Pinus: External Morphology and Different Parts

External Morphology of Pinus:

1. Pinus is a large, perennial, evergreen plant.

2. Branches grow spirally and thus the plant gives the appearance of a conical or pyramidal structure.

3. Sporophytic plant body is differentiated into roots, stem and acicular (needle-like) leaves (Fig. 26).

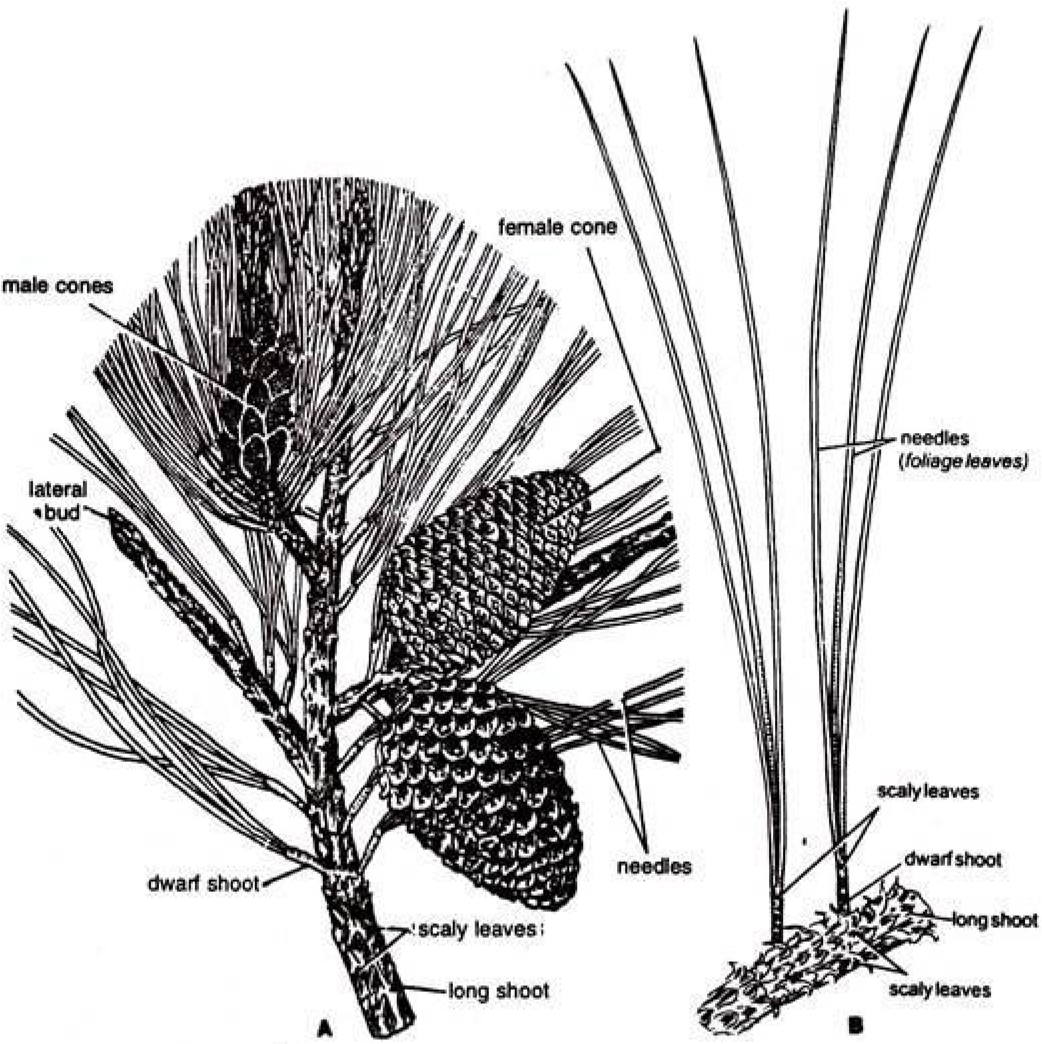

Fig. 26. Pinus gerardiana. A, Branch of a mature plant bearing male and female cones; B, A part of stem showing two types of shoots.

4. A tap root with few root hair is present but it disappears soon. Later on many lateral roots develop, which help in absorption and fixation.

5. The ultimate branches of these roots are covered by a covering of fungal hyphae called ectotrophic mycorrhiza.

6. The stem is cylindrical and erect, and remains covered with bark. Branching is monopodial.

7. Two types of branches are present: long shoots and dwarf shoots. These are also known as branches of unlimited and limited growth, respectively.

8. Long shoots contain apical bud and grow indefinitely. Many scaly leaves are present on the long shoot.

9. Dwarf shoots are devoid of any apical bud and thus are limited in their growth. They arise on the long shoot in the axil of scaly leaves.

10. A dwarf shoot (Fig. 27) has two scaly leaves called prophylls, followed by 5-13 cataphylls arranged in 2/5 phyllotaxy, and 1-5 needles.

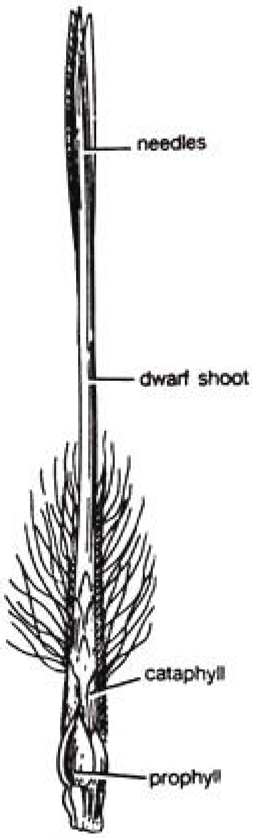

Fig. 27. *Pinus roxburghii. A young dwarf shoot.*

11. The leaves are of two types, i.e., foliage and scaly.

12. Scaly leaves are thin, brown-coloured and scale like and develop only on long as well as dwarf shoots.

13. Foliage leaves are present at the apex of the dwarf shoots o

14. Foliage leaves are large, needle-like, and vary in number from 1 to 5 in different species.

15. A spur (Fig. 28) is called unifoliar if only one leaf is present at the apex of the dwarf shoot, bifoliar if two leaves are present, trifoliar if three leaves are present, and so on.

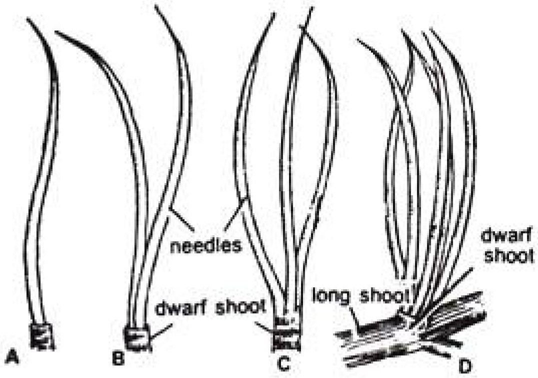

Fig. 28. Pinus. Spurs of different species. A, Monofoliar (Pinus monophylla); B, Bifoliar (P. sylvestris); C, Trifoliar (P. gerardiana); D, Pentafoliar (P. wallichiana).

Some of the species with different types of spurs are as follows:

(i) Pinus monophylla-unifoliar (having only one needle);

(ii) P. sylvestris-bifoliar (having two needles);

(iii) P. gerardiana-trifoliar (having three needles);

(iv) P. quadrifolia-quadrifoliar (having four needles

(v) P. wallichiana-pentafoliar (having five needles).

Anatomy of Different Parts of Pinus:

Cut thin sections of different parts of the plant (Young root, old root, young long shoot, old long shoot, T.L.S. wood, R.L.S. wood, young dwarf shoot, old dwarf shoot and needle), stain them separately in a safranin-fast green combination, mount in glycerine and study. Also compare your preparations with the permanent slides shown to you in the laboratory.

T.S. Young Root:

1. Outermost layer of the circular roots is thick-walled epiblema with many root hai

2. Epiblema is followed by many layers of parenchymatous cortex.

3. Inner to the cortex is present a layer of endodermis and many layers of pericycle.

4. Vascular bundles are radially arranged and diarch to tetrarch with exarch protoxylem.

5. Protoxylem is bifurcated (Y-shaped) towards the periphery, and in between each bifurcation is present a resin cannal (Fig. 29).

