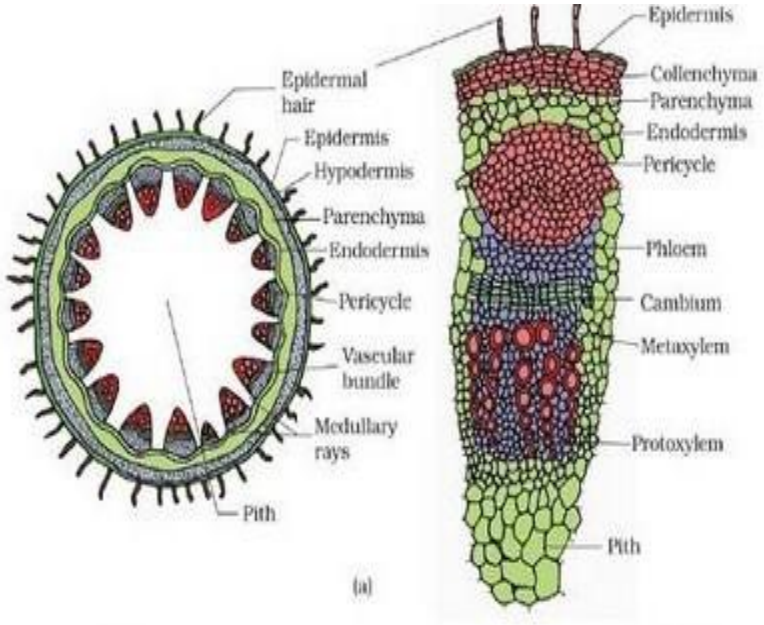
Anatomy of Root, Stem and Leaf

Primary structure of Dicot stem:

ANATOMY OF DICOT STEM - DEFINITION



1. Epidermis

- It is a protective outermost single layer of parenchymatous cells without intercellular spaces.
- The outer walls of the epidermal cells have a layer called cuticle and multicellular hairs (trichomes).

2. Cortex

- Below the epidermis, cortex is differentiated into few layers of collenchyma cells that make hypodermis which gives mechanical strength to the stem.
- A few layers of chlorenchyma cells are present with conspicuous intercellular spaces. Some resin ducts also occur here.
- The third zone is made up of parenchyma cells. These cells store food materials.

3. Endodermis:

- The cells of this layer are barrel shaped arranged compactly without intercellular spaces.
- Due to abundant starch grains in these cells, this layer is also known as starch sheath.

3. **Stele**

- It consists of pericycle, vascular bundles and pith.

A) Pericycle(Bundle cap)

- Pericycle occurs between the endodermis and vascular bundles in the form of a few layers of sclerenchyma cells.

B) Vascular bundles

- In dicot stem, vascular bundles are arranged in a ring around the pith.
- Each vascular bundle is conjoint, collateral, open and endarch.

C) Pith

- The large central portion called pith composed of parenchyma cells with intercellular spaces.
- The extension of pith between vascular bundles are called as pith ray or medullary rays.

- Function of the pith is storage of food.

Primary structure of dicot root:

Epidermis:

It is single-layered and composed of thin- walled cells. The outer walls of epidermal cells are not cutinised. Many epidermal cells prolong to form long hairy bodies, the typical unicellular hairs of roots. Epidermis of root is also called epiblema or piliferous layer (pilus = hair; ferous—bearing).

II. Cortex:

It is quite large and extensive in roots. Cortex is made of thin-walled living parenchymatous cells with leucoplasts, which convert sugar into starch grains. The last layer of cortex is endodermis. It is of universal occurrence in roots.

Endodermis is composed of one layer of barrel-shaped cells which are closely arranged without having intercellular spaces. The endodermal cells have thickened radial walls, which are called Casparian strips, after the name of Caspary, the gentleman who first noted them.

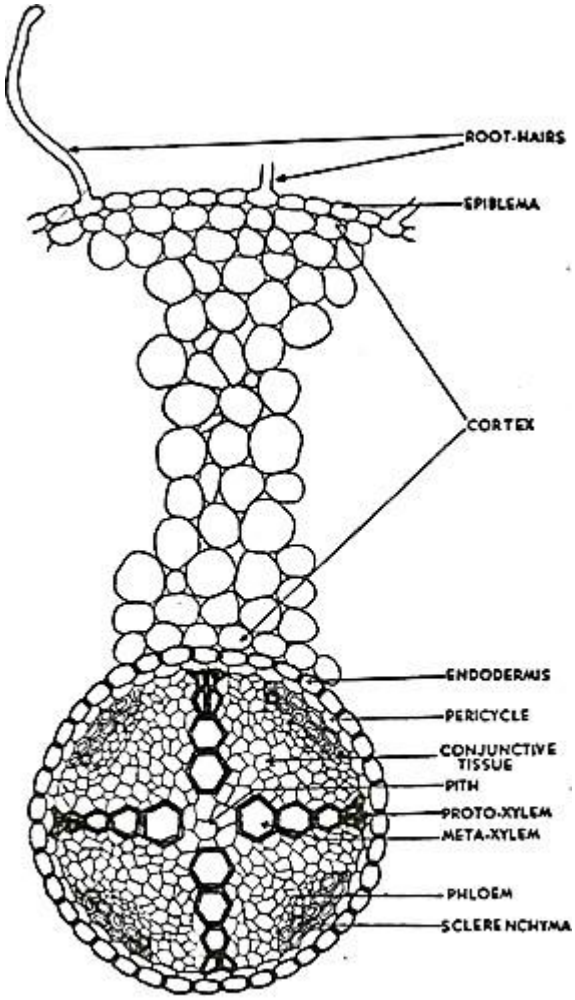


Fig. 153. Portion of transverse section of young dicotyledonous root (gram) showing the plan of arrangement of tissues.

