II B.Sc. BOTANY

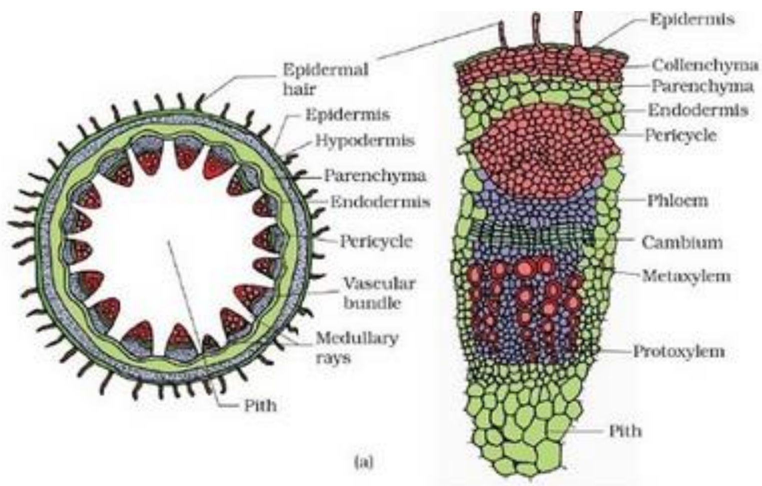
ANATOMY AND EMBRYOLOGY

UNIT:II & IV

UNIT : II Anatomy of Root and Stem   Sub. Code:18UBT4

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(Bundlecap)

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

B)Vascularbundles

- 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.

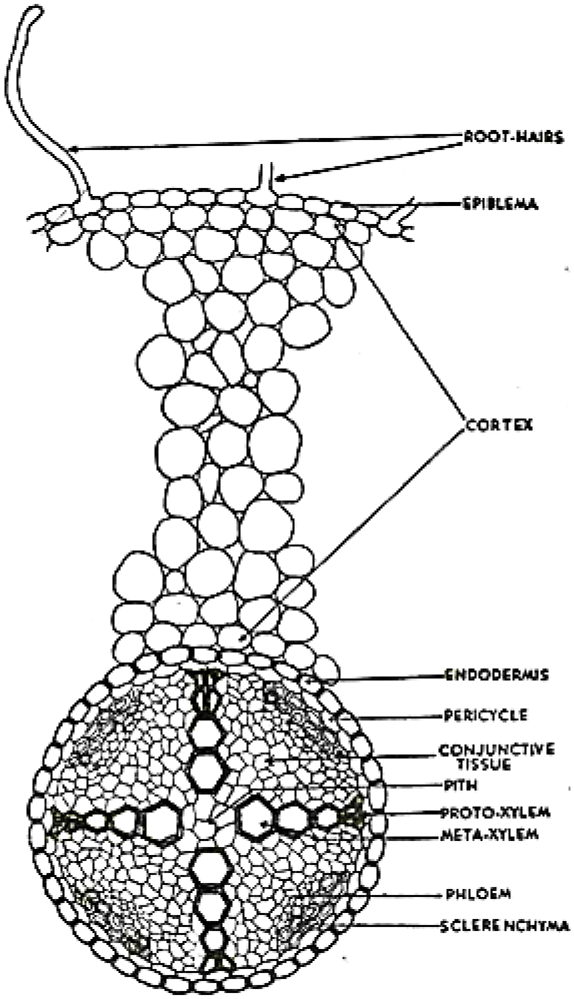


Fig. 153. Portion of transverse section of young dicotyledonous root (gram) showing the plan of arrangement of tissues.

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:

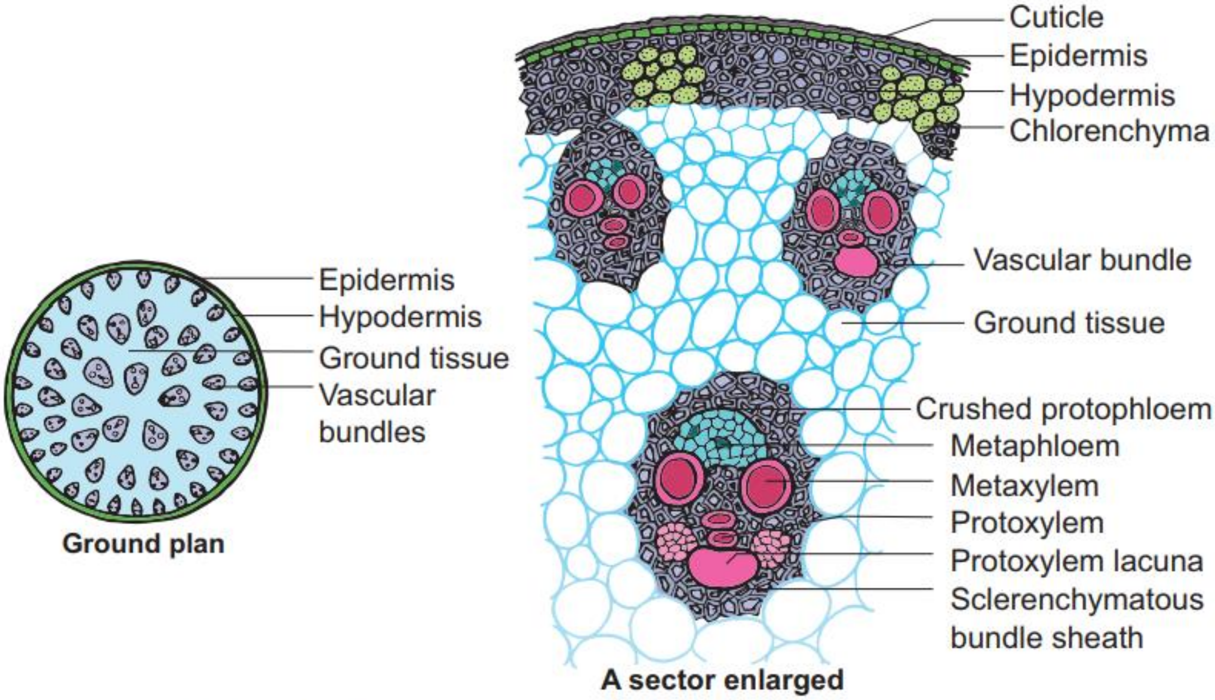


Figure 9.22: T.S. Monocot stem (Maize stem)

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.

Vascularbundles

- 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.