6. Phloem is present alternate to the protoxylem.

7. Pith is poorly-developed or absent.

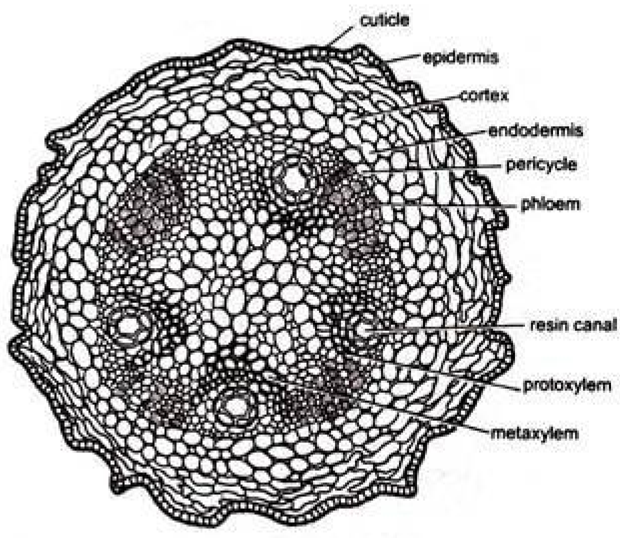

Fig. 29. Pinus. T.S. young root (diagrammatic).

T.S. Old Root Showing Secondary Growth:

1. On the outer side are present a few layers of cork, formed by the meristematic activity of the cork cambium.

2. Cork cambium cuts secondary cortex towards inner side.

3. Many resin canals and stone cells are present in the secondary cortex, the cells of which are separated with the intercellular spaces.

4. Below the phloem patches develop cambium, which cuts secondary phloem towards outer side and secondary xylem towards inner side.

5. Crushed primary phloem is present outside the secondary phloem (Fig. 30

6. Many uniseriate medullary rays are present in the secondary xylem.

7. Primary xylem is the same as in young roots, i.e., each group is bifurcated (Y-shaped) and a resin canal is present in between the bifurcation.

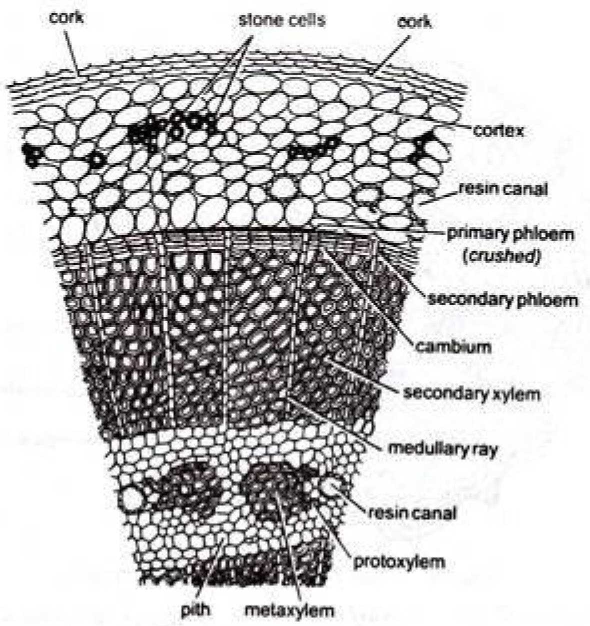

Fig. 30. Pinus. T.S. old root.

T.S. Long Shoot (Young):

1. Many leaf bases are present on the stem (Fig. 31), due to which it appears wavy in outline.

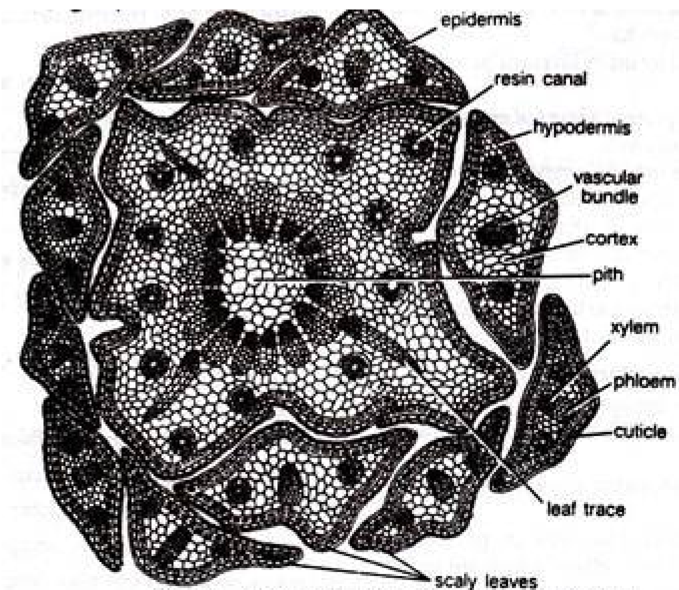

Fig. 31. Pinus roxburghii. T.S. long shoot (young).

2. Outermost single-layered, thick-walled epidermis is heavily cuticularized and followed by multilayered cortex.

3. A few outer layers of cortex are sclerenchymatous, and some inner layers are parenchymatous.

4. In the inner layers of cortex are present many resin canals.

5. The stele is eustelic or polyfascicular endarch siphonostele.

6. Vascular bundles are conjoint, collateral, open and endarch, and resemble greatly with that of a dicot stem. 5-10 vascular bundles are arranged in a ring.

7. Endodermis and pericycle are indistinguishable.

8. Narrow xylem rays connect the cortex and pith.

9. Endarch xylem consists of only tracheids.

10. Phloem is present on the ventral side and consists of sieve cells, sieve plates, phloem parenchyma and some albuminous cells.

11. Intrafascicular cambium is present in between the xylem and phloem.

12. Many leaf traces are also present.

13. A small parenchymatous pith is present in the centre of stem.

T.S. Long Shoot (Old):

1. Secondary growth, similar to that of a dicotyledonous stem, is present in the old stem of Pinus.

2. Cork cambium cuts cork towards outer side and a few layers of secondary cortex towards inner side.

3. Many tannin-filled cells and resin canals are distributed in the primary cortex.

4. Cambium cuts secondary phloem towards outer side and secondary xylem towards inner side (Fig. 32).

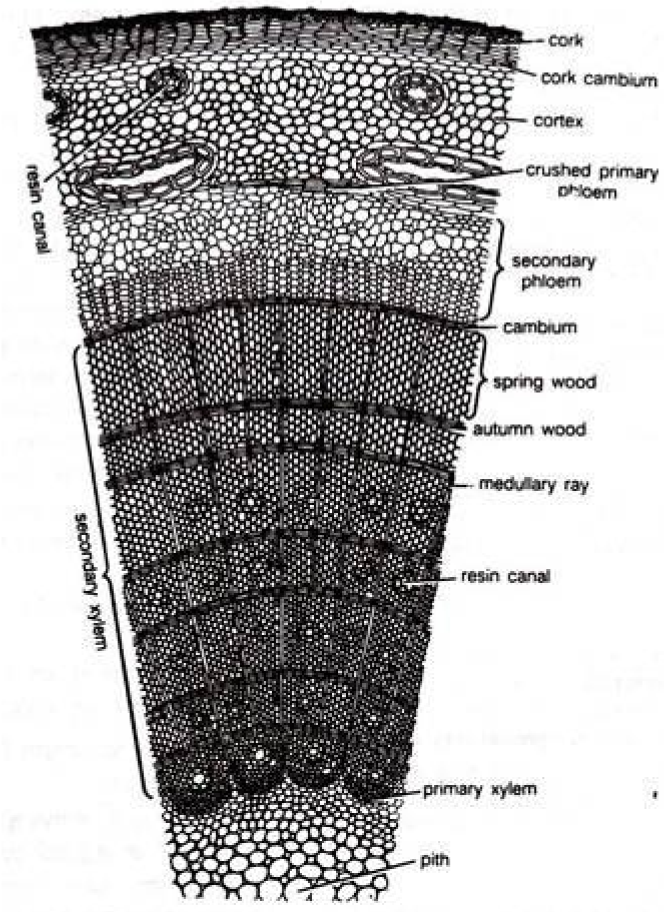

Fig. 32. Pinus. T.S. of a two-year old long shoot.

5. Primary phloem is crushed and pushed towards outer side by the secondary phloem.

6. In the secondary xylem, annual rings of thin-walled spring wood (formed in spring season) and thick- walled autumn wood (formed in autumn season) are present alternately. Such a compact wood is called pycnoxylic (Age of the plant can be calculated by counting the number of these annual rings).

7. Below the secondary xylem are present a few groups of endarch primary xylem.

8. Some of the medullary rays connect the pith with the cortex and called primary medullary rays while the others run in between secondary xylem and secondary phloem and called secondary medullary rays.