III. Stele or Central Cylinder:

Next to endodermis there is a single-layered pericycle made up of thin-walled parenchyma cells. Pericycle is the seat of the origin of lateral roots. Vascular bundles are typically radial in roots. Xylem and phloem form separate patches and are intervened by non-conducting cells. In dicotyledonous roots the number of bundles is limited.

Xylem has protoxylem towards circumference abutting on pericycle and metaxylem towards centre. This is called exarch arrangement (of endarch arrangement of stems). Phloem with sieve tubes, etc., form patches

arranged alternately with xylem. A small patch of sclerenchyma cells is present outside every group of phloem.

Conjunctive Tissue:

Thin-walled parenchymatous cells lying in between xylem and phloem groups constitute the conjunctive tissue.

Pith:

At the centre there is a small parenchymatous pith. It may be even absent in dicotyledonous roots.

Anatomy of monocot stem:

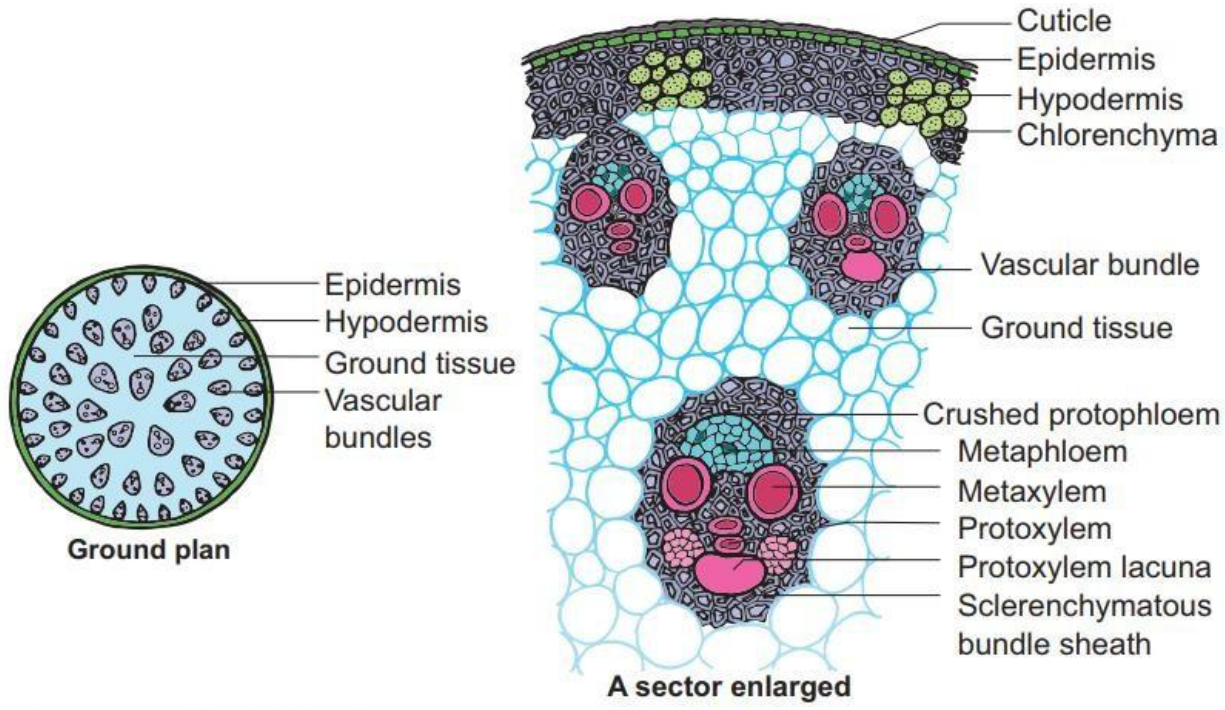


Figure 9.22: T.S. Monocot stem (Maize stem)

1.Epidermis

- It is the outermost layer made up of single layer of tightly packed parenchymatous cells with thick cuticle.
- There are no epidermal outgrowths.

2. Hypodermis

- A few layer of sclerenchymatous cells lying below the epidermis constitute the hypodermis, gives mechanical strength to the plant.

3. Ground tissue

- It is not differentiated into cortex, endodermis, pericycle and pith.
- The ground tissue is represented by several layers of loosely arranged parenchyma cells enclosing prominent intercellular spaces.
- The ground tissue is meant for storage of food.

Vascular bundles

- Vascular bundles are scattered in the parenchymatous ground tissue.
- Vascular bundles are numerous, small and closely arranged in the peripheral portion.
- Towards the centre, the bundles are comparatively large in size and loosely arranged.
- Each vascular bundle is surrounded by a sheath of sclerenchymatous fibres called bundle sheath.
- The vascular bundles are conjoint, collateral, endarch and closed.

