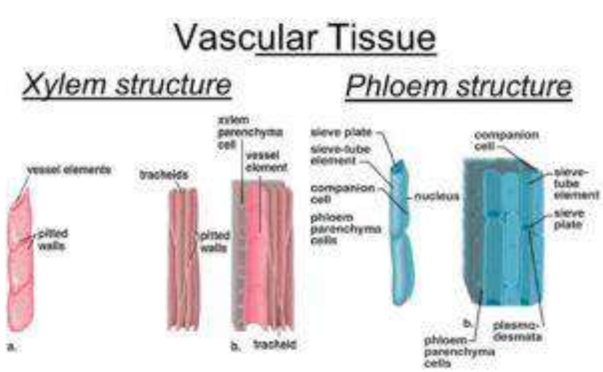
- **Parenchyma**– These tissues are found in the soft parts of a plant such as the roots, stems, leaves, and flowers. The cells of this tissue are loosely packed and contain large intercellular spaces between them. Each cell has a vacuole at the center. The functions of parenchyma tissues are storage, photosynthesis, and to help the plant float on water.

- **Collenchyma-** Are similar to parenchyma cells with thicker cell walls. They are meant to provide mechanical support to the plant structure in parts such as petiole of the leaf.

- **Sclerenchyma-** The cells of this tissue are dead. They are rigid, contain thick and lignified secondary walls. Their main function is to provide strength and support to parts of the plant.

Complex Permanent Tissue

Unlike simple permanent cells which look the same and are made up of one type of cells, complex permanent tissues are made up of more than one type of cells. These different types of cells coordinate to perform a function. Xylem and Phloem are complex permanent tissues and are found in the vascular bundles in the plants.



Xylem- It consists of tracheids, vessels, xylem parenchyma and xylem fibres. Tracheids and vessels are hollow tube-like structures that help in conducting water and minerals. The xylem conducts only in one direction i.e vertically. The xylem parenchyma is responsible for storing the prepared food and assists in the conduction of water. Xylem fibres are supportive in function.

Phloem- It consists of four of elements: sieve tubes, companion cells, phloem fibres and the phloem parenchyma. Unlike the xylem, phloem conducts in both directions. It is responsible for transporting food from the leaves to the other parts of the plant. Phloem contains living tissues except for fibres that are dead tissues.

Functions of plant tissues

Plant tissues have different functions depending upon their structure and location

- Help provide mechanical strength to organs.
- They help in providing the elasticity and flexibility to the organs.
- They help the tissues to bend easily in various parts of a plant like- leaf, stem, and branches without damaging the plant
- The xylem and phloem tissues help in transportation of material throughout the plants
- They divide to produce new cells and help in the growth of the plants.
- They help in various cellular metabolisms like photosynthesis, regeneration, respiration, etc.

Complex Tissues: Xylem and Phloem (With Diagram)

- The complex tissues are heterogeneous in nature, being composed of different types of cell elements. The latter remain contiguous and form a structural part of the plant, adapted to carry on a specialised function.
- Xylem and phloem are the complex tissues which constitute the component parts of the vascular bundle. They are also called vascular tissues.
- The vascular system occupies a unique position in the plant body, both from the point of view of prominence and physiological importance. The term 'vascular plants' has been in use since a long time.
- In recent years a new phylum Tracheophyta has been introduced to include all vascular plants; it covers pteridophyta and spermatophyta of old classifications. Vascular bundles form a continuous and interconnected system in the different organs of the plants.
- They are primarily responsible for transport of water and solutes and elaborated food matters.

Xylem:

- Xylem is a complex tissue forming a part of the vascular bundle. It is primarily instrumental for conduction of water and solutes, and also for mechanical support. Primary xylem originates from the procambium of apical meristem, and secondary xylem from the vascular cambium. As a complex tissue it consists of different types of cells and elements, living and non-living.

- The tissues composing xylem are tracheids, tracheae or vessels, fibres, called xylem fibres or wood fibres, and parenchyma, referred to as xylem or wood parenchyma. Of the above mentioned elements only the parenchyma cells are living and the rest are dead. A term hadrome was once used for xylem. It included the elements excepting the fibres.

Tracheids:

- A tracheid is a very much elongate cell (Fig. 538) occurring along the long axis of the organ. The cells are devoid of protoplast, and hence dead. A tracheid has a fairly large cavity or lumen without any contents and tapering blunt or chisel-like ends.

- The end walls usually do not uniformly taper in all planes. Tracheids are round or polyhedral in cross-section. They are really the most primitive and fundamental cell-types in xylem from phylogenetic point of view. The wood of ancient vascular plants was exclusively made of tracheids. This is the only type of element found in the fossils of seed-plants.

- In modern plants they practically occur in all groups including the angiosperms, though they predominate in lower vascular plants, the pteridophytes and gymnosperms. More effective conducting elements, tracheae or vessels, have evolved from the tracheids.

- The wall is hard, moderately thick and usually lignified. Secondary walls are deposited in different manners, so that the tracheids may be annular, spiral, reticulate, scalariform or pitted. But pits of the bordered type are most abundant. Through these pits they establish communication with adjoining tracheids and also with other cells, living or non-living.

- The nature of the pits on the walls of the tracheids is variable; in lower vascular plants the pits are elongated giving them scalariform appearance (Fig. 538 C & D), those of gymnosperms and angiosperms have round pits with well-developed borders (Fig. 538 A & B). Tracheids occur both in primary and secondary xylem.

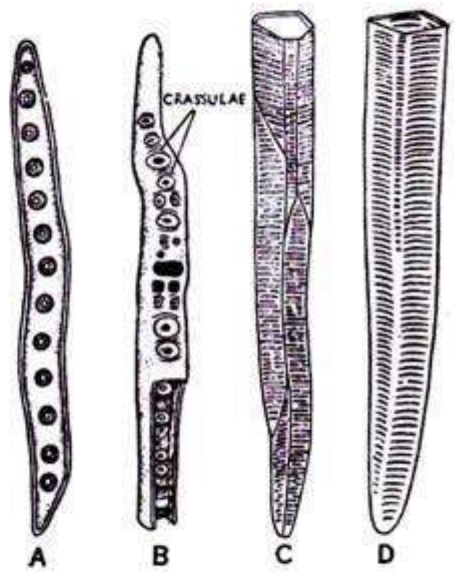


FIG. 538. Tracheids. A. A tracheid with bordered pits. B. A part showing bordered pits with crassulae. C & D. Parts with scalariform thickening.

- Due to the presence of central lumen and hard lignified wall tracheids are nicely adapted for transport of water and solutes. They also serve as supporting tissue.
- A typical fibre differs from a tracheid in more pronounced thickening of the wall and correspondingly much smaller lumen, as well as in reduction of the size of the pits. An intermediate type of cell element, called fibre-tracheid, is found in some plants.
- They have smaller pits with reduced or vestigial borders. In some cases protoplast persists up to the mature stage, and may even divide, so that transverse partition walls are noticed within the original wall. These are called septate fibre-tracheids.
- These are long tube-like bodies ideally suited for the conduction of water and solutes. A trachea or vessel is formed from a row of cylindrical cells arranged in longitudinal series where the partition walls become perforated, so that the whole thing serves like a tube.
- In tracheids the only openings are the pit-pairs, whereas the vessels are distinct 'perforate' bodies. Thus translocation of solutes becomes more easy in a vessel, as it proceeds more or less in a straight line; but the line of conduction is rather indirect in a group of tracheids.
- Perforations are commonly confined to the end-walls, but they may occur on the lateral walls as well.
- The walls undergoing perforations are referred to as perforation plates, which are mainly of two types multiple plates and simple ones. In primitive plants it has been found that the end-walls between the cells do not completely dissolve, but the openings or perforations remain either in more or less parallel series like bars called scalariform

perforation (Fig. 539A) or in form of a network known as reticulate perforation, or even may form a group of circular holes (foraminate perforation).