9. Central part of the stem is filled with the parenchymatous pith.

10. Resin canals are present in cortex, secondary xylem, primary xylem and rarely in the pith.

Tangential Longitudinal Section (T.L.S.) of Wood:

In T.L.S. the longitudinal section is cut along the tangent of the wood.

Following structures are visible:

1. Bordered pits and medullary rays are present in sectional view.

2. Each border pit is enclosed by a pit chamber bounded by a pit membrane and contains a centrally located swollen torus (Fig. 33).

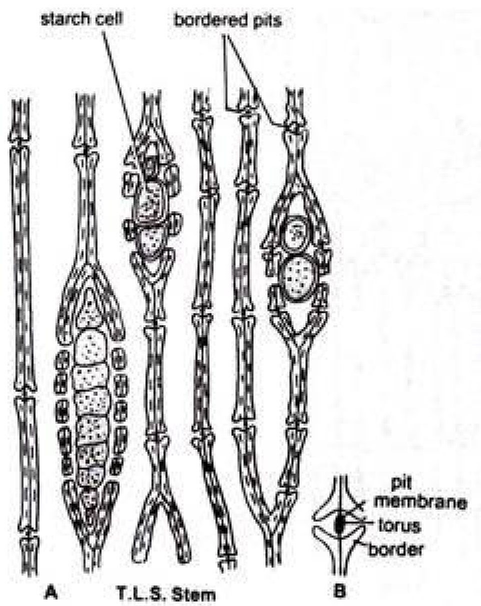

Fig. 33. Pinus. A, T.L.S. wood (a part); B, A magnified bordered pit.

3. Tracheids are composed of rectangular cells. Middle lamella is very clear.

4. Many uniseriate medullary rays are present.

5. In the xylem region medullary rays contain a centrally located starch cell surrounded by tracheidial cells.

6. Albuminous cells are also present in medullary rays in phloem region.

7. Pith is absent.

Radial Longitudinal Section (R.L.S.) of Wood:

In R.L.S., the stem is cut along the radius, and so the pith is also visible.

Following other details are visible:

1. It is bounded externally by cork, cork cambium, secondary phloem and crushed primary phloem.

2. Bordered pits surrounded by bars of Sanio in tracheids are seen in surface view.

3. Uniseriate medullary rays run horizontally.

4. In the xylem region thick medullary ray cells are surrounded by ray tracheids (Fig. 34).

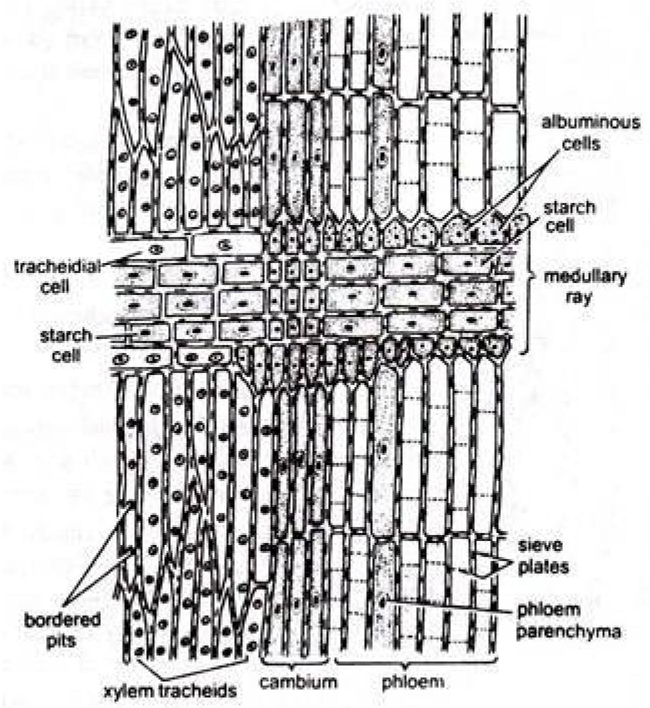

Fig. 34. Pinus. R.L.S. Stem.

5. Thin-walled ray parenchyma is also present.

6. Xylem is separated from phloem with the help of cambium.

7. Albuminous cells are present in medullary ray in the phloem region.

8. Phloem consists of sieve tubes, sieve plates and phloem parenchyma.

9. Pith is present.

T.S. Dwarf Shoot (Young):

It is exactly similar to that of T.S. of young long shoot except following differences:

1. The number of the resin canals present in the cortex is not indefinite but generally six (Fig. 35).

Though it is variable in different species.

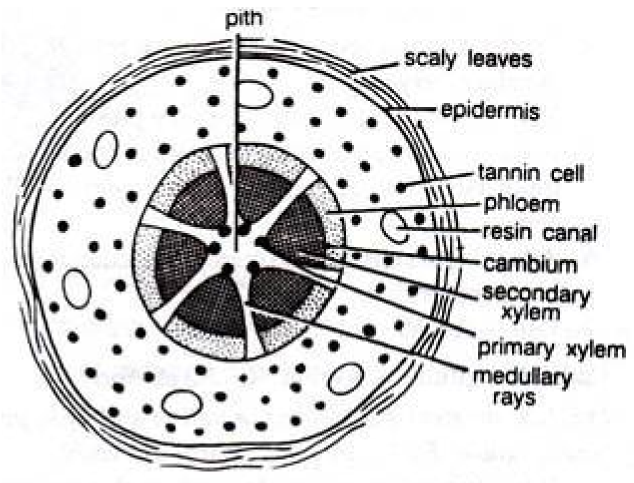

Fig. 35. Pinus. T.S. dwarf shoot.

2. The number of the vascular bundles is also generally six. However, it is also variable in different species.

3. Pith in dwarf shoot is comparatively smaller than the long shoot.

4. Structure of the vascular bundles is same, i.e., conjoint, collateral, open and endarch.

T.S. Dwarf Shoot (Old):

1. It is also similar to old long shoot in many aspects.

2. Cork, cork cambium and secondary cortex are not normally present, but the epidermis surrounded externally by scaly leaves and followed internally by multilayered cortex is present.

3. Inner to the cortex is crushed primary phloem, secondary phloem, cambium and secondary xylem with medullary rays (Fig. 36). Protoxylem is endarch.

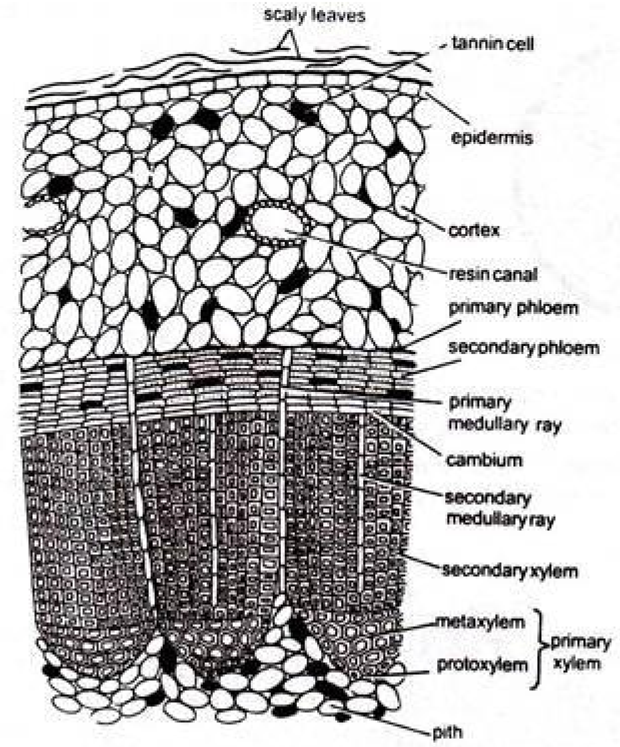

Fig. 36. *Pinus. T.S. old dwarf shoot (a part cellular).*

4. A small pith with some tannin cells is present in the centre.

If a section of distal end of dwarf shoot is cut, the needles get separated, each having the same structure. In a bifoliar spur two needles are present while in a trifoliar spur there are present three foliage leaves or needles (Fig. 37).

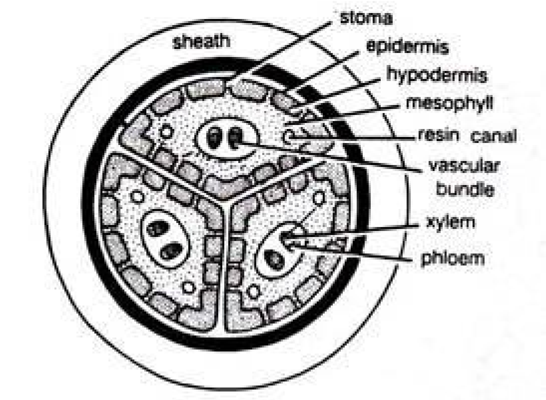

Fig. 37. *Pinus. T.S. upper part of dwarf shoot showing the formation of three needles in a trifoliar spur.*

T.S. Needle (Foliage Leaf):

1. It is circular in outline in Pinus monophylla, semicircular in P. sylvestris and triangular (Fig. 38) in P. longifolia, P. roxburghii, etc.