Phloem:

- The phloem in the monocot stem consists of sieve tubes and companion cells.
- Phloem parenchyma and phloem fibres are absent.

Xylem:

- The two metaxylem vessels are located at the upper two arms and one or two protoxylem vessels at the base. (Y shaped)
- In a mature bundle, the lowest protoxylem disintegrates and forms a cavity known as protoxylem lacuna.

Anatomy of monocot root:

Epidermis/Epiblema/Rhizodermis:

- It is the outermost layer composed of compact parenchymatous cells having no intercellular spaces and stomata.
- The tubular unicellular root hairs are also present on this layer
- Both epiblema and root hairs are without cuticle.
- In older parts, epiblemma either becomes impervious or is shed.
- Epiblemma and root hairs absorb water and mineral salts.

Cortex:

- It lies just below the epidermis.
- Cortex consists of thin walled multilayered parenchyma cells having sufficiently developed intercellular spaces among them.
- Usually in an old root of *Zea mays*, a few layers of cortex undergo suberization and give rise to a single or multi-layered zone- the exodermis.
- This is a protective layer which protects internal tissues from outer injurious agencies.
- The starch grains are abundantly present in the cortical cells.

- **Cortex functions** :
    - a) conduction of water and mineral salts from root hairs to inner tissues
    - b) storage of food
    - c) protection when exodermis is formed in older parts.

Endodermis:

- The innermost layer of the cortex is termed as endodermis.
- It is composed of barrel-shaped compact cells that lacks intercellular spaces among them.
- Young endodermal cells have an internal strip of suberin and lignin which is called casparian strip.
- The strip is located close to the inner tangential wall.
- There are some unthickened cells opposite to the protoxylem vessels known as passage cells which serve for conducting of fluids.
- The function of endodermis is to regulate the flow of both inward as well as outward.

Pericycle:

- It lies just below the endodermis and is composed of single layered sclerenchymatous cells intermixed with parenchyma.

Vascular tissue*:*

- The vascular tissue contains alternating strands of xylem and phloem.
- The phloem is visualized in the form of strands near the periphery of the vascular cylinder, beneath the pericycle.
- The xylem forms discrete strands, alternating with phloem strands.

- The center is occupied by large pith which maybe parenchymatous or sclerenchymatous.
- The number of vascular bundles is more than six, hence called as polyarch.
- Xylem is exarch i.e. the protoxylem is located towards the periphery and the metaxylem towards the center.
- Vessels of protoxylem are narrow and the walls possess annular and spiral thickenings in contrast, metaxylem are broad and the walls have reticulate and pitted thickenings.
- Phloem strands consist of sieve tubes, companion cells and phloem parenchyma.
- The phloem strands are also exarch having protophloem towards the periphery and metaphloem towards the center.

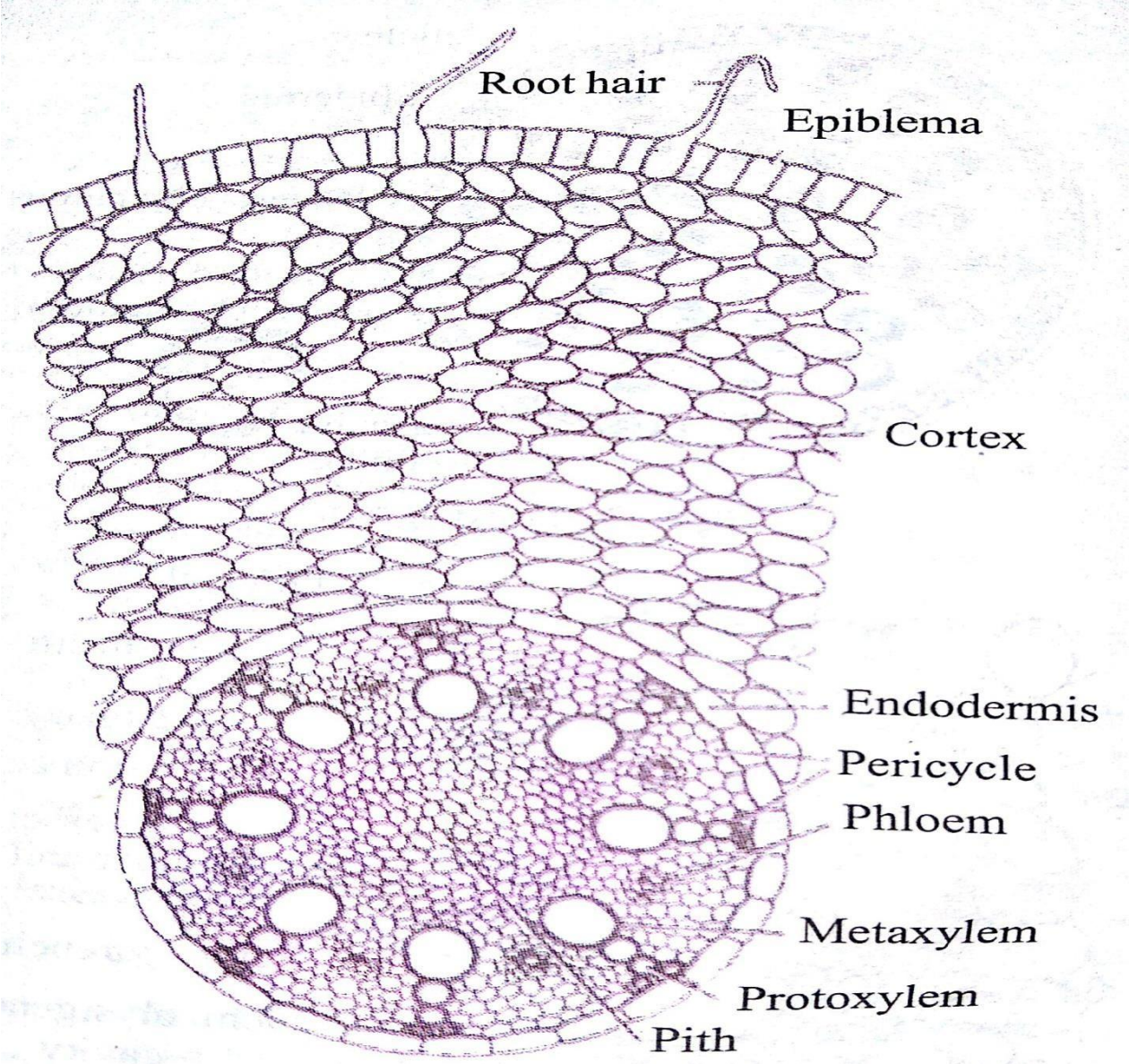
Conjunctive tissues:

- In between the xylem and phloem bundles, there is the presence of many layered parenchymatous or sclerenchymatous tissue.
- These help in storage of food and help in mechanical support.

Pith:

- It is the central portion usually composed of thin-walled parenchymatous cells which appear polygonal or rounded in T.S.
- Intercellular spaces may or may not be present amongst pith cells.
- In some cases pith becomes thick walled and lignified.
- Pith cells serve to store food.

Monocot Root T. S.



Secondary Growth in Dicot Stem of plants.

Primary growth produces growth in length and development of lateral appendages. Secondary growth is the formation of secondary tissues from lateral meristems. It increases the diameter of the stem. In woody plants, secondary tissues constitute the bulk of the plant. They take part in providing protection, support and conduction of water and nutrients.

Secondary tissues are formed by two types of lateral meristems, vascular cambium and cork cambium or phellogen. Vascular cambium produces secondary vascular tissues while phellogen forms periderm.

Secondary growth occurs in perennial gymnosperms and dicots such as trees and shrubs. It is also found in the woody stems of some herbs. In such cases, the secondary growth is equivalent to one annual ring, e.g., Sunflower.

Formation of Secondary Vascular Tissues:

They are formed by the vascular cambium. Vascular cambium is produced by two types of meristems, fascicular or intra-fascicular and inter-fascicular cambium. Intra-fascicular cambium is a primary meristem which occurs as strips in vascular bundles. Inter-fascicular cambium arises secondarily from the cells of medullary rays which occur at the level of intra-fascicular strips.

These two types of meristematic tissues get connected to form a ring of vascular cambium. Vascular cambium is truly single layered but appears to be a few layers (2-5) in thickness due to presence of its immediate derivatives. Cells of vascular cambium divide periclinally both on the outer and inner sides (bipolar divisions) to form secondary permanent tissues.

The cells of vascular cambium are of two types, elongated spindle-shaped fusiform initials and shorter isodiametric ray initials. Both appear rectangular in T.S. Ray initials give rise to vascular rays.

Fusiform initials divide to form secondary phloem on the outer side and secondary xylem on the inner side . With the formation of secondary xylem on the inner side, the vascular cambium moves gradually to the outside by adding new cells.

Ray initials produce radial system (= horizontal or transverse system) while fusiform initials form axial system (= vertical system) of secondary vascular tissues.