- In advanced types of plants the dissolution of the end-wall is more or less complete, and the perforation occurs in form of a single large circle. This is referred to as simple perforation (Fig. 539B).

- There is anatomical evidence in support of the fact that the single large circular or oval perforation has been formed by gradual disappearance of the transverse bars of scalariform and other types. The vessels are considerably long bodies; in ash plant, Fraxinus excelsior of family Oleaceae vessels has been reported to be as long as 10 ft.

- Like tracheids these elements are devoid of protoplast and have hard and lignified cell-wall with different types of localised thickenings. Some forms intermediate between typical tracheids and vessels have been noticed. These elements, analogous to fibre-tracheids, are called vessel-tracheids.

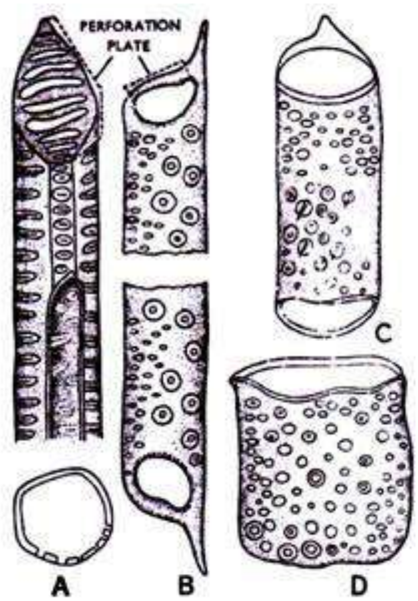


FIG. 539. Tracheae—different types. A. With multiple perforation plate in l.s. and t.s. B, C & D. With simple perforation plates.

Ontogeny of a Vessel:

- A vessel or a trachea originates from a row of meristematic cells of procambium or vascular cambium which remain attached end on end in longitudinal series (Fig. 540).

- As usual the cells grow and secondary walls are laid down, only the primary walls where perforations will take place remain uncovered. The secondary walls undergo lignification and other changes.

- The protoplast in the mean time becomes progressively more and more vacuolated and ultimately dies and disappears. The primary walls swell due to increase of pectic inter-cellular substance and break down, thus forming the continuous vessel.

- It should be noted that a vessel or trachea arises from a group of cells, unlike a tracheid, which is an elongate 'imperforate' single cell. The individual cells taking part in the formation of the vessel are called vessel elements.

- The walls undergoing perforations are referred to as perforation plates, which are mainly of two types multiple plates and simple ones. In primitive plants it has been found that the end-walls between the cells do not completely dissolve, but the openings or perforations remain either in more or less parallel series like bars called scalariform perforation (Fig. 539A) or in form of a network known as reticulate perforation, or even may form a group of circular holes (foraminate perforation).

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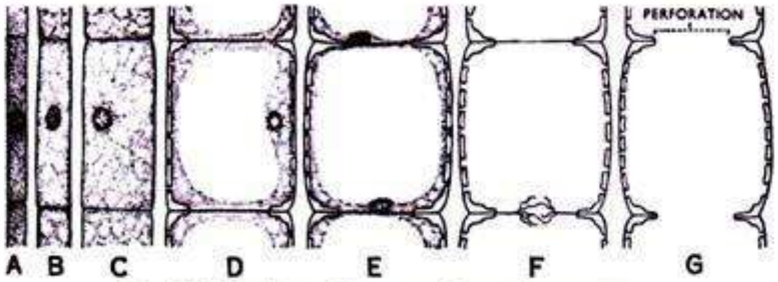

Fig. 540. Tracheae. Ontogeny of a trachea—stages.

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ylem Fibres:

Some fibres remain associated with other elements in the complex tissue, xylem, and they mainly give mechanical support. As previously stated, fibres are very much elongated, usually dead cells with lignified walls.

Xylem fibres or wood fibres are mainly of two types: fibre-traeheids (Fig. 536 D & E) and libiriform fibres (Fig. 536 A & B) which usually intergrade, so much so that it is difficult to draw a line of demarcation between them.

Fibre-tracheids, as already reported, are intermediate forms between typical fibres and tracheids; they possess bordered pits, though the borders are not well-developed. Libiriform fibres ate narrow ones with highly thickened secondary wall.

The central lumen is almost obliterated and pits are simple. They resemble the phloem fibres, and hence the name. They occur abundantly in many woody dicotyledons.

Phylogeny of Tracheary Elements:

The tracheary elements have developed during the evolution of land plants (Bailey, ’53). In the lower vascular plants the function of conduction and support were combined in the tracheids.

With increasing specialisation woods evolved with conducting elements—the vessel members being more efficient in conduction that in providing mechanical support. On the other hand fibres evolved as principal supporting tissue.

Thus from the primitive tracheids two lines of specialisation diverged—one toward the vessel and the other toward the fibre.

The following structural features may be taken as the basis in support of the evolution of the tracheary elements from primitive tracheids which are usually long imperforate cells with small diameter, angular in cross-section, having lignified scalariformly pitted walls.

(i) The primitive vessels are also elongate bodies like the tracheids with rather small diameter and tapering ends. Similar condition is still noticed in lower dicotyledons. With evolutionary advance they gradually become shorter and wider, often becoming drum-shaped in appearance.
(ii) The wall of the primitive tracheid is rather thin, more or less of equal thickness, and it is angular in cross-section. Same condition prevails in primitive vessels. With progressive advance considerable thickening appeared and the vessels became circular or nearly so in cross-section.
(iii) In the primitive vessels the perforation plates are multiple, usually scalariform with numerous bars, and oblique end-walls. Progressive increase in specialisation led to gradual decrease in the number of bars and their ultimate disappearance, so that the perforation plates become simple with transverse end-walls. These are positively advanced characters.
(iv) The pitting of the vessel wall also changed from early scalariform arrangement, characteristic of tracheids, to small bordered pit pairs, first in opposite (arranged in transverse rows) and ultimately in alternate (arranged spirally or irregularly) pattern. Moreover the pit pairs between vessels and parenchyma changed from bordered to half-bordered and then to simple.
In the specialisation of the xylem fibres adapted for more efficient support there has been steady increase in thickness of the wall leading to decrease in cell-lumen. The pits changed from elongate to circular, the borders becoming reduced and functionless, and ultimately disappeared. Thus the evolutionary sequence was from tracheids, through fibre-tracheids to libiriform fibres.

Xylem Parenchyma:

Living parenchyma is a constituent of xylem of most plants. In primary xylem they remain associated with other elements and derive their origin from the same meristem. In secondary xylem parenchyma occurs in two forms: xylem parenchyma (Fig. 541 A) is somewhat elongate cells and lie in vertical series attached end on end; ray parenchyma (Fig. 541 B) cells occur in radial transverse series in many woody plants.
Parenchyma is abundant in the secondary xylem of most of the plants, excepting a few conifers like Pinus, Taxus and Araucaria. These are the only living cells in xylem.