2. Outermost layer is epidermis, which consists of thick-walled cells. It is covered by a very strong cuticle.

3. Many sunken stomata are present on the epidermis (Fig. 38).

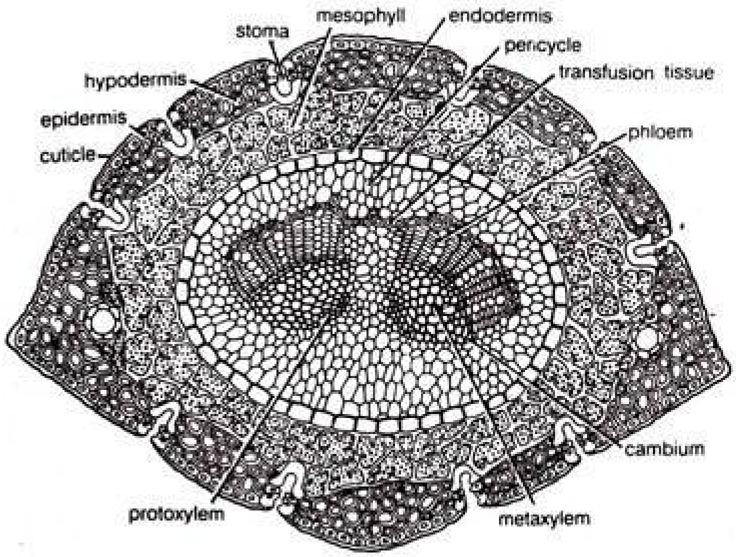

Fig. 38. Pinus. T.S. needle.

4. Each stoma opens internally into a substomatal cavity and externally into a respiratory cavity or vestibule.

5. Below the epidermis are present a few layers of thick-walled sclerenchymatous hypodermis. It is well-developed at ridges.

6. In between the hypodermis and endodermis is present the mesophyll tissue.

7. Cells of the mesophyll are polygonal and filled with chloroplasts. Many peg-like infoldings of cellulose also arise from the inner side of the wall of mesophyll cells.

8. Few resin canals are present in the mesophyll, adjoining the hypodermis. Their number is variable but generally they are two in number.

9. Endodermis is single-layered with barrel-shaped cells and clear casparian strips.

10. Pericycle is multilayered and consists of mainly parenchymatous cells and some sclerenchymatous cells forming T-shaped girder, which separates two vascular bundles (Fig. 38). Transfusion tissue consists of tracheidial cells.

11. Two conjoint and collateral vascular bundles are present in the centre. These are closed but cambium may also present in the sections passing through the base of the needle.

12. Xylem lies towards the angular side and the phloem towards the convex side of the needle.

Reproductive Structures of Pinus:

1. Plant body is sporophytic.

2. Pinus is monoecious, and male and female flowers are present in the form of cones or strobili on the separate branches of the same plant.

3. Many male cones are present together in the form of clusters, each of which consists of many microsporophylls. The female cones consist of megasporophylls.

4. The male cones on the plant develop much earlier than the female cones.

Male Cone:

Separate a male cone from the cluster, study its structure, cut its longitudinal section, study the structure of a single microsporophyll, and also prepare a slide of pollen grains and study.

1. The male cones develop in clusters (Fig. 39) in the axil of scaly leaves on long shoot.

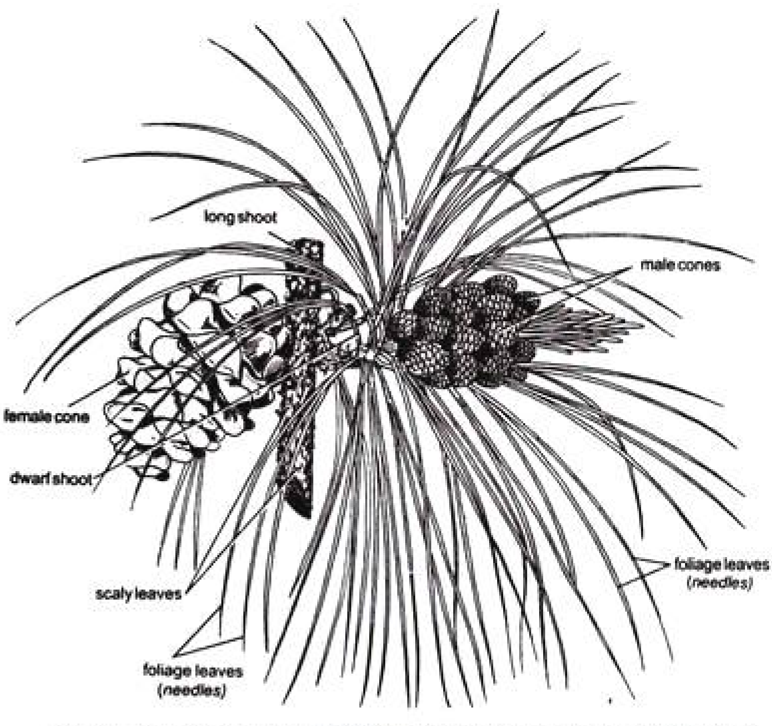

Fig. 39. Pinus. A long shoot bearing cluster of male cones and a mature female cone.