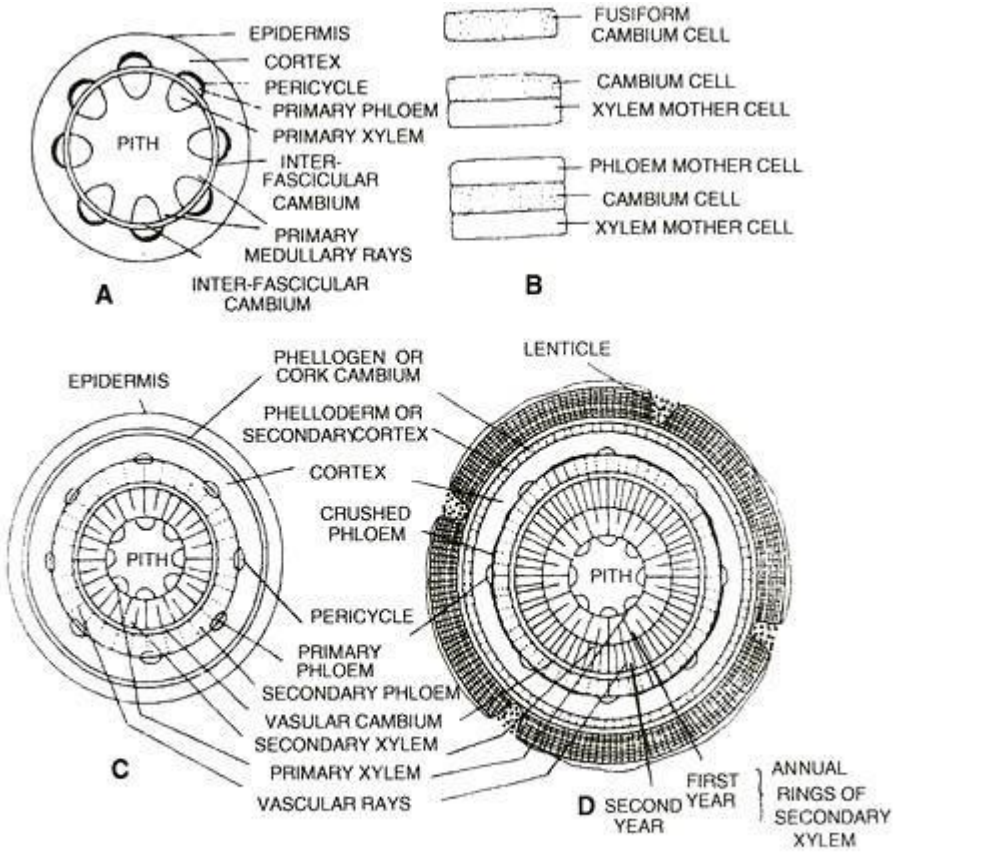


Fig. 6.28. A, complete ring of vascular cambium formed by strips of intrafascicular cambium and inter-fascicular cambium. B, formation of secondary vascular tissue mother cells; C, the beginning of secondary growth (mostly made up of secondary vascular tissues) of dicot stem (diagrammatic); D, two-year stage of secondary growth of a dicot stem.

Vascular Rays:

The vascular rays or secondary medullary rays are rows of radially arranged cells which are formed in the secondary vascular tissues. They are a few cells in height.

Depending upon their breadth, the vascular rays are uniseriate (one cell in breadth) or multiseriate (two or more cells in breadth). Vascular rays may be homo-cellular (having one type of cells) or hetero-cellular (with more

than one type of cells). The cells of the vascular rays enclose intercellular spaces.

The part of the vascular ray present in the secondary xylem is called wood or xylem ray while the part present in the secondary phloem is known as phloem ray. The vascular rays conduct water and organic food and permit diffusion of gases in the radial direction. Besides, their cells store food.

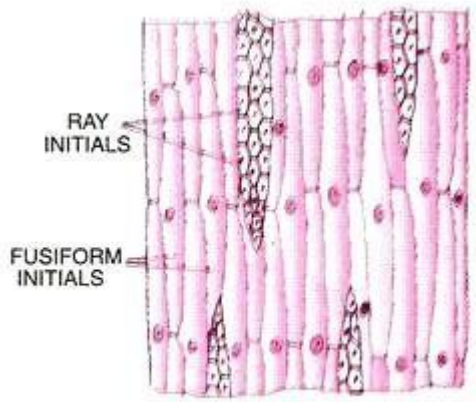


Fig. 6.29. L.S. Vascular cambium showing fusiform and ray initials.

2. Secondary Phloem (Bast):

It forms a narrow circle on the outer side of vascular cambium. Secondary phloem does not grow in thickness because the primary and the older secondary phloem present on the outer side gets crushed with the development of new functional phloem . Therefore, rings (annual rings) are not produced in secondary phloem. The crushed or non-functioning phloem may, however, have fibres and sclereids.

Secondary phloem is made up of the same type of cells as are found in the primary phloem (metaphloem)— sieve tubes, companion cells, phloem fibres and phloem parenchyma.

Phloem pairenchyma is of two types— axial phloem parenchyma made up of longitudinally arranged cells and phloem ray parenchyma formed of radially arranged parenchyma cells that constitute the part of the vascular ray present in the phloem.

Elements of secondary phloem show a more regular arrangement. Sieve tubes are comparatively more numerous but are shorter and broader. Sclerenchyma fibres occur either in patches or bands. Sclereids are found in many cases. In such cases secondary phloem is differentiated into soft bast (secondary phloem without fibres) and hard bast (part of phloem with abundant fibres).

3. Secondary Xylem:

It forms the bulk of the stem and is commonly called wood. The secondary xylem consists of vessels, tracheids (both tracheary elements), wood fibres and wood parenchyma.

Wood parenchyma may contain tannins and crystals besides storing food. It is of two types— axial parenchyma cells arranged longitudinally and radial ray parenchyma cells arranged in radial or horizontal fashion. The latter is part of vascular ray present in secondary xylem.

Secondary xylem does not show distinction into protoxylem and meta-xylem elements. Therefore, vessels and tracheids with annular and spiral thickenings are absent. The tracheary elements of secondary xylem are similar to those of meta-xylem of the primary xylem with minor differences. They are comparatively shorter and more thick-walled. Pitted thickenings are more common. Fibres are abundant.