The cells may be thin-walled or thick-walled. If lignified secondary wall is present, the pit-pairs between the cells and the adjacent xylem element may be bordered, half-bordered or simple. Between two parenchyma cells the pit is obviously simple.

These cells are particularly meant for storage of starch and fatty food; other matters like tannins, crystals, etc., may also be present. As a constituent part of xylem they are possibly involved in conduction of water and solutes and mechanical support.

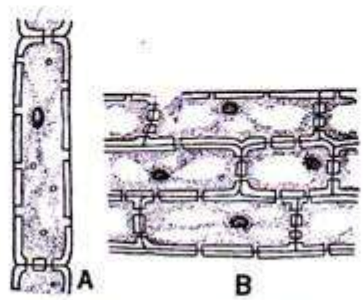


FIG. 541. Xylem Parenchyma.
A. Parenchyma. B. Ray cells.

Phloem:

The other specialised complex tissue forming a part of the vascular bundle is phloem It is composed of sieve elements, companion cells, parenchyma and some fibres. Sclerotic cells may also be present.

Phloem is chiefly instrumental for translocation of organic solutes—the elaborated food materials in solution. The elements of phloem originate from the procambium of apical meristem or the vascular cambium.

Two terms, bast and leptome, have been used for phloem, though they are not exactly synonymous with it. Bast, derived from the word 'bind', was introduced before the discovery of sieve elements; it mainly meant the fibres. The soft-walled parts of phloem, obviously excluding the fibres, were referred to as leptome.

Sieve Elements:

The most important constituents of phloem are the sieve elements, the sieve tubes and sieve cells. From ontogenetic point of view a sieve tube resembles a vessel and a sieve cell a tracheid.

Sieve tubes (Fig. 542) are long tube-like bodies formed from a row of cells arranged in longitudinal series where the end-walls are perforated in a sieve-like manner. The perforated end-walls are called the sieve plates, through which cytoplasmic connections are established between adjacent cells.

The perforations or sieve areas, as they are called, may be compared to the pit fields of the primary wall with plasmodesmata connections. But the sieve areas are more prominent than pit fields and the connecting strands are more wide and conspicuous.

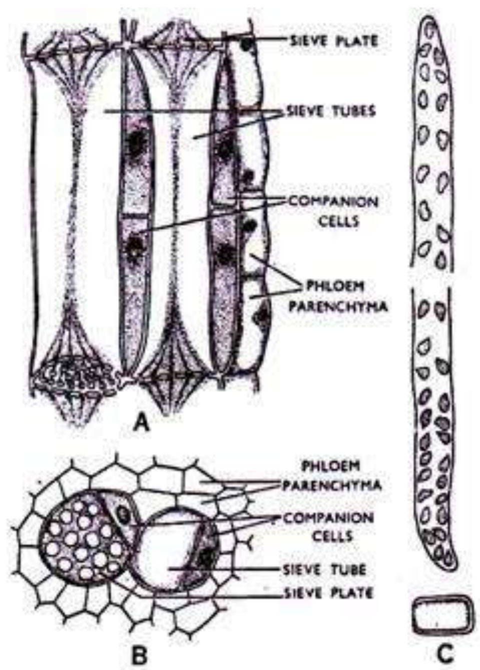


FIG. 542. Sieve elements. A. Sieve tubes in l.s. B. Same in t.s. C. Sieve cell in l.s. and t.s.

It may be that a number of plasmodesmata fuse to form a connecting strand. Moreover, an insoluble substance, called callose, probably a carbohydrate of unknown chemical composition, is impregnated into cellulose or replaces cellulose forming a case round each connecting strand which passes through the sieve area (Fig. 543A).

A sieve area in surface view looks like a depression on the wall having a pretty good number of dots. Each dot represents a connecting strand in cross-section and remains surrounded by a case of callose (Fig. 543).

In sectional view sieve areas appear like thin places on the wall through which the connecting strands pass from one cell to another (Fig. 543). The sieve plate or the perforated end-wall is really the primary walls of two cells with the middle lamella in between them. The end-walls may be obliquely inclined or transverse.

A sieve plate is called simple (Figs. 542 & 543), if it has only one sieve area, whereas the plate may be compound (Fig. 544) with several sieve areas arranged in scalariform, reticulate or other manners. Though rare, the sieve areas may occur on the side walls as well. From evolutionary point of view simple sieve plates on transverse end-walls are more advanced characters than compound plates on oblique walls.

The cylindrical cells which take part in the formation of the sieve tube are called sieve tube elements. Like vessel elements the sieve tubes have also undergone decrease in length with evolutionary advance.

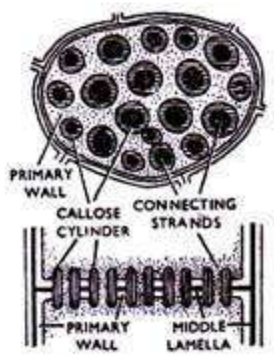


FIG. 543. Sieve tube. Structure of sieve area of an angiosperm in surface (upper) and sectional (lower) views (diagrammatic).

Sieve cells (Fig. 542C), which may be compared to the tracheids, are narrow elongated cells without conspicuous sieve areas. They usually have greatly inclined walls, which overlap in the tissue, sieve areas being more numerous in the ends.

Sieve cells are more primitive than the sieve tubes. They occur in lower vascular plants and

gymnosperms. In fact, sieve tubes have evolved from the sieve cells, as vessels have evolved from the tracheids, and so sieve tubes occur in all angiosperms. In monocotyledons, unlike the xylem elements, sieve tubes first appeared in the aerial organs, the course being from the leaves to the stem and, lastly, to the roots.

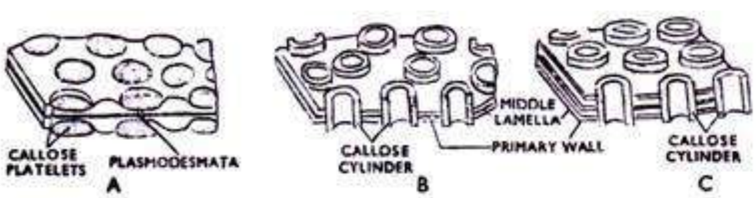


FIG. 543A. A sieve plate—showing stages of development and maturation.

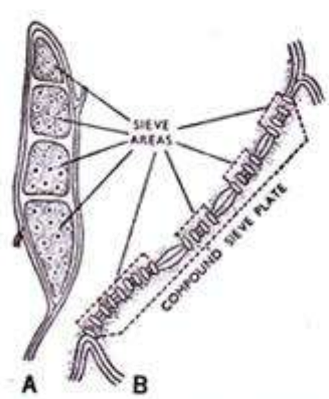


FIG. 544. Sieve tube. Compound sieve plate. A. Surface view. B. Sectional view.

Ontogeny of the Sieve Elements:

In spite of close ontogenetic resemblance between tracheary elements of xylem and sieve elements of phloem, the latter unlike the former, are living. They originate from the mother cells (Fig 545) which are usually short cylindrical or elongate ones.

The mother cell divides longitudinally into two daughter cells, one of which serves as the sieve element and the other one becomes the companion cell, of course in those cases where companion, cells occur. The sieve element undergoes gradual differentiation. It grows in length, cytoplasm gets more and more vacuolated, so that it may have a lining layer of cytoplasm round a large central vacuole.

The most outstanding character is the disintegration of the nucleus with the maturity of the sieve elements. In fact, a distinct nucleus is present in every cell at the meristematic stage. During differentiation the nucleus disorganises (Fig. 545F).