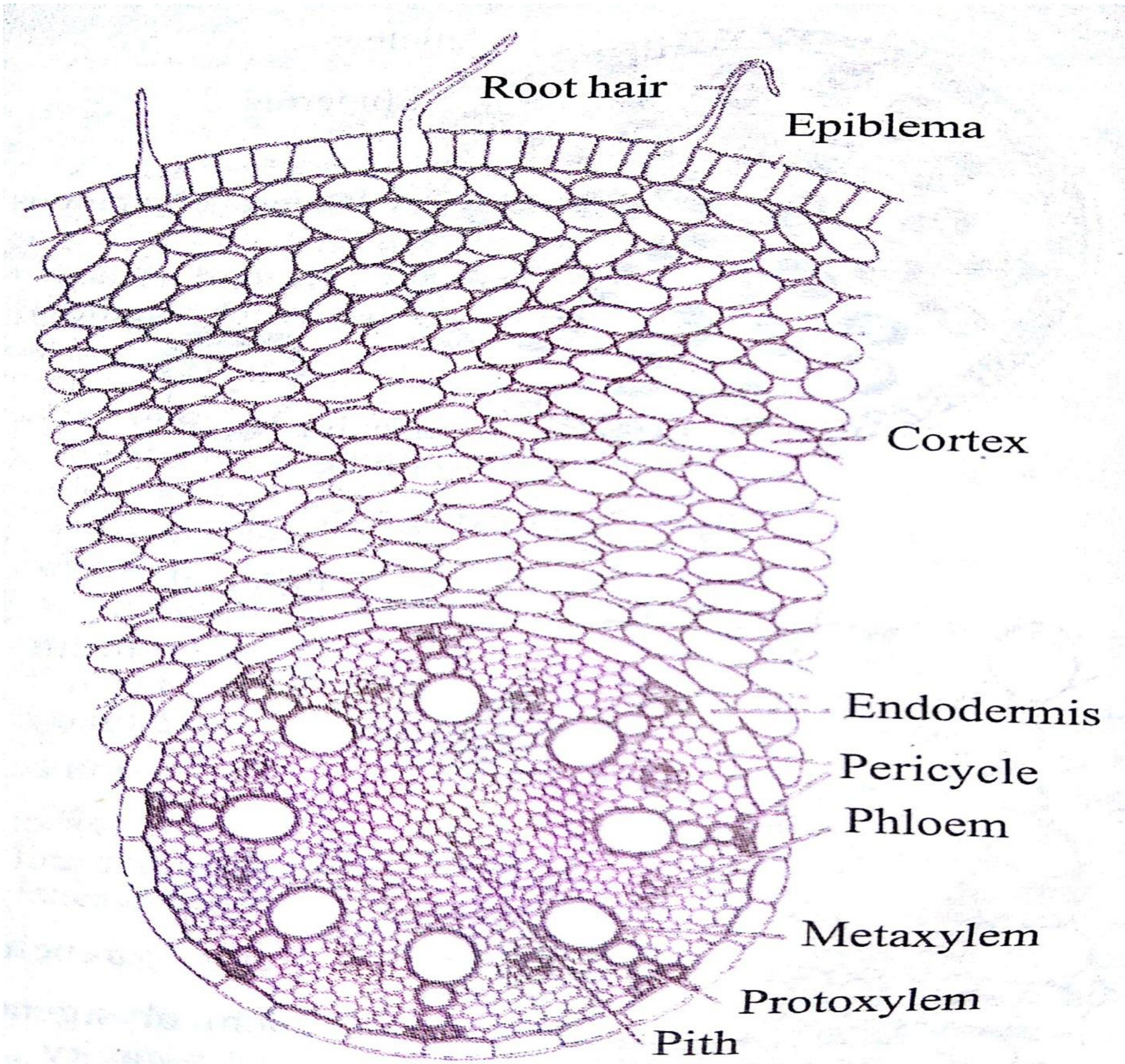
Conjunctive tissues:

- 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.

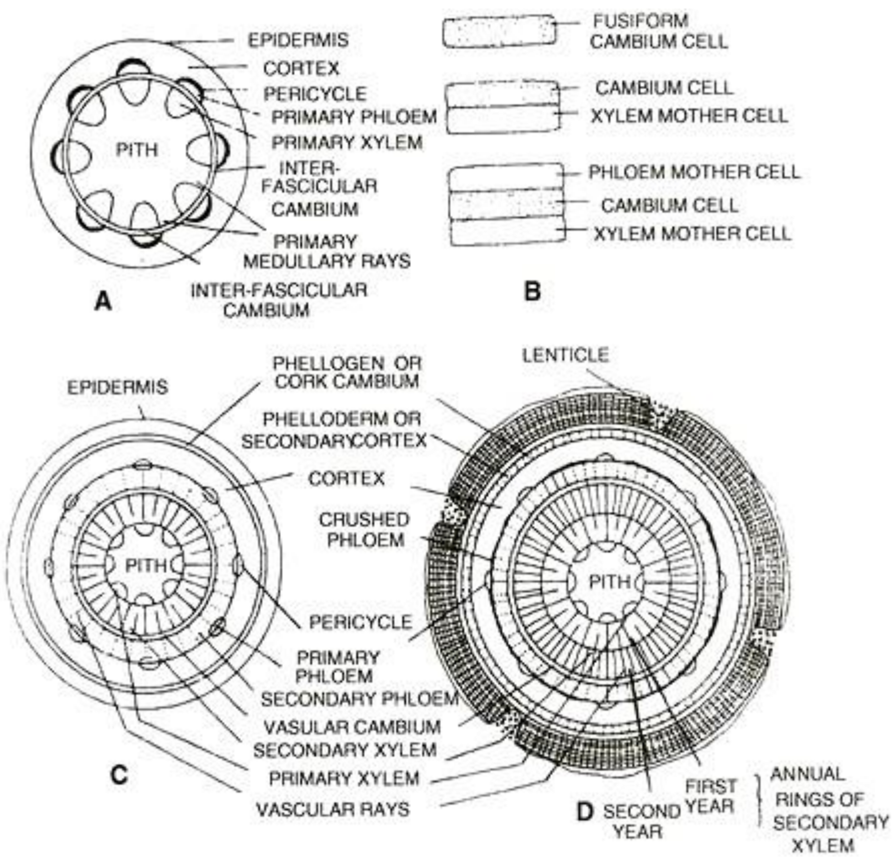


Fig. 6.28. A, complete ring of vascular cambium formed by strips of intrafascicular cambium and inter-fascicular cambium. B, formation of secondary vascular tissue mother cells; C, the beginning of secondary growth (mostly made up of secondary vascular tissues) of dicot stem (diagrammatic); D, two-year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

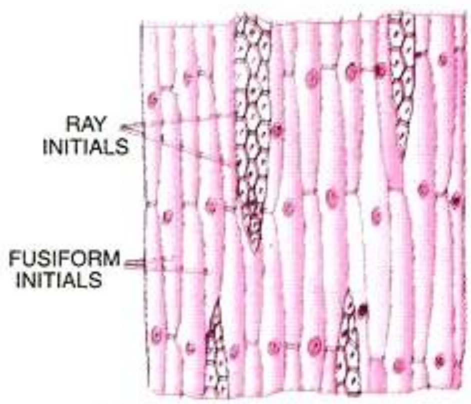


Fig. 6.29. L.S. Vascular cambium showing fusiform and ray initials.

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 .

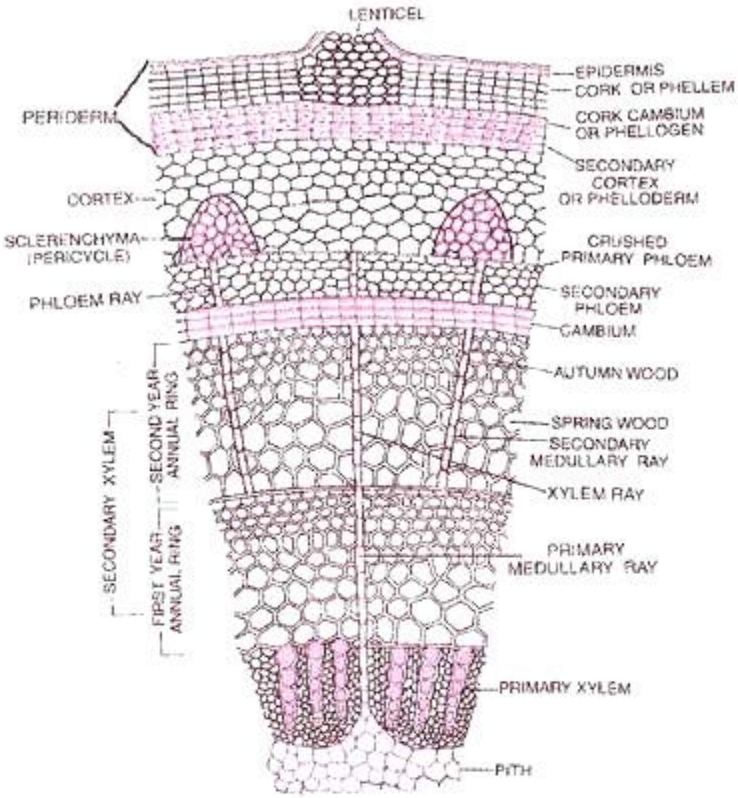


Fig. 6.31. Part of detailed structure of transverse section of two year old dicot stem showing secondary growth.