2. They replace the dwarf shoots of the long shoot.

3. Each male cone is ovoid in shape and ranges from 1.5 to 2.5 cm. in length (Fig. 40).

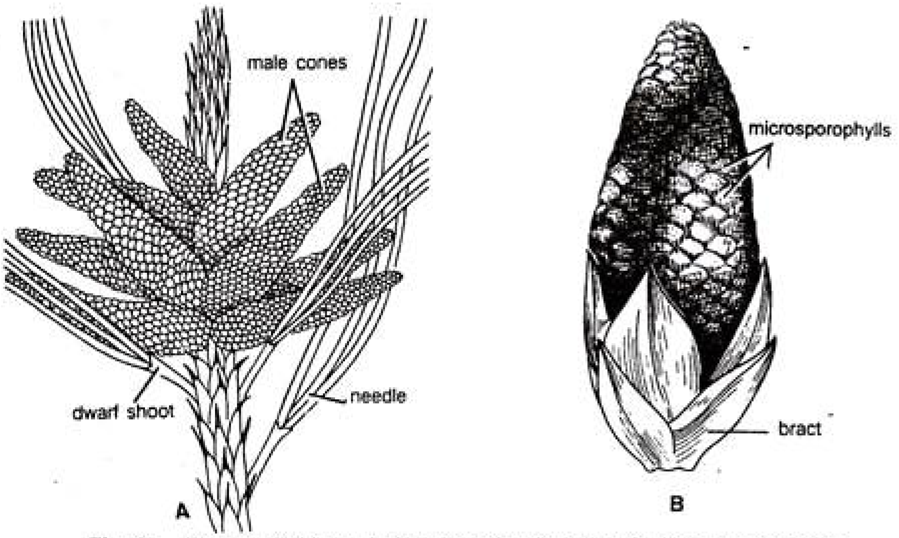

Fig. 40. *Pinus wallichiana. A, A cluster of male cones; B, A single male cone.*

4. A male cone (Fig. 41) consists of a large number of microsporophylls arranged spirally on the cone axis.

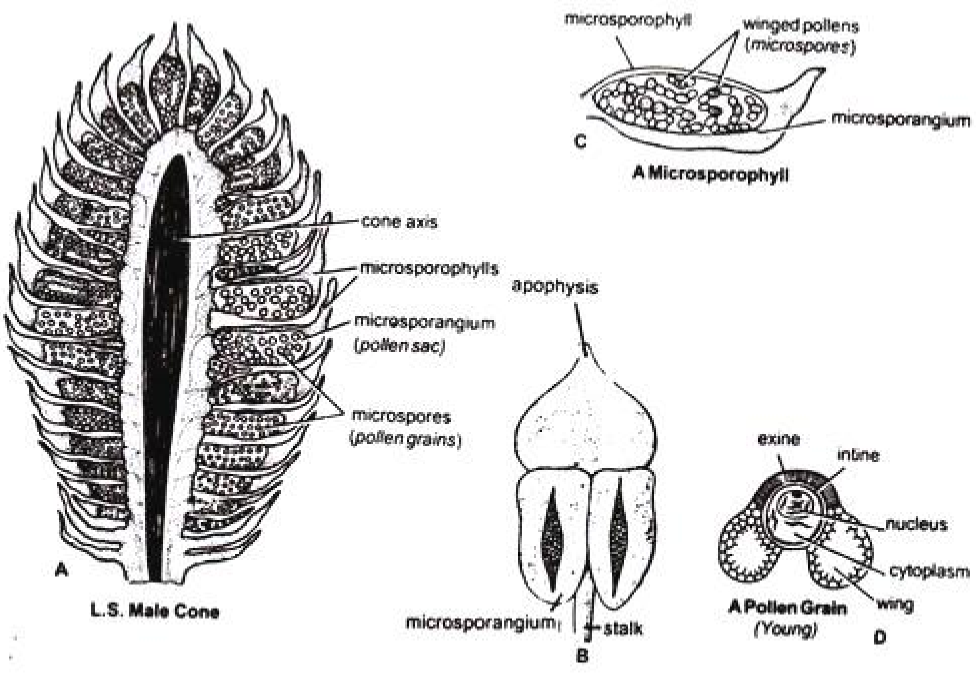

Fig. 41. *Pinus. A, L.S. male cone; B, A single microsporophyll with microsporangia in surface view; C, A microsporophyll; D, A young pollen grain.*

5. Each microsporophyll is small, membranous, brown-coloured structure.

6. A microsporophyll (Fig. 41) is comparable with the stamen of the flower of angiosperms because it consists of a stalk (=filament) with a terminal leafy expansion (= anther), the tip of which is projected upwards and called apophysis.

7. Two pouch-like microsporangia (= pollen sacs) are present on the abaxial or undersurface of each microsporophyll. In each microsporangium are present many microspores (= pollen grains).

8. Each microspore or pollen grain is a rounded and yellow-coloured, light, uninucleate structure with two outer coverings, i.e., thick outer exine and thin inner intine (Fig. 42).

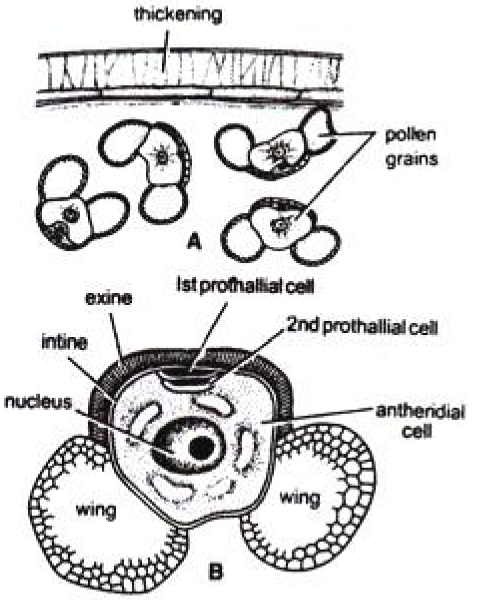

Fig. 42. Pinus. A few pollen grains and a mature winged pollen grain.

9. The exine protrudes out on two sides in the form of two balloon-shaped wings. Wings help in floating and dispersal of pollen grains.

10. Wings help in floating and dispersal of pollen grains.

11. A few microsporophylls of lower side of cone are sterile. Sporangia are also not present on the adaxial surface of each microsporophyll of the male cone.

Female cone:

Observe the external features and longitudinal section of a young female cone and also study 1st year, 2nd year and 3rd year female cones.

1. Female cone develops either solitary or in groups of 2 to 4.

2. They also develop in the axil of scaly leaves on long shoots (Fig. 43) like male cones.

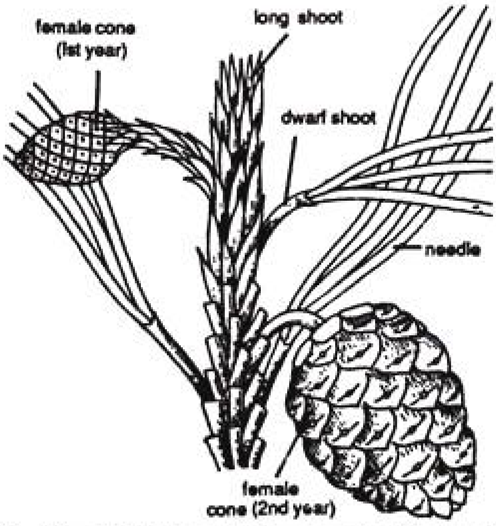

Fig. 43. Pinus. A fertile long shoot bearing 1st and 2nd year female cones.

3. Each female cone is an ovoid, structure when young but becomes elongated or cylindrical at maturity.

L.S. Female Cone:

1. In the centre is present a cone axis (Fig. 44).

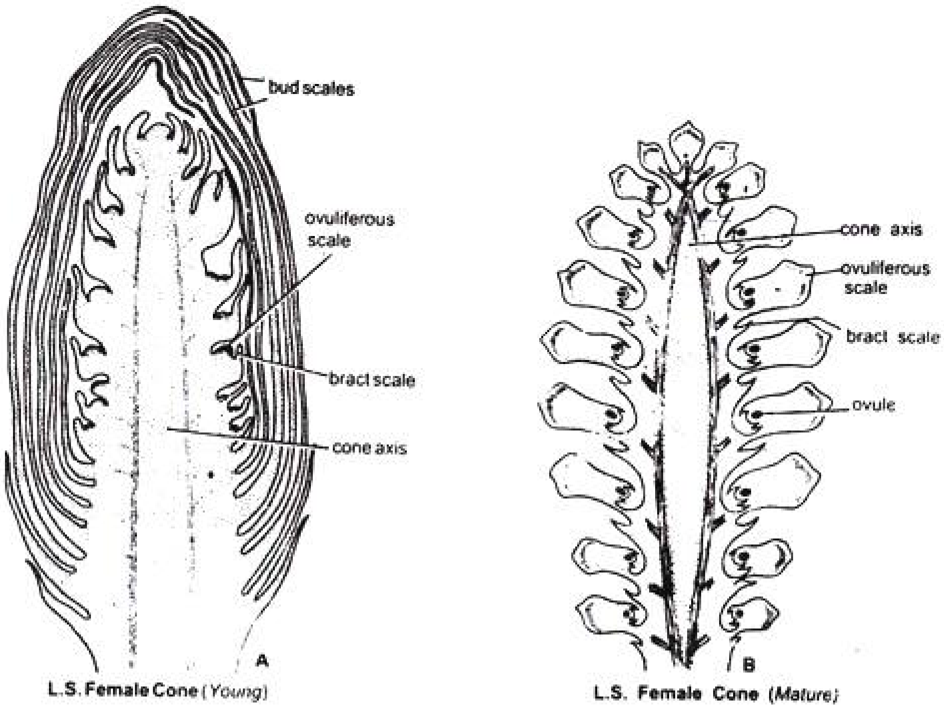

Fig. 44. Pinus. A, L.S. female cone (young); B, L.S. female cone (old).

2. Many megasporophylls are arranged spirally on the cone axis.

3. A few megasporophylls, present at the base and at the apex of strobilus, are sterile.

4. Megasporophylls present in the middle of the strobilus are very large and they decrease in size towards the base and apex.

5. Each megasporophyll consists of two types of scales, known as bract scales and ovuliferous scales.

6. Bract scales are thin, dry, membranous, brown- coloured structures having fringed upper part. These are also called carpellary scales.

7. An ovuliferous scale is present on the upper surface of each bract scale.

8. Each oruliferous scale is woody, bigger and stouter than bract scale and it is triangular in shape. A broad sterile structure, with pointed tip, is present at the apex of these scales. This is called apophysis.

9. At the base of upper surface of each ovuliferous scale are present two sessile and naked ovules.

10. Micropyle of each ovule faces towards the cone axis.

11. Each ovule is orthotropous, and it remains surrounded by a single integument, consisting of an outer fleshy, a middle stony and an inner fleshy layer. It opens with a mouth opening called micropyle.

12. Integument surrounds the megasporangium or nucellus.

13. Just opposite the micropyle is present a pollen chamber.

14. In the endosperm or female gametophyte are present 2 to 5 archegonia.

Female Cone of 1st Year:

1. It is oval (Fig. 45) in shape.

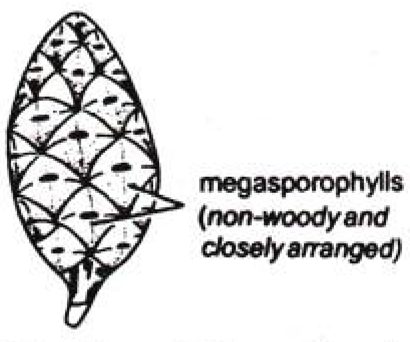

Fig. 45. Pinus. A 1st year female cone.