It is the only living functioning element without a nucleus. Small colourless plastids are also present in the protoplast. They contain carbohydrates which give wine-red reaction with iodine and are interpreted as starch grains. Slimy proteinaceous bodies abundantly occur in the sieve tubes, what is commonly called slime. It is said that slime originates in the cytoplasm as small discrete bodies, which eventually fuse and get dispersed in the vacuoles.

In fixed preparations funnel-shaped slime bodies may be distinctly seen in form of plates referred to as slime plugs (Fig. 545H), on the sieve plates. In this connection a very interesting statement has come from a well-known authority, Prof. K. Esau, to the effect that in some plants the nucleolus is extruded from the nucleus before it finally disorganises and that the nucleolus persists in the tube.

Slime bodies have not been observed in pteridophytes, gymnosperms and monocotyledons. Sieve areas develop from the primary pit fields and the connecting strands originating from one or a group of plasmodesmata become more conspicuous which remain surrounded by callose cylinders.

Another theory demands that pores are formed by dissolution of cell wall and no plasmodesmata occur at the pore sites. The connecting strands were thought to be entirely cytoplasmic in nature; but it is argued that may contain vacuolar substances and thus establish connections between vacuoles of neighbouring elements.

The wall of sieve elements is primary and chiefly composed of cellulose. Thick walls are found only in exceptional cases. The tubes often cannot withstand the pressure from adjoining cells and ultimately get crushed.

It has been stated that protoplasmic strands pass through the pores of the sieve areas and that the strands remain surrounded by callose. With the differentiation of the tube the amount of callose increases and finally forms something like a pad on the sieve plate.

This pad is referred to as callus pad. Due to its formation the cell to cell communication is considerably cut down or entirely prevented. The callus pad is usually formed with the approach of resting or inactive season; and it disappears when the active season (spring) sets in. This type is Known as seasonal or dormancy callus.

In old functionless sieve tubes callus becomes permanent, what is called definitive callus. Though the term definitive callus is often used to designate the former type, it is desirable to confine it to permanent callus of old and functionless tubes.

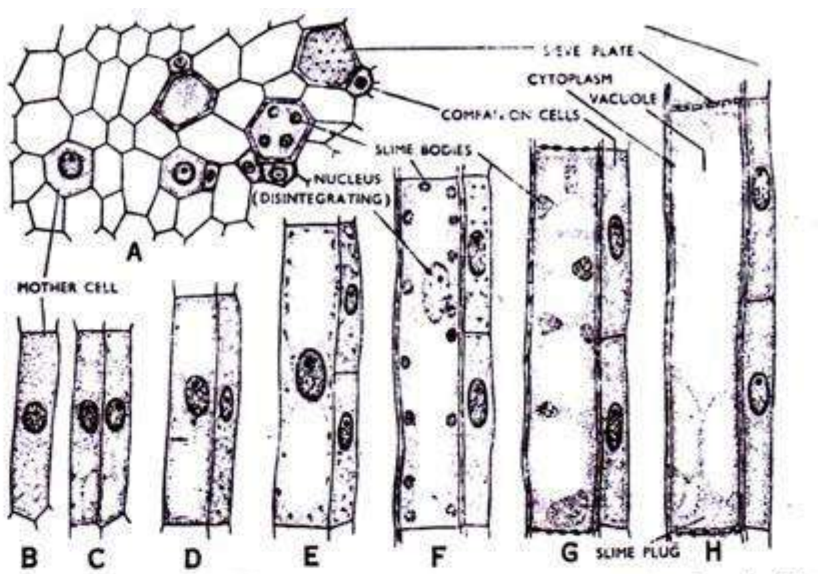


FIG. 545. Sieve tube. Differentiation of sieve tube in an angiosperm. A. T.s. through phloem showing stages. B to H. L.s. through phloem showing stages (*After Esau.*)

Companion Cells:

Companion cells (Figs. 542 & 545) remain associated with the sieve tubes of angiosperms, both ontogenetically and physiologically. These are smaller elongate cells, having dense cytoplasm and prominent nuclei. Starch grains are never present.

They occur along the lateral walls of the sieve tubes. A companion cell may be equal in length to the accompanying sieve tube element or the mother cell may be divided transversely forming a series of companion cells (Fig. 545).

A sieve tube element and a companion cell originate from the same mother cell. Their functional association is evident from the fact that companion cells continue so long the sieve tubes function, and die when the tubes are disorganised.

The companion cells are so firmly attached to the sieve tubes that they cannot be normally separated by maceration. In transverse section it appears as a small triangular, rectangular or polyhedral cell with dense protoplast (Figs. 542 & 545).

In pteridophytes and gymnosperms some small parenchymatous cells remain associated with sieve cells, which are known as albuminous cells. They die in natural course when the sieve cells become functionless. Thus the relation between sieve Cells and albuminous Cells is similar to that existing between sieve tubes and companion cells, excepting that they have no common origin.

Companion cells occur abundantly in angiosperms, particularly in the monocotyledons. They are absent in some primitive dicotyledons and also in the primary phloem of some angiosperms. The wall between the sieve tube and companion cell is thin and provided with primary pit fields.

Parenchyma:

Besides companion cells and albuminous cells, a good number of parenchyma cells remain associated with sieve elements. These are living cells with cellulose walls having primary pit fields. They are mainly concerned with storage of organic food matters. Tannins, crystals and other materials may also be present.

The parenchyma cells of primary phloem are somewhat elongate and occur with the sieve elements along the long axis (Fig. 542). In secondary phloem they may be of two types.

Those which occur in vertical series are called phloem parenchyma; and others occurring in horizontal planes are known as ray cells, the position being just like the parenchyma and ray cells of secondary xylem. The cell wall is primary, composed of cellulose. Parenchyma is absent in the phloem of monocotyledons.

Fibres:

Sclerenchymatous fibres constitute a part of phloem in a large number of seed plants, though they are rare in pteridophytes and some spermatophytes. They occur both in primary and secondary phloem. These are typical elongated cells having interlocked ends, lignified walls with simple pits. The fibres of primary phloem are essentially similar to those occurring in cortex and secondary phloem.

They are of considerable commercial importance, as these fibres are abundantly used for the manufacture of ropes and cords. The flax fibres, unlike others, have non-lignified walls. Sclerotic cells are often present in primary phloem. They probably develop from parenchyma with the age of the tissue. So it is a case of 'secondary sclerosis'.

STOMATA – TYPES OF STOMATA

Stomata are the tiny openings present on the epidermis of leaves. We can see stomata under the light microscope. In some of the plants, stomata are present on stems and other **parts of plants**. Stomata play an important role in gaseous exchange and photosynthesis. They control by transpiration rate by opening and closing.

Types of Stomata

There are different types of stomata and they are mainly classified based on their number and characteristics of the surrounding subsidiary cells. Listed below are the different types of stomata.

Anomocytic Stomata

They are surrounded by epidermal cells, which have a fixed shape and size. The stomata appear to be embedded in epidermal cells. There is no definite number and arrangement of cells surrounding the stomata.

Anisocytic Stomata

Stomata are surrounded by three subsidiary cells having unequal sizes, one is smaller compared to the other two.

Diacytic Stomata

The stomata are surrounded by a pair of subsidiary cells that are perpendicular to the guard cell.