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.

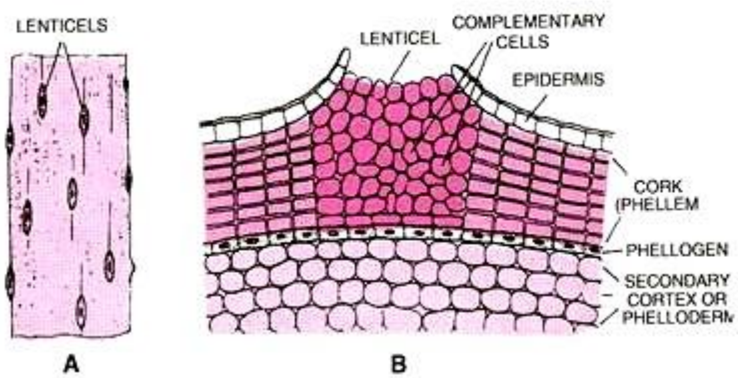


Fig. 6.34. Lenticels. A, external view of lenticels; B, T.S. lenticel.

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 .

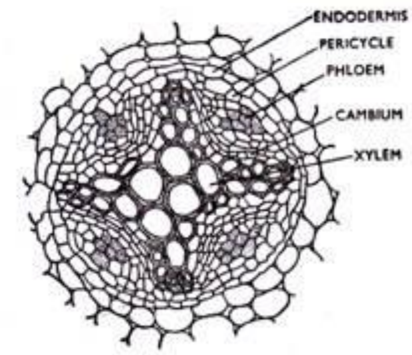


FIG. 645. Secondary growth in a dicotyledonous root—early stage, showing formation of the cambium ring.

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.

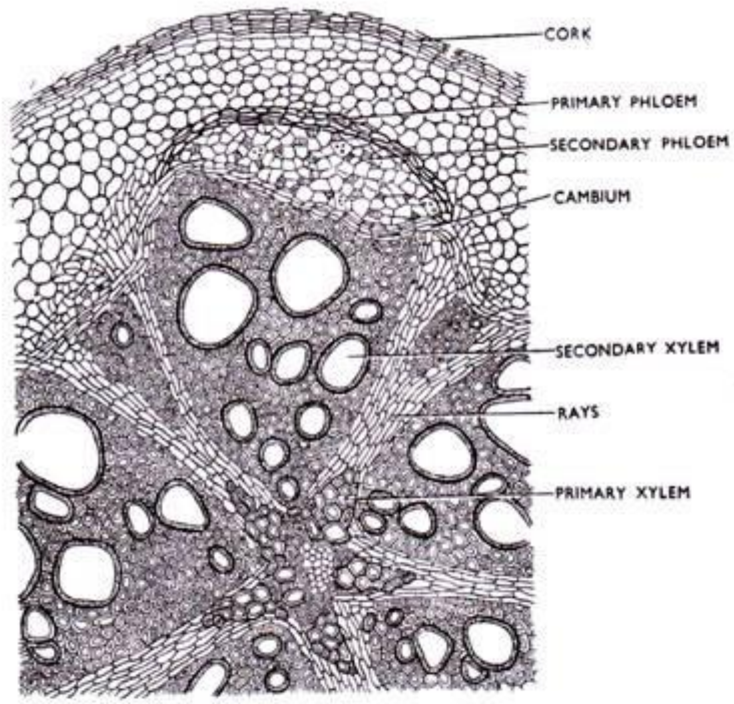


FIG. 647. Secondary growth in root of *Tinospora*—a portion in transverse section.

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.

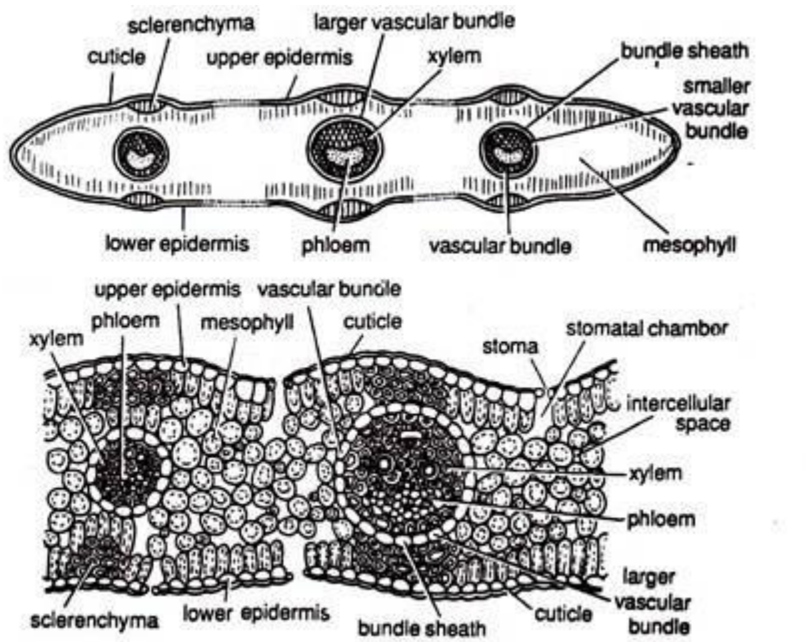


Fig. 174. *Triticum :* ***Upper****, T.S. leaf (diagrammatic);* ***Lower****, T.S. leaf (a part cellular).*

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.

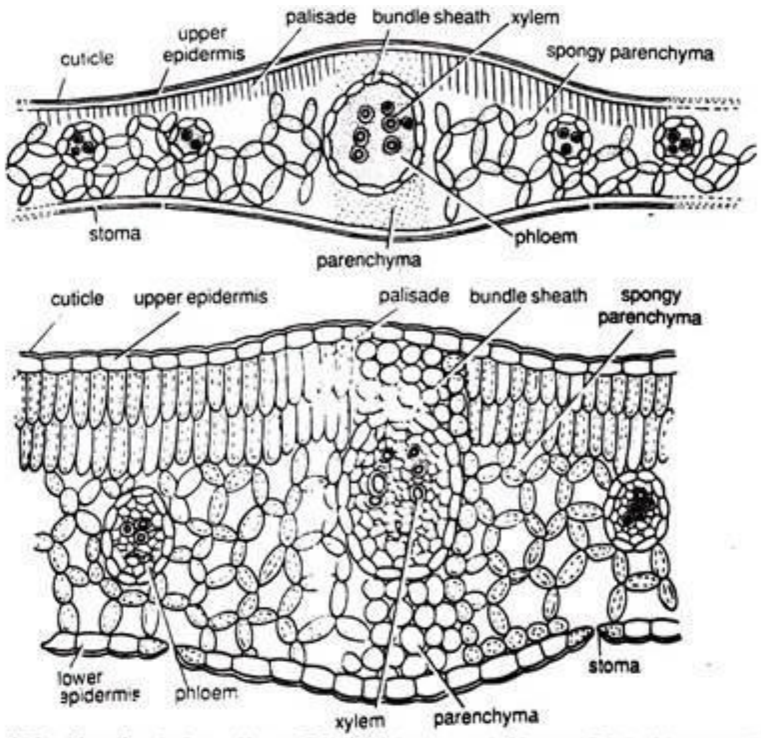


Fig. 175. Mangifera indica. ***Upper***, *T.S. leaf (diagrammatic);* ***Lower***, *T.S. leaf (a part cellular).*

Nodal anatomy:

Nodal Anatomy in Leaf Traces and Leaf Gaps*:*

A shoot bears nodes' and internodes. At each node, portions of the vascular system are deflected into the leaf, which is attached at this node. A vascular bundle located in the stem but directly related to a leaf, to represent the lower part of the vascular supply of this leaf, is termed the leaf trace.