Width of secondary xylem grows with the age of the plant. The primary xylem persists as conical projection on its inner side. Pith may become narrow and ultimately get crushed. The yearly growth of secondary xylem is distinct in the areas which experience two seasons, one favourable spring or rainy season) and the other un-favourable (autumn, winter or dry summer).

In favourable season the temperature is optimum. There is a good sunshine and humidity. At this time the newly formed leaves produce hormones which stimulate cambial activity. The activity decreases and stops towards the approach of un-favourable season. Hence the annual or

yearly growth appears in the form of distinct rings which are called annual rings .

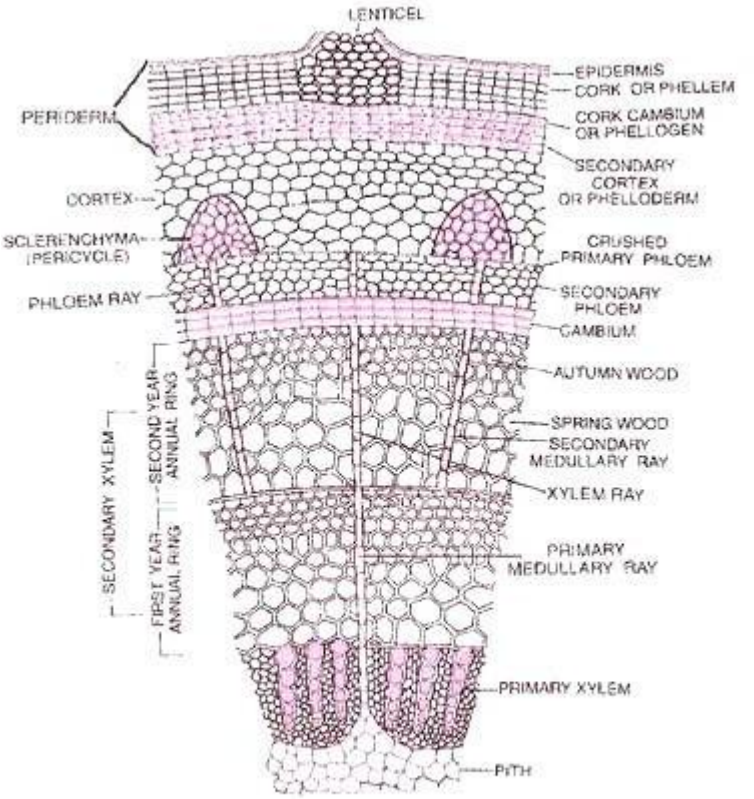


Fig. 6.31. Part of detailed structure of transverse section of two year old dicot stem showing secondary growth.

B. Formation of Periderm:

In order to provide for increase in girth and prevent harm on the rupturing of the outer ground tissues due to the formation of secondary vascular tissues, dicot stems produce a cork cambium or phellogen in the outer cortical cells. Rarely it may arise from the epidermis (e.g., Teak, Oleander), hypodermis (e.g., Pear) or phloem parenchyma.

Phellogen cells divide on both the outer side as well as the inner side (bipolar) to form secondary tissues. The secondary tissue produced on the inner side of the phellogen is parenchymatous or collenchymatous. It is called secondary cortex or phelloderm. Its cells show radial arrangement.

Phellogen produces cork or phellem on the outer side. It consists of dead and compactly arranged rectangular cells that possess suberised cell walls. The cork cells contain tannins. Hence, they appear brown or dark brown in colour. The cork cells of some plants are filled with air e.g., Quercus suber (Cork Oak or Bottle Cork). The phelloderm, phellogen and phellem together constitute the periderm.

Cork prevents the loss of water by evaporation. It also protects the interior against entry of harmful micro-organisms, mechanical injury and extremes of temperature. Cork is light, compressible, nonreactive and sufficiently resistant to fire.

It is used as stopper for bottles, shock absorption and insulation. At places phellogen produces aerating pores instead of cork. These pores are called lenticels. Each lenticel is filled by a mass of somewhat loosely arranged suberised cells called complementary cells.

Lenticels:

Lenticels are aerating pores in the bark of plants. They appear on the surface of the bark as raised scars containing oval, rounded or oblong depressions. They occur in woody trees but not in climbers. Normally they are formed in areas with underlying rays for facilitating gas exchange. Lenticels may occur scattered or form longitudinal rows.

A lenticel is commonly produced beneath a former stomate or stoma of the epidermis. Its margin is raised and is formed by surrounding cork cells. The lenticel is filled up by loosely arranged thin walled rounded and suberised (e.g., Prunus) or un-suberised cells called complementary cells.

They enclose intercellular spaces for gaseous exchange. The complementary cells are formed from loosely arranged phellogen cells and division of sub-stomatal parenchyma cells. The suberised nature of complementary cells checks excessive evaporation of water.

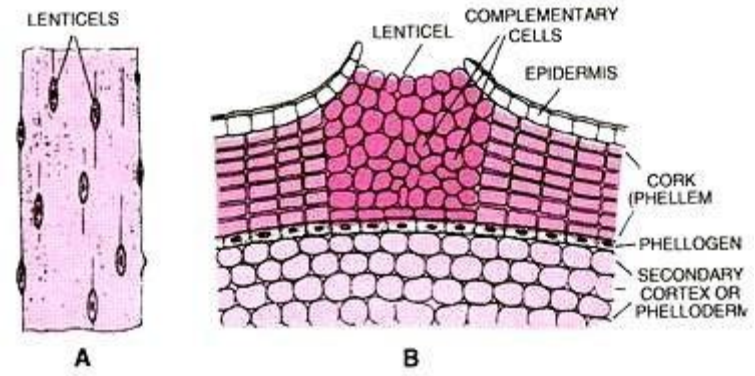


Fig. 6.34. Lenticels. A, external view of lenticels; B, T.S. lenticel.