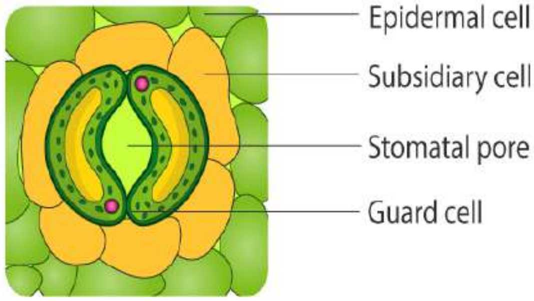
Paracytic Stomata

The stomata are continuously surrounded by two subsidiaries, which are arranged parallel to the stomatal pore and the guard cells.

Gramineous Stomata

Each stoma possesses two guard cells, which are shaped like dumbbells. The subsidiary cells are parallel to the guard cells. The guard cells are found narrow in the middle and wider at the ends.

Structure of Stomata



The stomata consist of minute pores called stoma surrounded by a pair of guard cells. Stomata, open and close according to the turgidity of guard cells. The cell wall surrounding the pore is tough and flexible. The shape of guard cells usually differs in both monocots and dicots, though the mechanism continues to be the same. Guard cells are bean-shaped and contain **chloroplasts.** They contain chlorophyll and capture light energy.

The subsidiary cells surround the guard cells. They are the accessory cells to guard cells and are found in the epidermis of plants. They are present between guard cells and epidermal cells and protect epidermal cells when the guard cells expand during stomatal opening.

The average number of stomata is about 300 per square mm of the leaf surface.

Also, refer to Distribution of Stomata in the Lower and Upper Surfaces of the Leaves

The table given below explains the total number of stomata present on the upper and lower surfaces of leaves of different plants.

We can conclude that dicots have more stomata on the lower surface, whereas monocots have stomata distributed equally on both the surfaces of leaves.

UNIT - II

Primary structure of monocot root:

The monocot root is circular in outline. The arrangement of tissues is as follows.

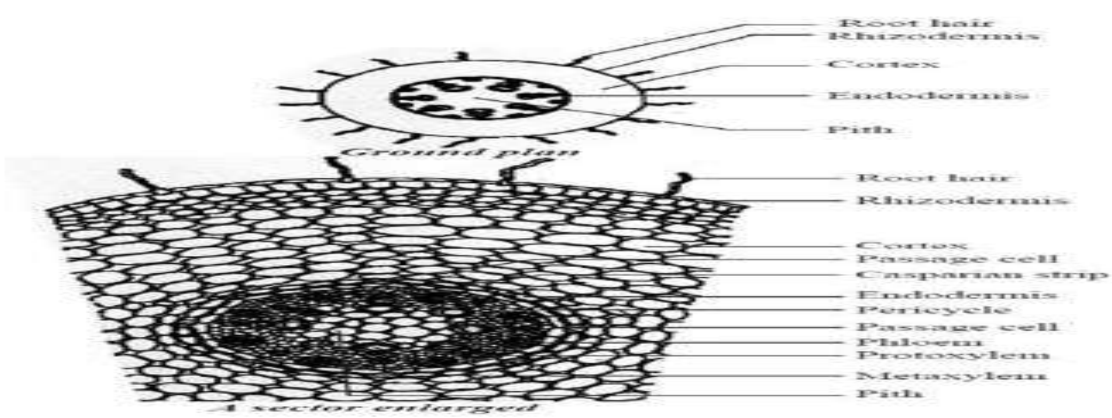
1. Rhizodermis of epiblema: The outermost layer is the Rhizodermis. It is made up tubular living cells. Some of the epidermal cells are protruded out in the form of root hairs. These root hairs are useful in the absorption of water. The epiblema gives protection to the roots.

2. Cortex: The cortex is broad and consists of parenchyma cells with large intercellular spaces. The cells are living and possess leucoplasts. Their function is storage. The last layer of the cortex is endodermis. The endodermal cells contain bands like structure made of suberin in their radial and transverse walls. These band-like structures are known as Casparian strips. Those endodermal cells in front of protoxylem are thin walled and known as passage cells. These passage cells conduct water from the cortex to xylem.

3. Stele: Stele in dicot root is differentiated into pericycle and vascular system.

4. Pericycle: Pericycle is a single layer of thin-walled parenchyma cells forming the outermost layer of the stele. Lateral roots arise endogenously from pericycle.5.

5. Vascular system: The primary xylem and phloem are arranged in alternate radii. Xylem and phloem are separated by the conjunctive tissue. Such a vascular bundle is said to be radial vascular bundles. Xylem occurs in the form of a solid core with a ridge like projections extending towards the pericycle. The number of protoxylem points is four. Hence the xylem is called tetrarch. As the first-formed xylem is pointing towards the periphery the xylem of roots is exarch. Phloem consists of sieve tubes, companion cells and phloem parenchyma. Pith is usually absent.



Primary structure of dicots root

Secondary growth occurs in many roots and usually results in the thickening of the root diameter by the addition of vascular tissue. Primary structure of dicotyledonous root - Bean root

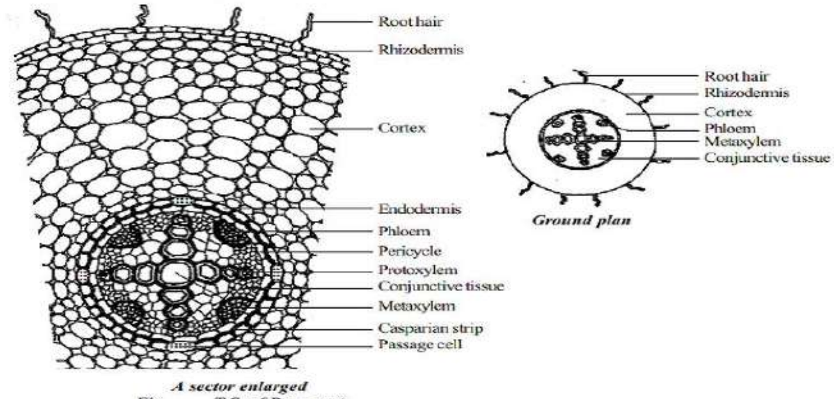


Fig. T.S. of Bean root

The transverse section of the dicot root (Bean) shows the following plan of arrangement of tissues from the periphery to the centre.

Rhizodermis or epiblema

The outermost layer of the root is known as rhizodermis. It is made up of a single layer of parenchyma cells which are arranged compactly without intercellular spaces. It is devoid of stomata and cuticle. Root hair is always single celled. It absorbs water and mineral salts from the soil. The chief function of rhizodermis is protection.

Cortex

Cortex consists of only parenchyma cells. These cells are loosely arranged with intercellular spaces to make gaseous exchange easier. These cells may store food reserves. The cells are oval or rounded in shape. Sometimes they are polygonal due to mutual pressure. Though chloroplasts are absent in the cortical cells, starch grains are stored in them. The cells also possess leucoplasts.

The inner most layer of the cortex is endodermis. Endodermis is made up of single layer of barrel shaped parenchymatous cells. Stele is completely surrounded by the endodermis. The radial and the inner tangential walls of endodermal cells are thickened with suberin.

This thickening was first noted by Casparay. So these thickenings are called Casparian strips. But these casparian strips are absent in the endodermal cells which are located opposite to the protoxylem elements.

These thin-walled cells without casparian strips are called passage cells through which water and mineral salts are conducted from the cortex to the xylem elements. Water cannot pass through other endodermal cells due to the presence of casparian thickenings.