The leaf trace is defined as follows— The leaf trace is a vascular bundle that connects the vascular system of the leaf with that of the stem. A leaf trace is extended between the base of a leaf and the point where it is completely merged with other parts of the vascular system in the stem. One or more leaf traces may be associated with each leaf.

In the shoot of a pteropsid (seed plants and ferns) where the leaf trace diverges into a leaf, it appears as though a portion of the vascular cylinder of the stem is deflected to one side. Immediately above the diverging trace, a parenchymatous tissue is being differentiated instead of vascular tissue in the vascular region of the stem for a limited distance.

The parenchy-matous regions in the vascular system of the stem, located adaxially from the diverging leaf traces, are called leaf gaps or lacunae. Actually these gaps are not breaks in the continuity of the vascular system of the axis. Lateral connections occur between the tissues above and below the gap. In transverse sections of an axis at the level of a leaf gap, the gap resembles an inter-fascicular area.

The gaps are quite conspicuous in the ferns and angiosperms where the vascular system in the inter-nodal parts of the stem forms a more or less continuous cylinder. In some ferns the leaves are so crowded that the gaps formed at the successive nodes overlap one another and the vascular cylinder appears highly dissected.

The transverse sections of such stems show a circle of vascular bundles with the parenchymatous leaf gaps. In certain ferns, gymnosperms and most angiosperms the vascular system consists of anastamosing strands. In such cases, the parenchyma that occurs above the diverging leaf trace becomes confluent with the interfascicular areas, thus the recognition of the gaps become uncertain.

There are three common types of nodes in the dicotyledons. The node with a single gap and a single trace to a leaf is known as unilacunar; the node with three gaps and three traces to a leaf (one median and two lateral) is known as trilacunar; and the node with several to many gaps and traces to a leaf is known as multi-lacunar.

The most accepted concept is that the trilacunar condition is primitive in the dicotyledons and that the unilacunar and the multi-lacunar have been derived from it. Several monocotyledonous plants possess leaves with sheathing bases and nodes with a large number of leaf traces separately inserted around the stem.

In ferns the number of traces to a leaf varies from one to many, but they are always associated with a single gap. In gymnosperms a unilacunar node is common.

The leaf trace relationships at the nodes are thought to be of phylogenetic importance, and therefore, nodal anatomy is concerned with the study of systematics and phylogeny of angiosperms.

In this cylinder approximately half of the bundles are leaf traces from the nearest leaf above and the other half of the bundles are from the internode above the insertion of the leaf (Fig. 38.7 E). The peripheral bundles are mostly leaf traces. The most conspicuous character of grass stems is the presence of transverse bundles in the nodal regions

When the branch possesses two traces, these bundles unite within a short distance, forming a complete vascular cylinder; when one trace occurs, this strand usually possesses the cross-sectional form of a horse-shoe shaped structure with the opening downward, and the vascular cylinder of the branch is formed by the closure of the opening as the branch traces passes out.

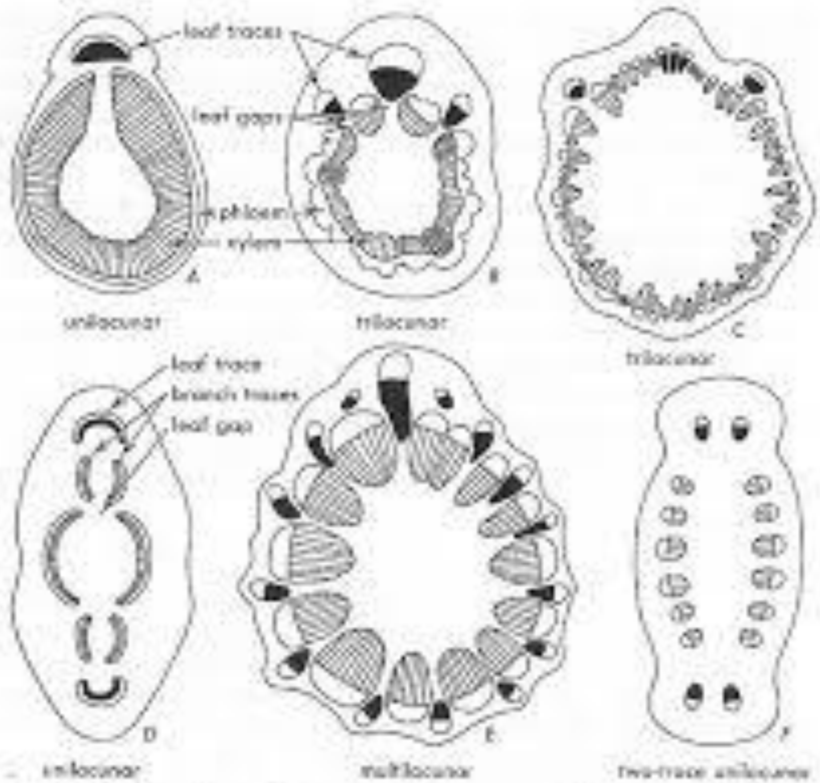


Fig. 16-5. Cross sections of stems with different types of nodal structure. Leaf traces are indicated by blackened xylem regions. *A*, *Spiraea*. *B*, *Salix*. *C*, *Brassica*. *D*, *Veronica*. *E*, *Rumex*. *F*, *Clerodendron*. (*A–E* after Esau, *Plant Anatomy*, John Wiley and Sons, 1953.)

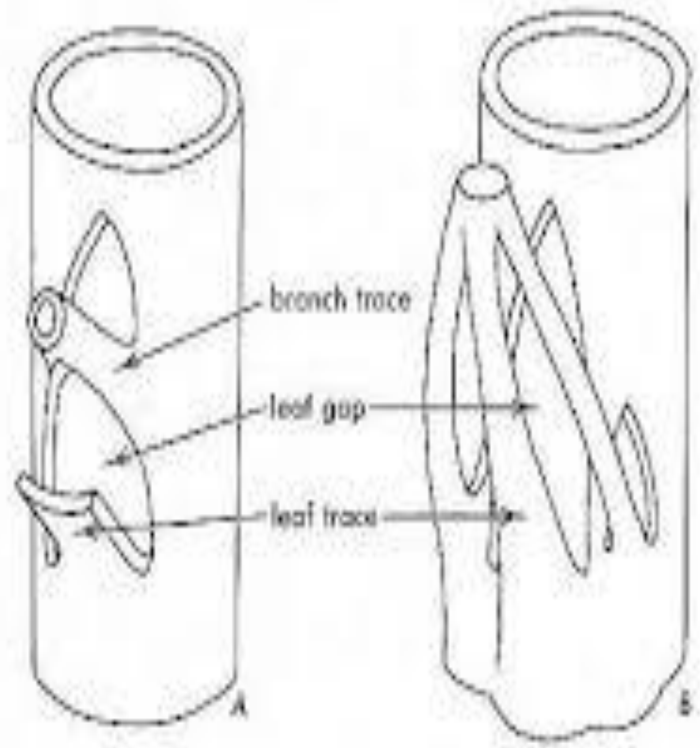


Fig. 16.3. Diagrams of vascular system from stems with a unilacunar node (*A*) and trilacunar node (*B*). In *A*, a single leaf trace diverges into a leaf and two branch traces into a branch; in *B*, the leaf has three traces, each confronted by a separate gap. (After Esau, *Plant Anatomy*, John Wiley and Sons, 1953.)