2. It ranges from 1 to 4 cm. in length.

3. It is green to reddish-green in colour.

4. It is attached with the help of a short stalk on the long shoot.

5. Megasporophylls are arranged very close to each other, and so the cone is a compact structure.

Female Cone of 2nd Year:

1. It is elongated and larger than the first year cone.

2. It ranges from 5 to 15 cm. or more in length.

3. It is red-coloured structure.

4. It is woody in nature.

5. Megasporophylls are compactly arranged (Fig. 46) but not so compact as in 1st year cone.

6. Seeds are present inside in the later stages (Fig. 46).

Fig. 46. Pinus. A 2nd year female cone.

Female Cone of 3rd Year:

1. It is elongated or roughly rounded in shape.

2. It is also woody in nature like the 2nd year cone.

3. Megasporophylls (Fig. 47) are loosely arranged.

4. Seeds are dispersed from 3rd year cone.

Fig. 47. Pinus. A 3rd year female cone.

Seed:

1. Both the ovules of each ovuliferous scale develop into seeds (Fig. 48).

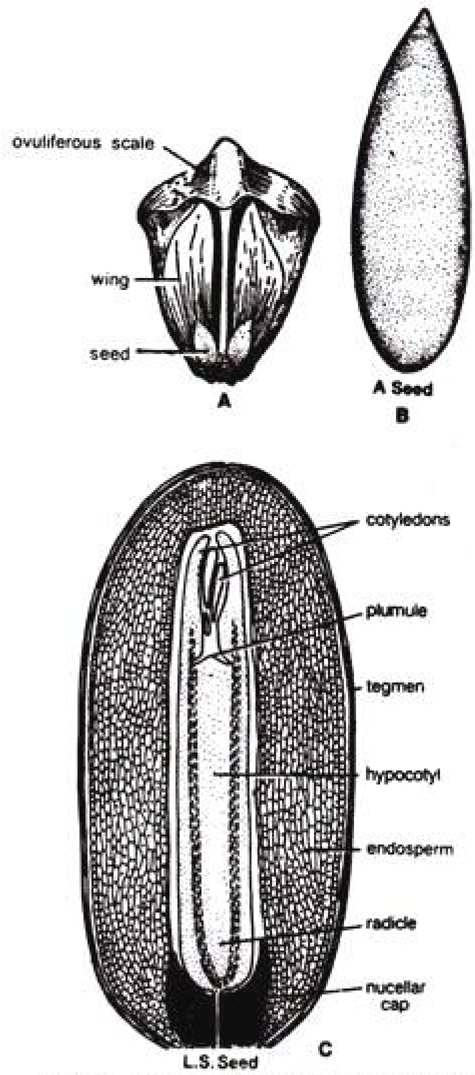

Fig. 48. Pinus. A, An ovuliferous scale bearing two winged seeds; B, A single seed; C, L.S. seed.

2. Each seed contains a large membranous wing formed from the ovuliferous scale.

Anatomy of seed shows following (Fig. 48C) details:

1. It is enveloped by a seed coat developed from the middle stony layer of the ovule.

2. Inner fleshy layer may survive in the form a thin membrane. Outer fleshy layer disappears.

3. A thin, membranous and papery structure, called perisperm, develops inner to the seed coat.

4. Well-developed endosperm is present.

5. In the centre is present the embryo consisting of a hypocotyle, radicle, plumule and 2 to 14 or more cotyledons.

Identification:

(i) Sporophytic plant body differentiated into roots, stem and leaves.

(ii) Ovules naked.

(iii) Xylem lacks vessels.

(iv) Phloem lacks companion cells.

(v) Sex organs are present in the form of cones…………. Gymnosperms

(b)(i) Leaves needle shaped.

(ii) Pycnoxylic wood.

(iii) Seeds show bilateral symmetry.

(iv) Male cones in clusters ………………. Coniferopsida

(c) (i) Presence of scaly and foliage leaves.

(ii) Foliage leaves are needle like.

(iii) Wood pycnoxylic and xylem contains bordered pits.

(iv) Pollen grains are winged.

(v) Resin canals present……………. coniferales

(d)(i) Plant is monoecious.

Gnetum: Distribution, Habitat and Relationships

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1. Distribution of Gnetum:

Gnetum, represented by about 40 species is confined to the tropical and humid regions of the world. Nearly all species, except G. microcarpum, occur below an altitude of 1500 metres. Five species (Gnetum contractum, G. gnemon, G. montanum, G. ula and G. latifolium) have been reported from India . Gnetum ula is the most commonly occurring species of India.

Gnetum ula:

It is a woody climber having branches with swollen nodes. It is found in Western Ghats near Khandala, forests of Kerala, Nilgiris, Godawari district of Andhra Pradesh and Orissa.

Gnetum contractum:

A scandent shrub growing in Kerala, Nilgiri Hills and Coonoor in Tamil Nadu.

Gnetum gnemon:

A shrubby plant found in Assam (Naga-Hills, Golaghat and Sibsagar).

Gnetum montanum:

A climber with smooth, slender branches, swollen at the nodes. It is found in Assam, Sikkim and parts of Orissa.

Gnetum latifolium:

A climber found in Andaman and Nicobar Islands.

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2. Habit of Gnetum:

Majority of the Gnetum species are climbers except a few shrubs and trees. G. trinerve is apparently parasitic. Two types of branches are present on the main stem of the plant, i.e. branches of limited growth and branches of unlimited growth. Each branch contains nodes and intemodes Stem of several species of Gnetum is articulated

In climbing species the branches of limited growth or short shoots are generally un-branched and bear the foliage leaves. The leaves (9-10) are arranged in decussate pairs (Fig. 13.2). They often lie in one plane giving the appearance of a pinnate leaf to the branch. The leaves are large and oval with entire margin and reticulate venation as also seen in dicotyledons. Some scaly leaves are also present.

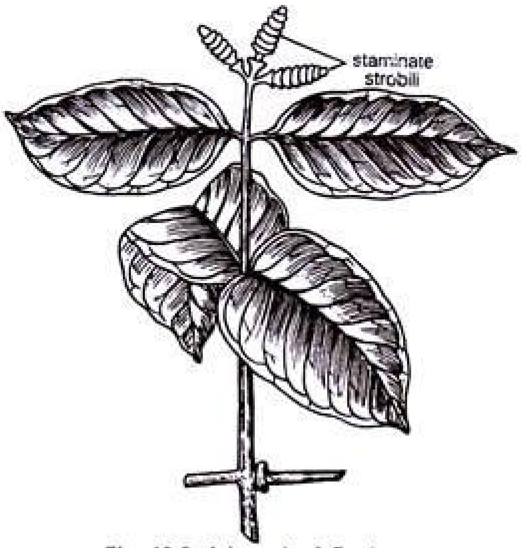

Fig. 13.2. A branch of *Gnetum*.

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3. Anatomy of Gnetum:

(i) Root:

Young root (Fig. 13.3) has several layers of starch-filled parenchymatous cortex, the cells of which are large and polygonal in outline. An endodermal layer is distinguishable. Casparian strips are seen in the cells of the endodermis. The endodermis follows 4-6 layered pericycle. Roots are diarch and exarch. Small amount of primary xylem, visible in young roots, becomes indistinguishable after secondary growth.

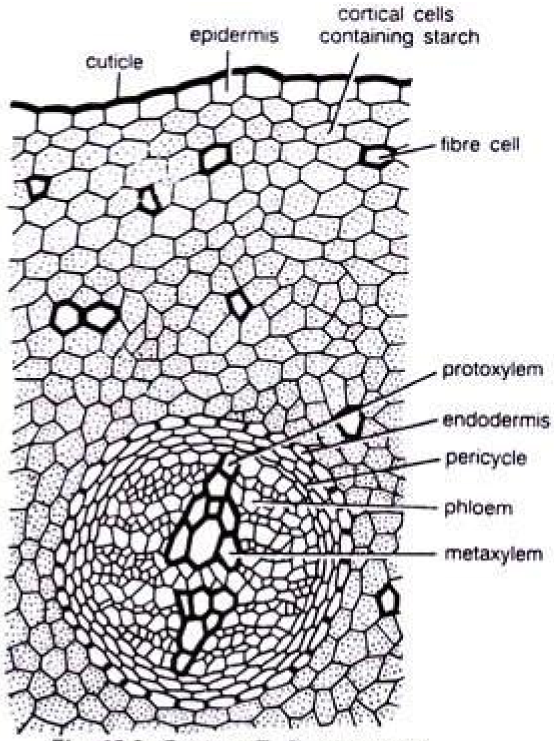

Fig. 13.3. *Gnetum.* T. S. young root.