Stele

All the tissues present inside endodermis comprise the stele. It includes pericycle and vascular system.

Pericycle

Pericycle is generally a single layer of parenchymatous cells found inner to the endodermis. It is the outermost `layer of the stele. Lateral roots originate from the pericycle. Thus, the lateral roots are endogenous in origin.

Vascular system

Vascular tissues are in radial arrangement. The tissue by which xylem and phloem are separated is called conjunctive tissue. In bean, the conjunctive tissue is composed of parenchymatous tissue.

Xylem is in exarch condition. The number of protoxylem points is four and so the xylem is called tetrarch. Each phloem patch consists of sieve tubes, companion cells and phloem parenchyma. Metaxylem vessels are generally polygonal in shape. But in monocot roots they are circular.

Monocot and Dicot Stems:

Normal Monocot Stems:

Zea mays-Stem:

It is circular in outline with a well-defined epidermis, hypodermis, ground tissue and many scattered vascular bundles (Fig. 160).

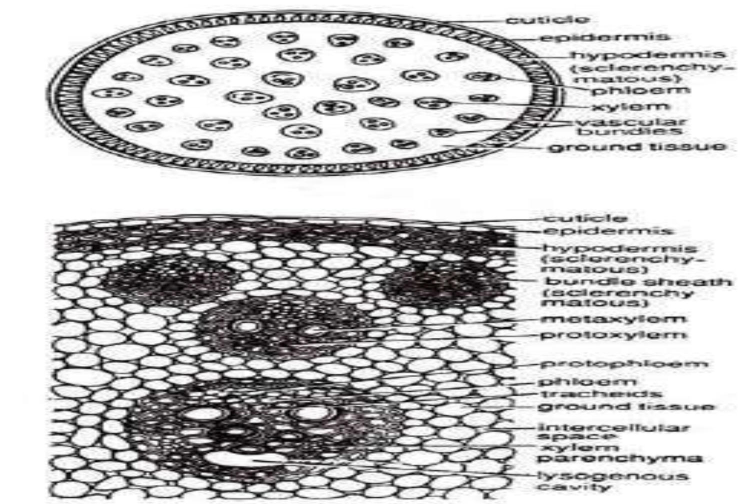


Fig. 160. Zea mays : Upper—T.S. stem (diagrammatic); Lower—T.S. stem (a part cellular).

Epider mis:

1.It is the outermost layer of stem.

2. The outer wall of cells is covered by a thick cuticle.
3. The continuity of the layer is broken by few stomata.
4. Epidermal hair are absent.

Hypodermis:

5. It is two to three cells thick, sclerenchymatous and present just below the epidermis.
6. Cells are polygonal is shape.

Ground tissue:

7. It is not differentiated into cortex, endodermis, pericycle and pith.

8. The cells are parenchymatous and extend from below the sclerenchyma up to the centre.
9. The cells are small and compactly arranged below the hypodermis but they are large, round and loosely arranged in the centre.

Vascular Bundles:
10. Vascular bundles are many and scattered in the ground tissue with no definite arrangement.
11.They are small and more in number towards the periphery than the centre of the section.
12. Each vascular bundle is conjoint, collateral, closed and endarch.
13. A well-developed sclerenchymatous sheath surrounds each vascular bundle which is more prominent at its upper and lower faces.
14. Xylem and phloem constitute the vascular bundle.

15. Xylem:
(i) Consists of vessels (protoxylem and metaxylem), tracheids and xylem parenchyma.
(ii) Vessels are in the form of 'Y'.
(iii) Metaxylem is present at the divergent ends of ' Y' in the form of two big oval vessels. iv) Protoxylem is present at the lower arm of' Y', consisting of two small vessels.
(v) Protoxylem is surrounded by tracheids and xylem parenchyma.
(vi) Inner protoxylem vessel and parenchyma break down and form a Water-containing cavity called lysigenous cavity.

16. Phloem:
(i) Consists of only sieve tubes and companion cells.
(ii) Phloem fibres and phloem parenchyma are absent.
(iii) The outer parts of the phloem, which is broken and disorganized, is called protophloem.
(iv) Inner phloem contains sieve tubes and companion cells, and called metaphloem.

Normal Dicot Stems:
T.S. exhibits following details:
It is wavy in outline, usually with five ridges and five furrows, and ten vascular bundles remain arranged in two rings of five each.

Epidermis:
1. Single-layered epidermis consists of many barrel- shaped cells covered with cuticle.

2. Some of the epidermal cells protrude out as multicellular shoot hair.

Cortex:

3. It consists of collenchymatous hypodermis. chlorenchyma and an innermost layer of endodermis.
4. Collenchyma is present just below the epidermis, in the form of six to ten or more layers in the ridges and only a few layers or none in the furrows.
5. Chlorenchyma is present in the form of two to three layers in between the collenchyma and endodermis. Its cells are filled with chloroplasts.
6. Endodermis is the innermost layer of cortex. It is wavy in outline. The cells are filled with starch grains and lack casparian strips.

Pericycle:

7. It consists of four to five layers of thick- walled, lignified sclerenchymatous zone present just below the endodermis.

Ground Tissue:

8. The space between sclerenchyma and the central pith cavity is filled with many thin-walled, parenchymatous cells of ground tissue, in which the vascular bundles remain embedded.

Vascular Bundles:

9. Ten vascular bundles are arranged in two rows of five each.
10. Five vascular bundles of outer ring are present opposite the ridges whereas the remaining five of the inner ring face the furrows.
11. Vascular bundles are conjoint, bicollateral, open and endarch.
12. Each vascular bundle consists of centrally located xylem, surrounded on its outer and inner faces by strips of outer and inner cambia. Outside the outer cambium is present a patch of outer phloem, and inner to the inner cambium is present the inner phloem, thus representing the open and bicollateral condition of vascular bundles.
13. Xylem consists of wide vessels present on the outer side representing the metaxylem and narrow vessels present towards inner side representing the protoxylem. Xylem also contains certain tracheids, wood fibres and xylem parenchyma.
14. Cambium is present in the form of strips on both the sides of the xylem. It consists of thin-walled, rectangular cells arranged in radial rows.

(i) Outer cambium is flat and many-layered.

(ii) Inner combium is curved and only few-layered.

15. Phloem is situated in the form of patches of outer phloem and inner phloem. It consists of companion cells, thin-walled cells of phloem parenchyma, and well-developed sieve tubes.

Pith:

16. Thin-walled parenchymatous cells of ground tissue form the pith.

Identification:

(a) 1. Presence of vessels in xylem ....Angiosperms

(b) 1. Vascular bundles are conjoint, bicollateral, open and endarch.

2. Multicellular epidermal hair ....Stem

(c) 1. Vascular bundles are arranged in rings.

2. Presence of cambium.

3. Well-differentiated cortex and well-developed pith. ....Dicot.

Special Point:

Presence of bicollateral, open, vascular bundles.