UNIT : IV EMBRYOLOGY

Microsporangium:

Microsporangia are sporangia that produce microspores that give rise to male gametophytes when they germinate. Microsporangia occur in all vascular plants that have heterosporic life cycles, such as seed plants, spike mosses and the aquatic fern genus *Azolla*. In gymnosperms and angiosperm anthers, the microsporangia produce microsporocytes, the microspore mother cells, which then produce four microspores through the process of meiosis. Microsporocytes are produced in the microsporangia of gymnosperm cones and the anthers of angiosperms. They are diploid microspore mother-cells, which then produce four haploid microspores through the process of meiosis. These become pollen grains, within which the microspores divide twice by mitosis to produce a very simple gametophyte.

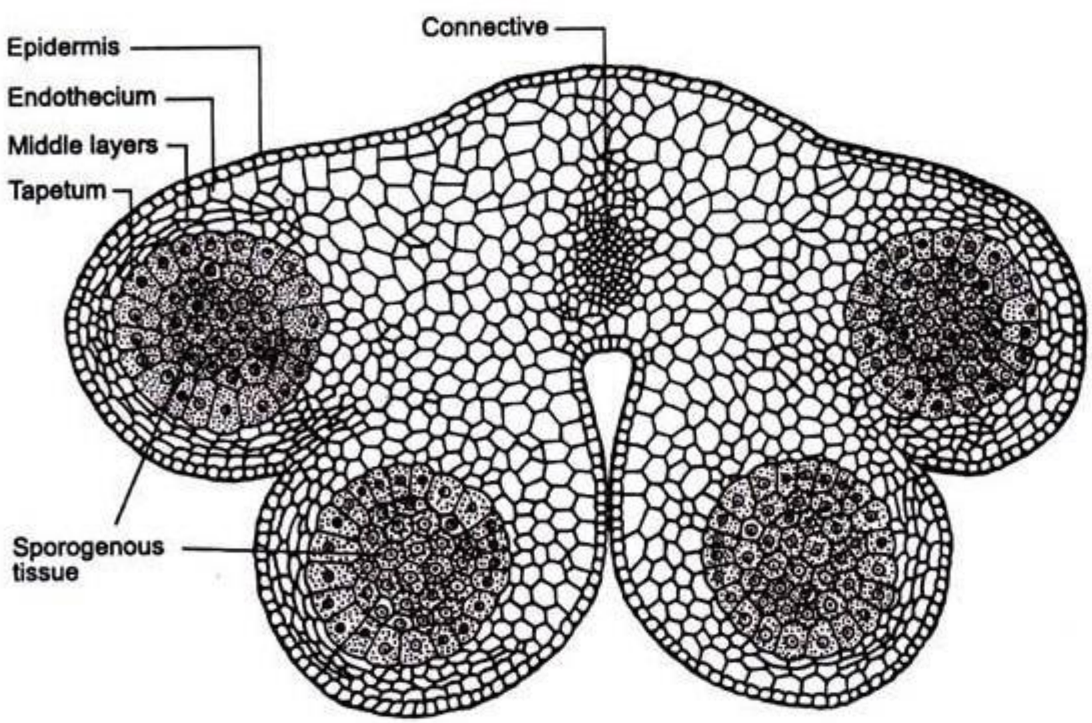
Heterosporous plants that produced microspores in microsporangia and megaspores in separate megasporangia evolved independently in several plant groups during the Devonian period. [1] Fossils of these plants show that they produced endosporic gametophytes, meaning that their gametophytes were not free-living as in bryophytes but developed within the spores, as in modern heterosporic vascular plants.[2]:280

In angiosperms, a very young anther (the part of the stamen that contains the pollen) consists of actively dividing meristematic cells surrounded by a layer of epidermis. It then becomes two-lobed. Each anther lobe develops two pollen sacs. Then, a two-lobed anther develops four pollen sacs that situate at four corners of the anther. Development of pollen sacs begins with the differentiation of archesporial cells in the hypodermal region below epidermis at four corners of the young anther. The archesporial cells divide by periclinal division to give a subepidermal primary parietal layer and a primary sporogenous layer. The cells of the primary parietal layer divide by successive periclinal and anticlinal divisions to form concentric layers of pollen sac wall.

The wall layers from periphery to center consist of:

- A single layer of epidermis between, which becomes stretched and shrivels off at maturity
- A single layer of endothecium. The cells of endothecium have fibrous thickenings.
- One to three middle layers. Cells of these layers generally disintegrate in the mature anther
- A single layer of tapetum. The tapetal cells may be uni-, bi- or multinucleate and possess dense cytoplasm. The cells of the primary sporogenous layer divide further and give rise to diploid sporogenous tissue.

Structure of microsporangium



Micorosporogenesis:

During the development of the microsporangium, the anther is seen at first as a homogeneous mass of meristematic cells, oblong in cross-section and surrounded by an epidermis

It then becomes more or less four-lobed and four longitudinal rows of archesporial cells are differentiated. The archesporial cells are marked off from the surrounding cells by their more deeply staining cytoplasm and conspicuous nuclei.

There may be only one such archesporial cell in each of the four lobes as in Boerhaavia, etc., or there may be more of them forming a plate (Ophiopogon, etc.).

Longitudinally, also, there may be one to many of them. Each archesporial cell now cuts off a primary parietal cell towards the epidermis and a primary sporogenous cell on the inner side.

The parietal cell now divides by periclinal and anticlinal walls giving rise to several layers of cells forming the wall of the anther while the sporogenous cell usually divides a few times giving rise to a number of microspore or pollen mother cells .

The innermost layer of wall cells directly abutting on the sporogenous tissue forms the tapetum which is a nutritive tissue nourishing the developing microspores . The wall cells just below the epidermis form the endothecium which later loses the cell contents, usually becomes fibrous, and forms the dry coat of the mature anther in which the epidermis becomes rather inconspicuous.

Between the tapetum and the endothecium there are one to three middle layers of cells. The middle layers and the tapetum are usually crushed by the time actual meiosis occurs in the sporogenous cells.

During microsporogenesis (i.e., development of microspores or pollens) the nucleus of each microspore mother cell undergoes meiosis or reduction division ultimately giving rise to four haploid (i.e., possessing ‘n’ number of chromosomes) nuclei.

These four nuclei are arranged tetrahedrally and are soon invested with cell walls. Many variations are known of this typical pattern of meiosis, e.g., in maize a wall is formed across the dyad (2-nucleated condition).

They are now the microspores or pollens which soon dry up and become powdery while the tapetum becomes absorbed.

The anther now becomes a dry structure, the partition walls between the sporangia (i.e., loculi) are usually destroyed and the microspores (pollens) are soon liberated by dehiscence of the anther.