In temperate plants the lenticels get closed during the winter by the formation of compactly arranged closing cells over the complementary cells.

Bark:

In common language and economic botany, all the dead cells lying outside phellogen are collectively called bark. The outer layers of the bark are being constantly peeled off on account of the formation of new secondary vascular tissues in the interior. The peeling of the bark may occur in sheets (sheets or ring bark, e.g., Eucalyptus) or in irregular strips (scaly bark).

The scaly bark is formed when the phellogen arises in strips instead of rings, e.g., Acacia (vem. Kikar). Bark formed in early growing season is early or soft bark. The one formed towards end of growing season is late or hard bark.

Bark is insect repellent, decay proof, fire-proof and acts as a heat screen. Commercially it is employed in tanning (e.g., Acacia), drugs (e.g., Cinchona— quinine) or as spice (e.g., Cannamon, vem. Dalchini). The cork of Quercus suber is employed in the manufacture of bottle stoppers, insulators, floats, sound proofing and linoleum.

Importance of Secondary Growth:

1. It is a means of replacement of old non-functional tissues with new active tissues.

2. The plants showing secondary growth can grow and live longer as compared to other plants.

3. It provides a fire proof, insect proof and insulating cover around the older plant parts.

4. Commercial cork is a product of secondary growth. It is obtained from Quercussuber (Cork Oak).

5. Wood is a very important product of secondary growth. It represents secondary xylem.

Secondary growth of dicot root:

The roots of some herbaceous dicotyledons and of all gymnosperms and woody dicotyledons show secondary increase in thickness, whereas most of the monocotyledonous roots, like those stems, are entirely primary.

The secondary tissues formed in the dicotyledonous roots are fundamentally similar to those of the stem, but the process is initiated in a different way .

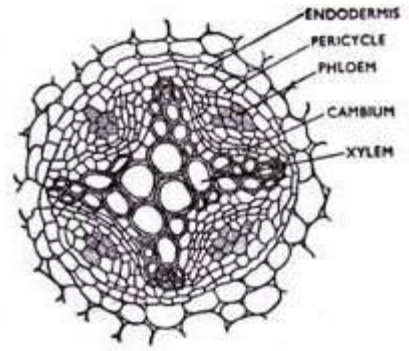


FIG. 645. Secondary growth in a dicotyledonous root—early stage, showing formation of the cambium ring.

The dicotyledonous roots have limited number of radially arranged vascular bundles with exarch xylem. Pith is usually absent. A few parenchyma cells beneath each phloem group become meristematic and thus form strips of cambium, the number of strips being equal to the number of phloem groups present.

Cambial cells go on dividing and produce secondary tissues. The cells of the uniseriate pericycle against the protoxylem group now divide and form a few layers. The first- formed cambium now extends both ways and reaches the innermost derivatives of the xylem groups.

As already stated, the secondary vascular tissues are fundamentally similar to those of the stem. They form a continuous cylinder and the primary xylem gets completely embedded in it.

At this stage the root structure is revealed only by the radially arranged exarch primary xylem located at the central region, the strands of secondary vascular tissues being collaterally arranged like those of the stem . The sieve elements of the primary phloem often get crushed.

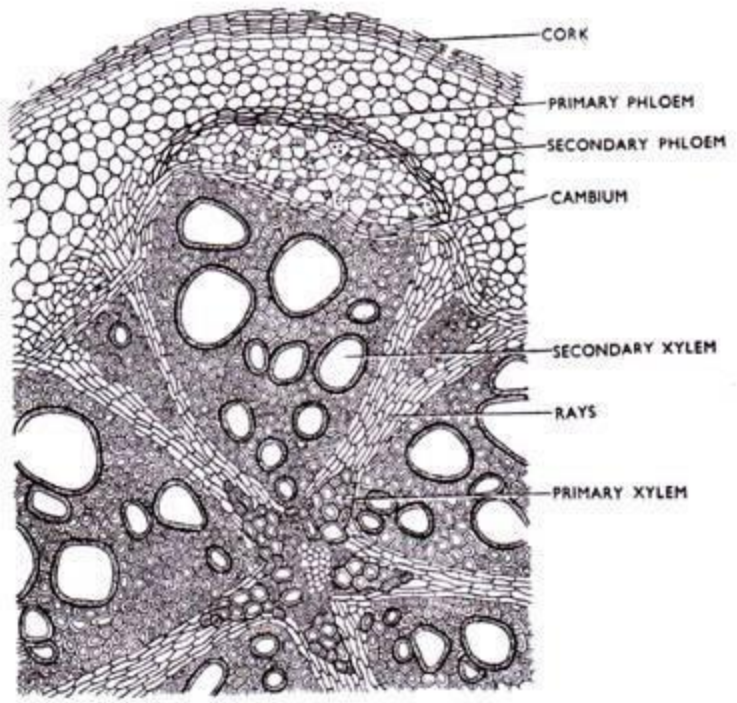


FIG. 647. Secondary growth in root of *Tinospora*—a portion in transverse section.