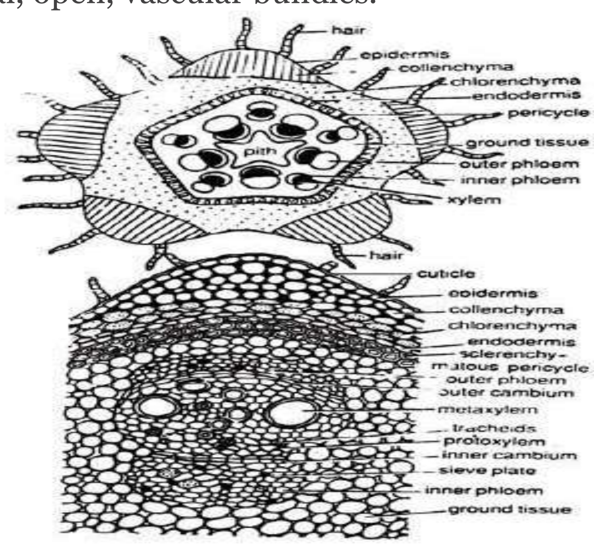


Fig. 163. Luffa : Upper—T.S. stem (diagrammatic); Lower—T.S. stem (a part cellular).

Primary structure of Monocot leaf

Epidermis:

1. Two epidermal layers are present, one each on upper and lower surfaces.

2. Uniseriate upper and lower epidermal layers are composed of more or less oval cells.

ew big, motor cells or bulliform cells are present in groups here and there in the furrows of upper epidermis.

4. Stomata, each consisting of a pore, guard cells and a stomatal chamber, are present on both the epidermal layers.

5. A thick cuticle is present on the outer walls of epidermal cells.

6. Bulliform cells help folding of leaves.

Mesopbyll:

7. It is not clearly differentiated into palisade and spongy parenchyma but the cells just next to the epidermal layers are a bit longer while the cells of the central mesophyll region are oval and irregularly arranged.

8. The cells are filled with many chloroplasts.

9. Many intercellular spaces are also present in this region.

10. Sub-stomatal chambers of the stomata are also situated in this region.

Vascular System:

11. Many vascular bundles are present. They are arranged in a parallel series.

12. The central vascular bundle is largest in size.

13. Vascular bundles are conjoint, collateral and closed.

Each vascular bundle remains surrounded by a double-layered bundle sheath.

15. Outer layer of bundle sheath consists of thin-walled cells while the inner layer is made up of thick-walled cells.

16. On the upper as well as lower surfaces of large vascular bundles are present patches of sclerenchyma which are closely associated with the epidermal layers. There is no such association between the sclerenchyma and small vascular bundles.

17. Xylem occurs towards the upper surface and phloem towards to lower surface.

18. Xylem consists of vessels and tracheids. Sometimes small amount of xylem parenchyma is also present.

19. Phloem consists of sieve tubes and companion cells.

Xerophytic Characters:

Thick cuticle on epidermis.

ii) Presence of motor cells.

(iii) Sclerenchyma patches are present.

(iv) Stomata in furrows.

Identification:

(a) 1.Presence of upper and lower epidermal layers.

2. Mesophyll is present.

3. Each vascular bundle is surrounded by bundle sheath Leaf

(b) 1. Many vascular bundles are arranged parallaly.

2. Absence of cambium.

3. Vascular bundles are collateral and closed.

4. Stomata on both the surfaces.

Isobilateral monocot leaf.

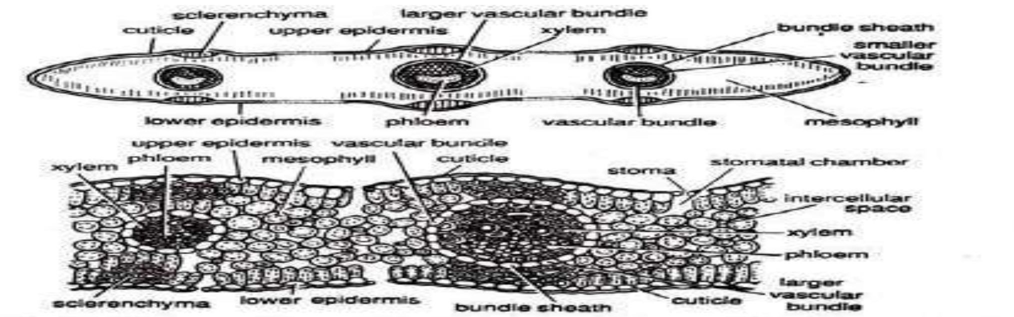


*Fig. 174. Triticum : **Upper**, T.S. leaf (diagrammatic); **Lower**, T.S. leaf (a part cellular).*

Primary structure of Dicot Leaf:

Following tissues are visible in the transverse section of the material:

Epidermis:

1. An epidermal layer is present on the upper as well as lower surfaces.

2. One-celled thick upper and lower epidermal layers consist of barrel-shaped, compactly arranged cells.

3. A thick cuticle is present on the outer walls of epidermal cells. Comparatively, thick cuticle is present on the upper epidermis.

4. Stomata are present only on the lower epidermis.

Mesophyil:

5. It is clearly differentiated into palisade and spongy parenchyma.

6. Palisade lies just inner to the upper epidermis. It is composed of elongated cells arranged in two layers.

7. The cells of palisade region are compactly arranged and filled with chloroplasts. At some places the cells are arranged loosely and leave small and big intercellular spaces.

8. Palisade cells are arranged at a plane at right angle to the upper epidermis, and the chloroplasts in them are arranged along their radial walls.

9. Parenchymatous cells are present above and below the large vascular bundles. These cells interrupt the palisade layers and are said to be the extensions of the bundle sheath.

10. Spongy parenchyma region is present just below the palisade and extends upto the lower epidermis.

11. The cells of spongy parenchyma are loosely arranged, filled with many chloroplasts and leave big intercellular spaces.

Vascular Region:

12. Many large and small vascular bundles are present.

13. Vascular bundles are conjoint, collateral and closed.

14. Each vascular bundle is surrounded by a bundle sheath.

15. Bundle sheath is parenchymatous and in case of large bundles it extends upto the epidermis with the help of thin-walled parenchymatous cells.

16. The xylem is present towards the upper epidermis and consists of vessels and xylem parenchyma. Protoxylem is present towards upper epidermis while the metaxylem is present towards the lower epidermis.

17. Phloem is situated is present towards the lower epidermis and consists of sieve tubes, companion cells and phloem parenchyma.

Identification:

(a) 1. Presence of expanded portion or blade.

2. Presence of mesophyll.

3. Bundle sheath is present Leaf

(b) 1. Upper and lower epidermal layers are clearly distinguishable.

2. Mesophyll is clearly differentiated into palisade and spongy parenchyma.

3. Stomata only on the lower surface.

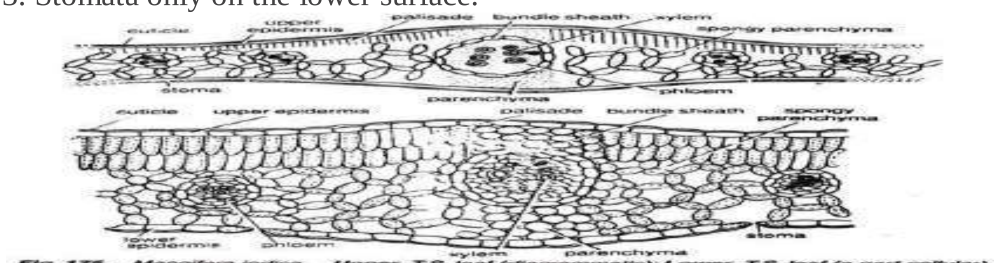


Fig. 175. Mangifera indica. Upper, T.S. leaf (diagrammatic); Lower, T.S. leaf (a part cellular).