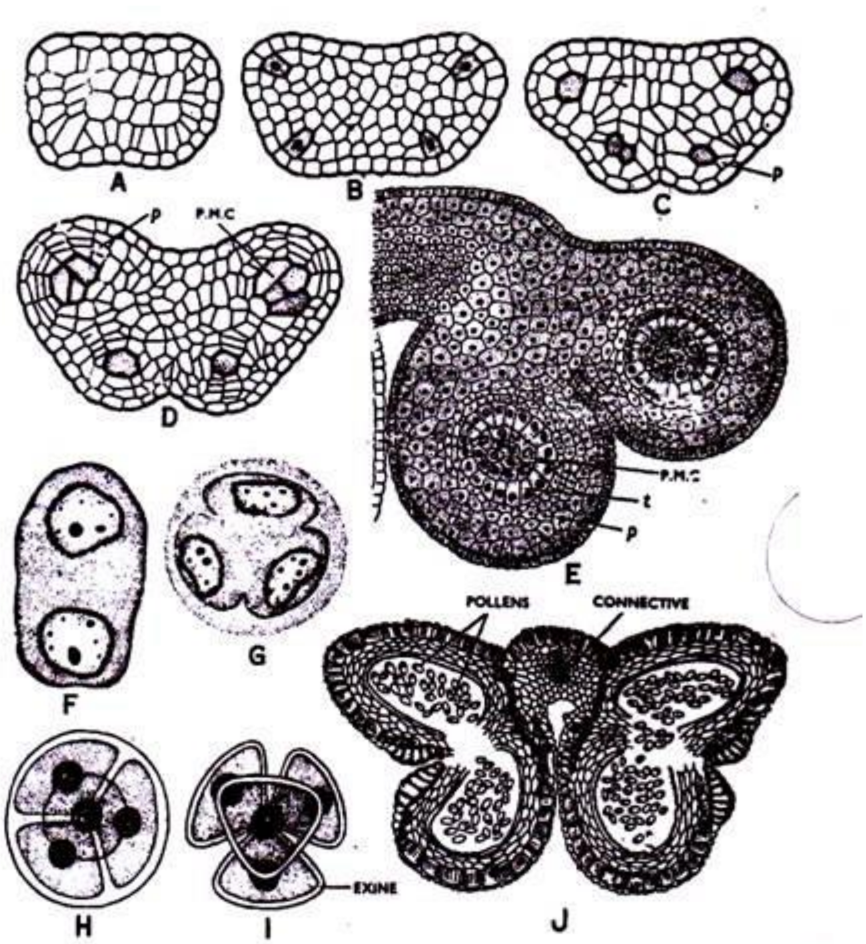


FIG. 404. Stages of anther development and microsporogenesis. A. T.s. of young anther. B. Differentiation of four rows of archesporial cells (shaded) in the four microsporangia. C. Primary sporogenous cells (shaded) and parietal cells (*p*). D. Microspore or pollen mother cells (P.M.C.). E. Microsporangia (pollen chambers) showing pollen mother cells (P.M.C.) and tapetum (*t*). F. Dyad stage of meiosis in P.M.C. G. Tetrad stage (the fourth nucleus is behind). H. & I. Tetrahedral arrangement and development of pollens. J. T.s. of mature anther.

The tapetal cells often become multinucleate and play a great part in the nutrition of the pollens. Sometimes they develop a Plasmodium after disintegration and play a part in the development of the exine of the pollen. Even a part of the sporogenous tissue may break down and serve for nutrition instead of developing spores.

While the pollens are dry and powdery in most flowers, peculiar conditions are often let with. In Annona, Elodea, Typha, etc., the four spores in a tetrad never separate but form compound pollen grains.

In the Mimoseae 8 to 64 pollens often aggregate together while in the gynostegium of Calotropis and the gynostemium of orchids all the pollens of each anther lobe from a characteristic mass called pollinium . Each pollinium is provided with a stalk called caudicle and a sticky base called disc or corpusculum.

The pollen or the microspore is a very minute structure (0.025 to 0.125 mm in diameter). It is unicellular and usually round although it may be oval, pyramidal, polyhedral, etc. It is provided with two coats—an inner, delicate cellulose layer called intine and an outer tough, cutinised layer called exine or extine. The exine is often sculptured or provided with spines, warts, etc. Occasionally, it is smooth.

The exine may have a waxy coating to render the pollen more or less waterproof. Very often, there are some definitely thinner, circular spots or slits in the exine called germ pores or slits.

These weak spots are utilised during the germination of the pollen. The pores are sometimes provided with lids which open out like valves during germination. Very often, before the pollen is discharged from the anther it becomes binucleate , the original single nucleus dividing-into a tube nucleus and a generative nucleus.

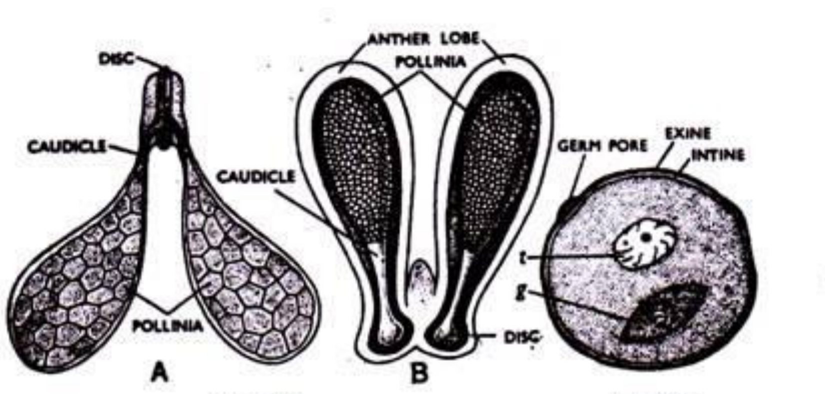


FIG. 405. Pollinia of A. *Calotropis* and B. Orchid. FIG. 406. A binucleate pollen showing tube nucleus (*t*) and generative cell (*g*).

The latter, with some cytoplasm surrounding it, becomes the generative cell (described later). Sometimes the pollen may even become trinucleate (Fig. 410), as in most cereal crops, by complete development of the male gametophyte even before it is shed. Fig. 407 shows some different forms of mature pollens. Palynology is the science involving the study of pollens.

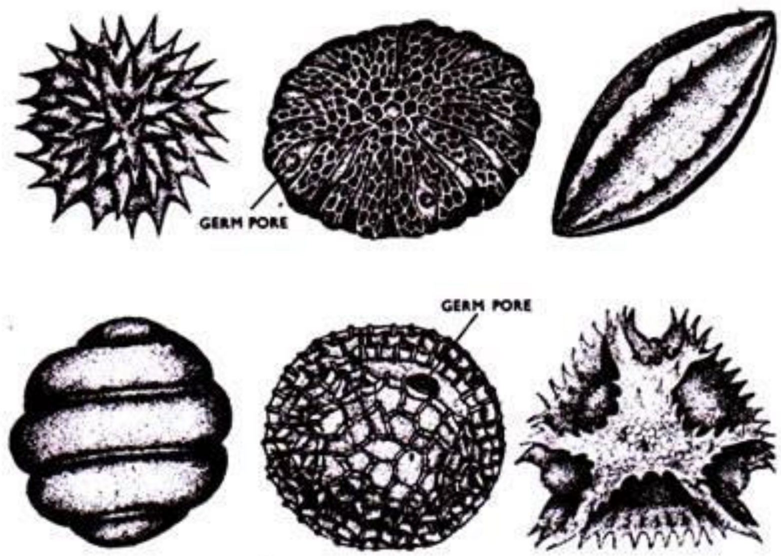


FIG. 407. Different pollens showing various types of sculpturing.

Development of The Male Gametophyte:

The nucleus of the microspore begins to divide very soon after it is formed. Its division is usually quicker in the warmer climate than in the cooler regions. Such division may begin even before the microspores dissociate from the tetrad condition.