The secondary growth is of normal type. A continuous zone of wood is present in the old roots (Fig. 13.4). It consists of tracheids, vessels and xylem parenchyma. The tracheids have uniseriate bordered pits along with bars of Sanio.

Vessels have simple or small multiseriate bordered pits. Some of the xylem elements have starch grains. Bars of Sanio are generally absent in the vessels. Phloem consists of sieve cells and phloem parenchyma.

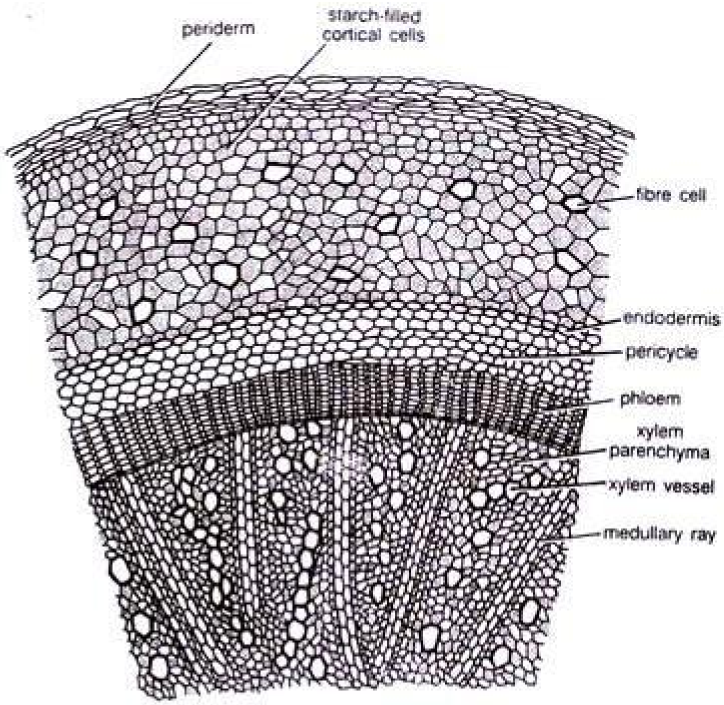

Fig. 13.4. *Gnetum*. T. S. old root showing secondary growth.

(ii) Young Stem:

The young stem in transverse section is roughly circular in outline, and resembles with a typical dicotyledonous stem. It remains surrounded by a single-layered epidermis, which is thickly circularized and consists of rectangular cells. Some of the epidermal cells show papillate outgrowths. Sunken stomata are present.

The cortex consists of outer 5-7 cells thick chlorenchymatous region, middle few-cells thick parenchymatous region and inner 2-4 cells thick sclerenchymatous region. Endodermis and pericycle regions are not very clearly distinguishable. Several conjoint, collateral, open and endarch vascular bundles are arranged in a ring (Fig. 13.5) in the young stem.

Xylem consists of tracheitis and vessels. Presence of vessels is an angiospermic character. Protoxylem elements are spiral or annular while the metaxylem shows bordered pits which are circular in outline. The phloem consists of sieve cells and phloem parenchyma.

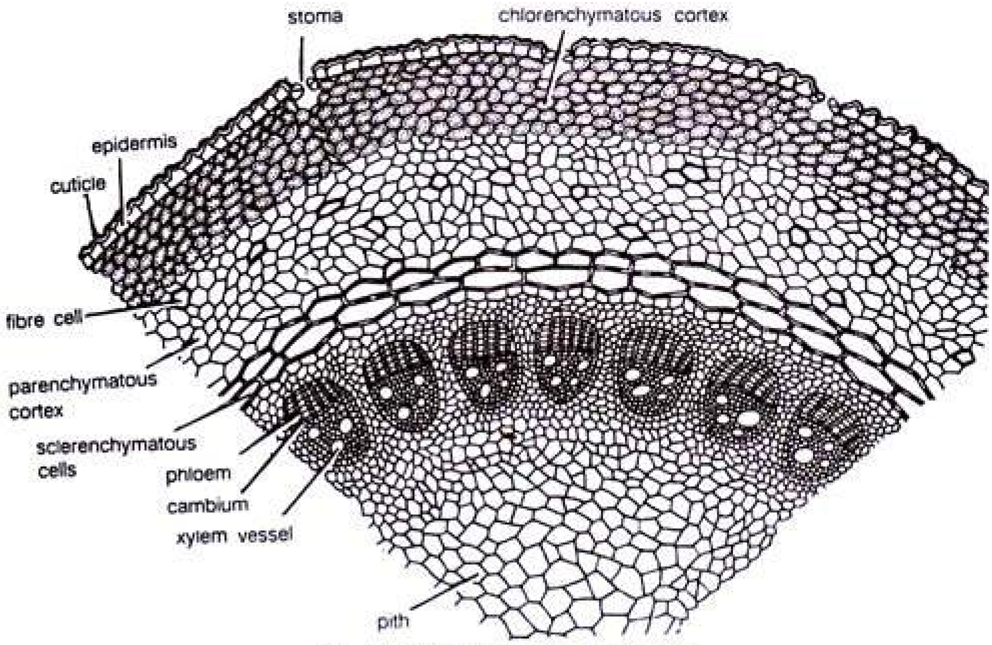

Fig. 13.5. Gnetum. T. S. young stem.

An extensive pith, consisting of polygonal, parenchymatous cells, is present in the centre of the young stem.

(iii) Old Stem

Old stems in Gnetum show secondary growth. In G. gnemon the secondary growth is normal, as seen also in the dicotyledons. But in majority of the species (e.g., G. ula, G. africanum, etc.) the anamolous secondary growth is present.

The primary cambium is ephemeral, i.e., short-lived. The secondary cambium in different parts of cortex develops in the form of successive rings, one after the other (Fig. 13.6). The first cambium cuts off secondary xylem towards inside and secondary phloem towards outside. This cambium ceases to function after some time.

Another cambium gets differentiated along the outermost secondary phloem region, and the same process is repeated. In the later stages, more secondary xylem is produced on one side and less on the other side, and thus the eccentric rings of xylem and phloem are formed in the wood. :

This type of eccentric wood is the characteristic feature of angiospermic lianes. The periderm is thin and develops from the outer cortex. It also possesses lenticels. The cortex also contains chlorenchvmatous and parenchymatous tissues along with many sclereids.

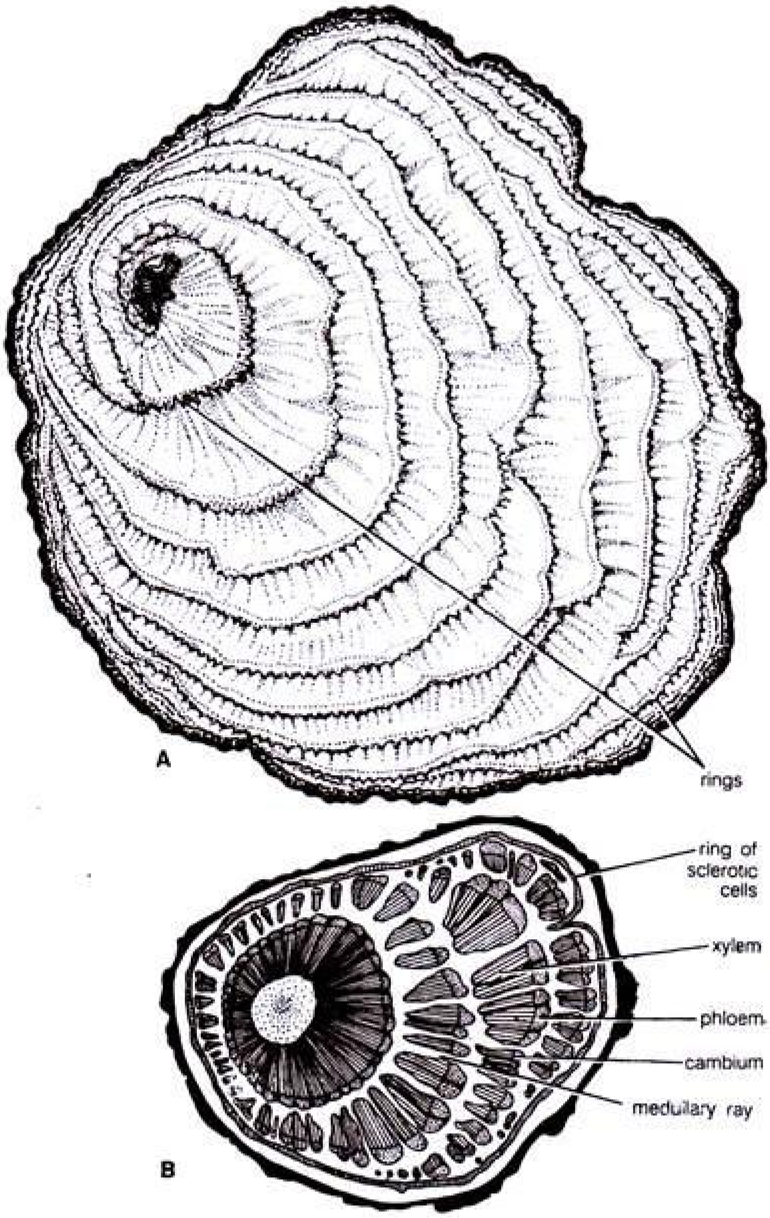

Fig. 13.6. *Gnetum ula.* T.S. old stem showing number of rings formed because of the anomalous secondary growth. (modified after Maheshwari and Vasil, 1961).