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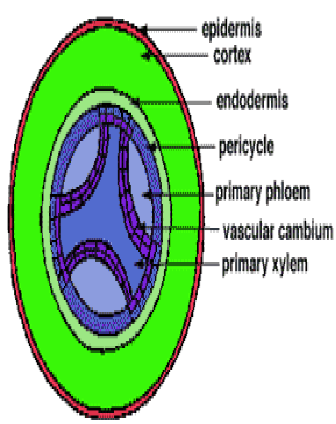
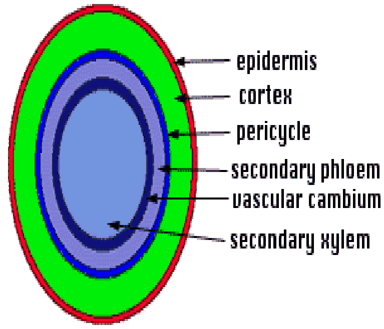
Normal Secondary Growth in Roots

Secondary growth occurs in many roots and usually results in the thickening of the root diameter by the addition of • vascular tissue.

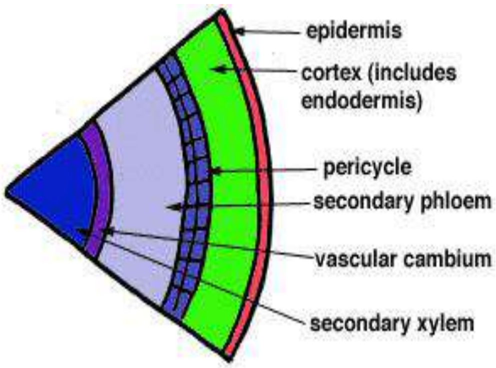


Initiation of secondary growth occurs when cells in the residual procambium and parts of the pericyle begin to make periclinal divisions. Only the pericyle cells opposite the xylem points start to make periclinal divisions. The inner layer of cells becomes the vascular cambium. The outer layer is retained as pericycle. The vascular cambium is continuous around the primary xylem.

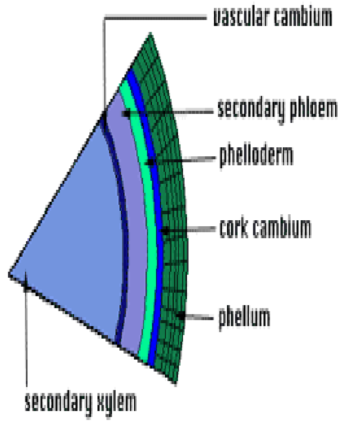
The vascular cambium continues to divide periclinally. The daughter cells that result from these divisions differentiate into secondary xylem cells if they divide off towards the inside of the root or secondary phloem cells if they divide towards the outer surface of the root. After many cell divisions and cell differentiation, a root exhibiting secondary growth might look like the one depicted in the diagram to the right.



Some roots also form an outer protective layer called the periderm which originates from the pericycle and replaces the epidermis.



The pericycle resumes its meristematic character and begins to divide periclinally again. At this point it is called the phellogen or the cork cambium. This diagram, which is a slice of the previous drawing, shows how the pericycle is dividing.



The cork cambium forms phellum cells (cork cells) towards the outside of the plant. These cells are dead at maturity. They are suberized which makes the cells impermeable to water. Phellum cells in cross section appear in neat, ordered files. The cork cambium also produces the phelloderm, a tissue consisting of cells that are living at maturity. The location of the phelloderm can be seen in the diagram to the left.

Normal Growth in Stems

Growth in plants occurs as the stems and roots lengthen. Some plants, especially those that are woody, also increase in thickness during their life span. The increase in length of the shoot and the root is referred to as primary growth. It is the result of cell division in the shoot apical meristem. Secondary growth is characterized by an increase in thickness or girth of the plant. It is caused by cell division in the lateral meristem. Herbaceous plants mostly undergo primary growth, with little secondary growth or increase in thickness. Secondary growth, or “wood”, is noticeable in woody plants; it occurs in some dicots, but occurs very rarely in monocots.

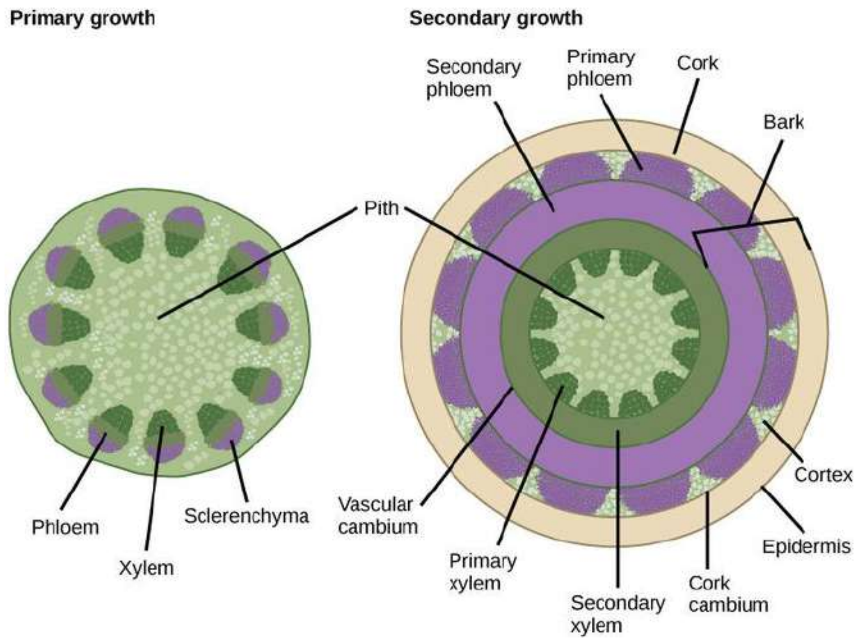


Figure 30.2C.130.2C.1: Primary and secondary growth: In woody plants, primary growth is followed by secondary growth, which allows the plant stem to increase in thickness or girth. Secondary vascular tissue is added as the plant grows, as well as a cork layer. The bark of a tree extends from the vascular cambium to the epidermis.

Some plant parts, such as stems and roots, continue to grow throughout a plant's life: a phenomenon called indeterminate growth. Other plant parts, such as leaves and flowers, exhibit determinate growth, which ceases when a plant part reaches a particular size.

Normal Secondary Growth stem

The increase in stem thickness that results from secondary growth is due to the activity of the lateral meristems, which are lacking in herbaceous plants. Lateral meristems include the vascular cambium and, in woody plants, the cork cambium. The vascular cambium is located just outside the primary xylem and to the interior of the primary phloem. The cells of the vascular cambium divide and form secondary xylem (tracheids and vessel elements) to the inside and secondary phloem (sieve elements and companion cells) to the outside. The thickening of the stem that occurs in secondary growth is due to the formation of secondary phloem and secondary xylem by the vascular cambium, plus the action of cork cambium, which forms the tough outermost layer of the stem. The cells of the secondary xylem contain lignin, which provides hardiness and strength.

In woody plants, cork cambium is the outermost lateral meristem. It produces cork cells (bark) containing a waxy substance known as suberin that can repel water. The bark protects the plant against physical damage and helps reduce water loss. The cork cambium also produces a layer of cells known as phelloderm, which grows inward from the cambium. The cork cambium, cork cells, and phelloderm are collectively termed the periderm. The periderm substitutes for the epidermis in mature plants. In some plants, the periderm has many openings, known as lenticels, which allow the interior cells to exchange gases with the outside atmosphere. This supplies oxygen to the living- and metabolically-active cells of the cortex, xylem, and phloem.