When the pollen is lodged on the stigma, usually its nucleus has already divided. The microspore cell divides into two very equal cells with the smaller cell attached to the wall .

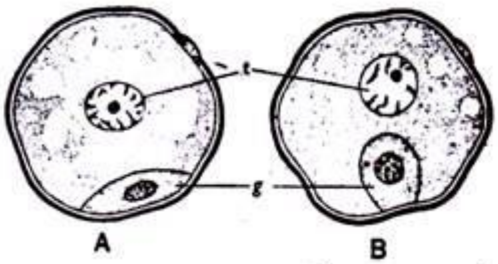


Fig. 408. Early stages of the development of the male gametophyte. A. The first division: t=tube nucleus, g=generative cell attached to wall. B. Later condition of the above: generative cell is detaching itself from the wall.

The latter soon loses contact with the wall and becomes the lens-shaped generative cell floating freely in the cytoplasm of the large vegetative or tube cell.

It is then in the binucleate (or two-celled) stage. As the pollen germinates and the pollen tube comes out through a germ pore the vegetative nucleus precedes the generative cell.

The generative cell soon divides mitotically to form two male gametes and this act is known as spermatogenesis as the male gametes of Angiosperms are equivalent to the ciliated sperms of the lower groups of plants. The gamete nuclei are enveloped in cytoplasmic sheaths, this forming gamete cells. At a later stage the two male gamete cells are seen to follow the vegetative ‘nucleus .

Soon the vegetative nucleus, which seems to be of no importance being a mere vestigial organ, disappears. As the pollen is the microspore, the contents within the pollen and the pollen tube formed by the germination of the microspore is the male gametophyte of Angiosperms.

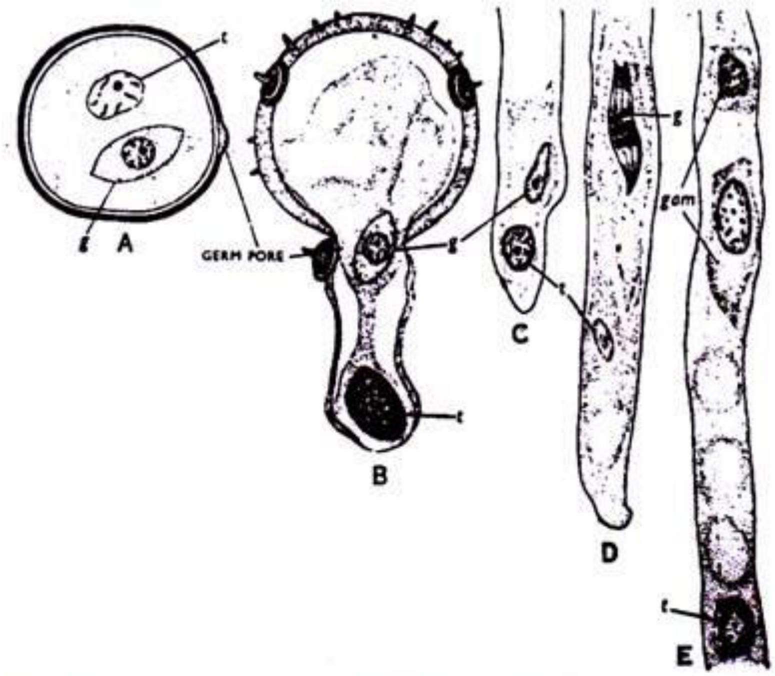


FIG. 409. Development of the male gametophyte and spermatogenesis. A. Binucleate stage. B. Intine coming out through a germ pore as a pollen tube forcing open the valvular lid. C. Tip of a pollen tube at a later stage. D. *Spermatogenesis* or 'division of the generative cell to form two male gametes. The tube nucleus is ahead. E. Pollen tube developed further showing two male gametes and tube nucleus. (A, C, D & E are stages in water hyacinth after Ganguee); *t*=tube or vegetative nucleus; *g*=generative cell; *gam*=male gamete.

While the male gametophyte, thus, usually develops after the pollen has germinated, there are many instances where it develops within the pollen before the pollen tube is formed and, in some cases, even before pollination. Trinucleate pollens with tube nucleus and two gamete cells are observed in such cases . Such trinucleate pollen formation is the rule in many plants (e.g., Portulaca), specially the cereal crops like wheat, rice, maize of Gramineae and sugarcane of the same family.

Development of male gametophyte

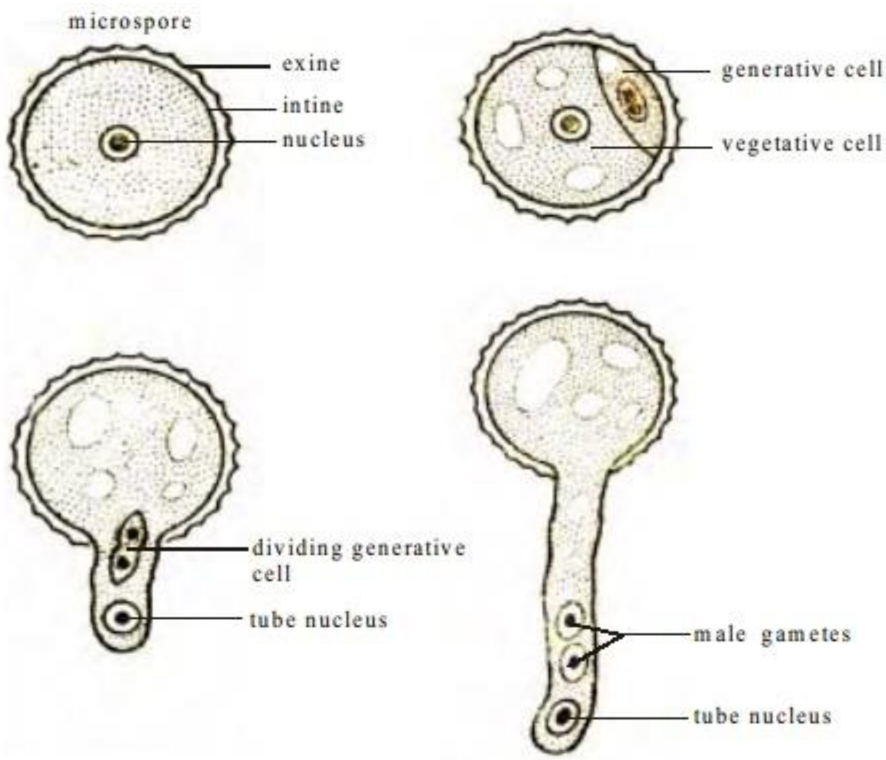
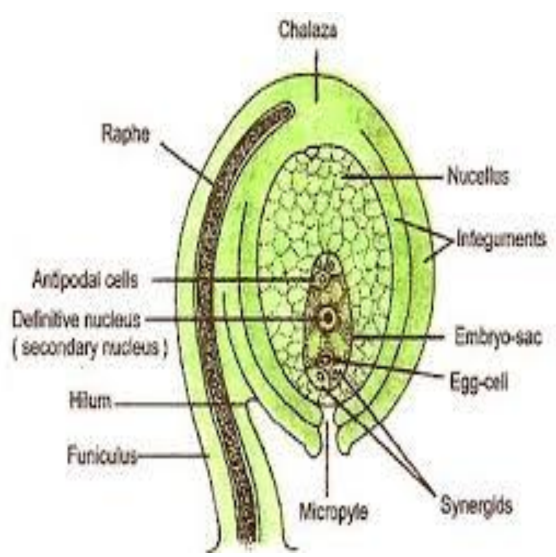


Fig. Development of male gametophyte

Angiosperms are defined by having seeds in the enclosing fruit derived from the ovary of a flower. The flower consists of primarily sporophytic tissues, with both male and female gametophytes which are highly reduced in size in comparison to all other land plants. Angiosperms also have the unique property of double fertilization, producing a usually triploid endosperm in addition to the embryo. The male gametophyte is formed in the anthers of the stamens, and the female gametophyte is located in the ovules within the pistil.