The cambial cells originating from the pericycle against protoxylem groups function as ray initials and produce broad bands of vascular rays. These rays running between xylem and phloem through the cambium are characteristic of the roots. They are also called main medullary rays.

Periderm is formed in the outer region. Phellogen arises in the outer cells of the pericycle . It produces phellem or cork cells on the outer side, and probably some phelloderm on the inner.

The pressure caused by formation of secondary tissues inside ruptures the cortex with endodermis, which is ultimately sloughed off. Lenticels may be formed. They usually occur in pairs as transversely elongated rough areas, one on each side of a lateral root.

1. Anatomy 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.

3. Few 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.

14. 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:

(i) Thick cuticle on epidermis.

(ii) Presence of motor cells.

(iii) Sclerenchyma patches are present.

(iv) Stomata in furrows.

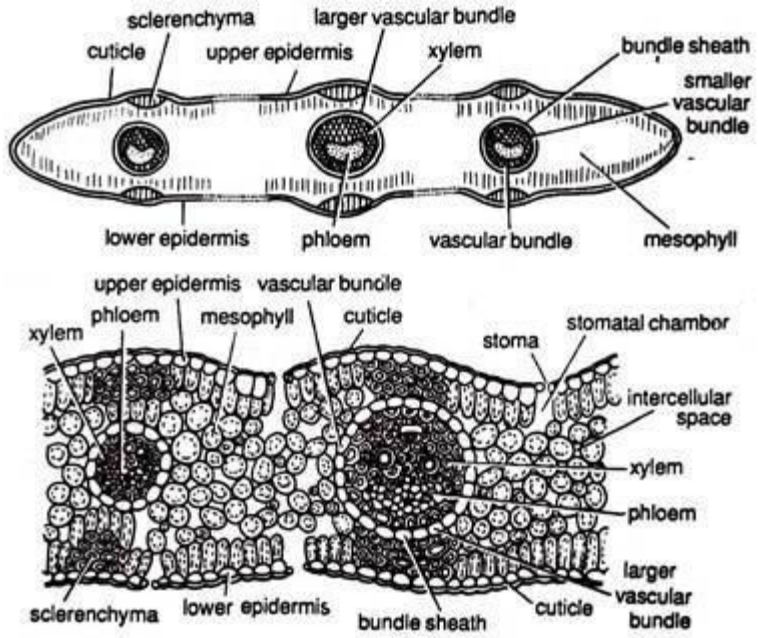


*Fig. 174. Triticum : **Upper**, T.S. leaf (diagrammatic); **Lower**, T.S. leaf (a part cellular).*

Anatomy of Dicot Leaf:

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.

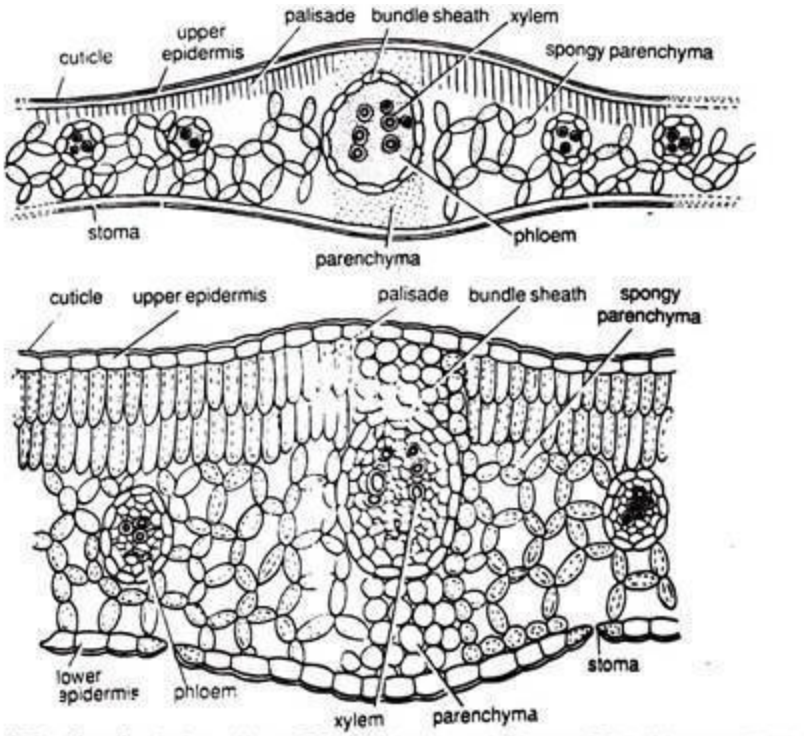


Fig. 175. Mangifera indica. Upper, T.S. leaf (diagrammatic); Lower, T.S. leaf (a part cellular).

Reference:

https://www.hhrc.ac.in/ePortal/Botany/II%20B.Sc%20Bot%20EM%2018UBT4%20M.C.Rajalakshmi-converted.pdf