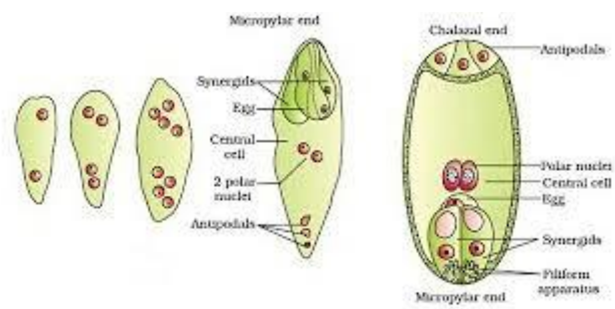
In the anther, four pollen sacs (locules) contain numerous microspore mother cells, each of which undergoes meiosis to produce four microspores in a tetrad . The male gametophyte generation begins with the microspore. Initially, the microspore has a uniformly distributed cytoplasm with a centrally located haploid nucleus. A large vacuole later forms at the center, displacing the nucleus to the side. In many flowering plants, including the model species *Arabidopsis* and maize, two mitotic divisions occur during pollen development. The first division produces a large vegetative cell and a much smaller generative cell. The vegetative cell inherits most of the cytoplasm from the microspore cell, has a relatively loose nucleus that is active in transcription, and completely envelopes the generative cells. In contrast, the generative nucleus is more tightly organized and less active in transcription. The generative cell later undergoes a second mitosis to produce two sperm cells. Pollen development depends on the function of a surrounding sporophytic tissue called tapetum.

Megasporangium:



The ovule consists of integument megasporangium. It is a small structure connected to the placenta by means of a funicle. The hilum is the point of attachment between ovule and funicle. Each ovule is covered by a protective covering called integuments which surround the nucellus. At the tip, the integuments are absent leaving a small opening called the micropyle. The chalaza is present opposite to the micropylar end and forms the basal part of the ovule. Nucellus is the main body of the ovule made up of parenchymatous mass. The embryo sac also called female gametophyte is present inside the nucellus. The diploid megaspore mother cell undergoes meiosis to form 4 haploid megaspores by the process of megasporogenesis. Three out of four megaspores degenerate and only one is functional. The functional megaspore develops into the female gametophyte. It is a 7 celled and 8 nucleated structure consisting of two synergids, three antipodal cells, two polar nuclei and 1 egg cell.

Megasporogenesis:



Megasporogenesis

Megasporogenesis refers to the development of megaspores from the megasporocyte, the cell that undergoes meiosis. Meiosis of the megasporocyte nucleus results in the formation of four haploid megaspore nuclei. In most taxa, meiosis is followed by cytokinesis, resulting in four megaspore cells. This pattern is termed **monosporic** megasporogene - sis; because of the four megaspores produced, only one of them contributes to the female gametophyte . In some angiosperm taxa, however, cytokinesis occurs after the first meiotic division, but not the second, resulting in two cells, each of which contain two haploid nuclei. This developmental pattern is termed **bisporic** megasporogenesis because one of the binucleate cells, containing two megaspore nuclei, contributes to the female gametophyte (Figure 11.9). Finally, in other taxa cytokinesis does not occur at all after meiosis, resulting in a single cell with four haploid nuclei. Because all four haploid megaspore nuclei contribute to the female gametophyte, this pattern is termed **tetrasporic** megasporogenesis .

Monosporic embryo sac – Polygonum type:

FEMALE GAMETOPHYTE (Embryo sac)

The functional megaspore represents the first cell of the female gametophyte. As the functional megaspore grows, many small vacuoles appear in its cytoplasm, which later join together to form a large vacuole. The nucleus undergo three mitotic divisions and form eight nuclei. After first mitotic division, two nuclei are formed and due to enlargement of vacuole one of the nucleus is pushed towards the micropylar end and the other towards the chalazal end. Both these nuclei towards their respective pole undergo two mitotic division resulting i the formation of four nuclei at each pole. One nucleus from each pole migrates towards the centre.
These nuclei are called as polar nuclei.

The three nuclei at the chalazal end from the antipodal cell. Of the three nuclei at the micropylar end, one nucleus forms the egg or female gamete and the other two as synergids.

The entire structure, the two polar nuclei, three antipodal cell, one egg and two synergids represent the mature female gametophyte or embryo sac. Since this type of embryo sac develop from single megaspore and has 8- nuclei, it is called as monosporic 8-nucleate embryo sac or polygonum type. It is the most common type and found in 81% of angiospermic plant. Types of Embryo Sac (Female gametophyte) Besides the monosporic, embryo sac, which develop from single megaspore, in many cases two or all the four megaspores take part in the development of embryo sac. Three different type of embryo sac have been reported on the basis of number of megaspore involve in the developing of embryo sac.

1. Monosporic
2. Bisporic
3. Tetrasporic

(1) Monosporic embryo sacs

A monosporic embryo sac develops from a single megaspore and as such all the nuclei present in this type of embryo sac are genetically alike. Monosporic embryo sacs are of the following two types. 1. Monosporic 8-nucleate or polygonum type. This type of embryo sac develops from the chalazal megaspore. Its nucleus divides thrice to form eight nuclei. This type is generally referred to as normal type of embryo sac. It is also called Polygonum type as it was first time described in Polygonum divericatum by Stransburger (1879).

(2) Bisporic embryo sacs

The bisporic embryo sac develops from one of the two dyads formed as a result of the first meiotic division (meiosis I) of megaspore mother cell. One of the dyads degenerates. Both the nuclei of the functional dyad take part in the formation of embryo sac. Each nucleus undergoes two mitotic divisions and as such the mature embryo sac is 8-nucleate. The eight nuclei are organised into antipodals, egg apparatus and polar nuclei as in Polygonum type of embryo sac. In this type of embryo sac the 4-nuclei derived from one megaspore nucleus are genetically different from the other four derived from the second megaspore nucleus. On the basis of the position of functional dyad the following two types have been recognized in bisporic embryo sacs. 1. Allium type. This type develops from the chalazal dyad.

(3) Tetrasporic embryo sacs

Sometimes meiotic division of the megaspore mother cell is not accompanied by cytokinesis and hence all the four haploid nuclei lie in a single cell called coenomegaspore. All the four nuclei of coeno-megaspore participate in the formation of embryo sac. This type of embryo sac is called tetrasporic and it is genetically more heterogeneous than the bisporic type of embryo sac. On the basis of (i) the position of haploid nuclei in the coeno-megaspore, (ii) the number of times these nuclei divide, and (iii) organisation of nuclei in the mature embryo sac, the following types of tetrasporic embryo sacs have been recognised. nucleus at the micropylar end is cut off by a membrane and forms the egg. There are no synergids. The other three nuclei (i.e., one chalazal and two lateral) usually disappear but occasionally they too may be cut off by membranes and appear as accessory egg cells. The Plumbago type of embryo sac is thus characterised by the absence of synergids and antipodals. This type embryo sac is known to occur in the Plumbaginaceae.

3. Multisporic embryosacPeperomia type.

In this type, the four haploid nuclei of the coeno-megaspore undergo two successive mitotic divisions forming 16 nuclei. These nuclei arrange themselves in four groups of four each, one at the micropylar end, one at the chalazal end .