In old stems the secondary wood consists of tracheids and vessels. Tracheids contain bordered pits on their radial walls while vessels contain simple pits. Transitional stages (Fig. 13.7), containing one to many perforations in the terminal part of the vessels, are also seen commonly.

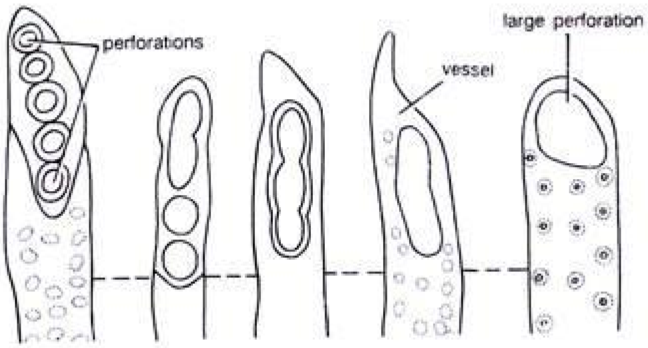

Fig. 13.7. *Gnetum africanum*. Perforation in the end walls of the vessels. (after Duthie, 1912).

In tangential longitudinal section (T.L.S) of the stem (Fig. 13.8), the wood xylem and medullary rays are visible. Bordered pits on both the radial and tangential walls are present. Medullary rays are either uniseriate or multiseriate and consist of polygonal parenchymatous cells. They are boat-shaped (Fig. 13.8) and their breadth varies from 2 to many cells. Sieve cells of the phloem contain oblique and perforated sieve plates.

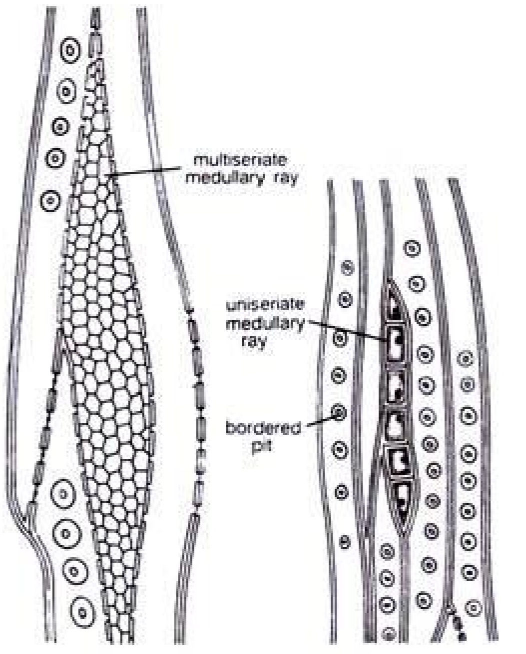

Fig. 13.8. *Gnetum gnemon*. T.L.S. stem. A, Showing multiseriate medullary ray; B, Showing uniseriate medullary ray.

(iv) Leaf:

Internally, Gnetum leaves also resemble with a dicot leaf. It is bounded by a layer of thickly circularized epidermis on both the surfaces. Stomata are distributed all over the lower surface except on the veins. The mesophyll is differentiated generally into a single-layered palisade and a well-developed spongy parenchyma.

The latter consists of many loosely-packed cells. Many stellately branched sclereids are present near the lower epidermis in the spongy parenchyma. Many stone cells and latex tubes are present in the midrib region of the leaf.

Several vascular bundles in the form of an arch or curve are present in the prominent midrib region (Fig. 13.9). A ring of thick-walled stone cells is present just outside the phloem. Each vascular bundle is conjoint and collateral.

The xylem of each vascular bundle faces towards the upper surface while the phloem faces towards the lower surface. The xylem consists of tracheids, vessels and xylem parenchyma while the phloem consists of sieve cells and phloem parenchyma.

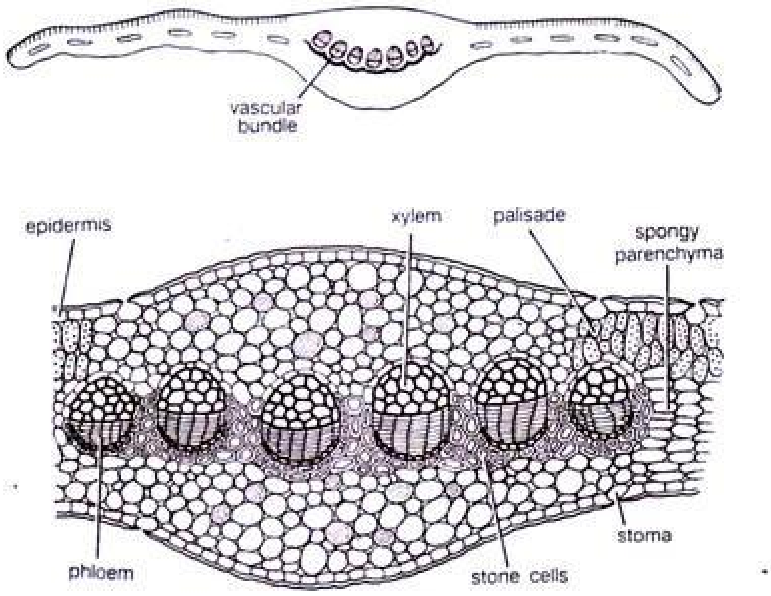

Fig. 13.9. *Gnetum.* Upper-T.S. leaf (diagrammatic) ; Lower-T.S. leaf (a part cellular).

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4. Reproduction of Gnetum:

Gnetum is dioecious. The reproductive organs are organised into well-developed cones or strobili. These cones are organised into inflorescences, generally of panicle type. Sometimes the cones are terminal in position.

A cone consists of a cone axis, at the base of which are present two opposite and connate bracts. Nodes and internodes are present in the cone axis. Whorls of circular bracts are present on the nodes. These are arranged one above the other to form cupulas or collars (Fig. 13.10). Flowers are present in these collars. Upper few collars may be reduced and are sterile in nature in G. gnemon.

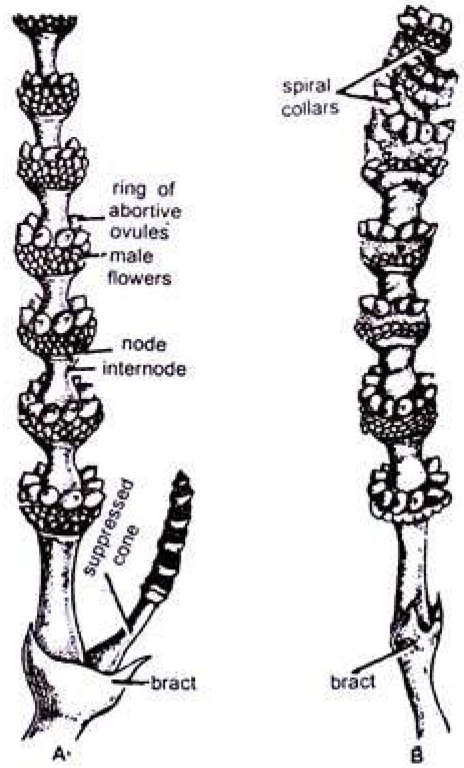

Fig. 13.10. *Gnetum*. A, A branch bearing a panicle of a well-developed male cone and a suppressed cone in *G. ula*; B, An old cone of *G. gnemon* showing spiral collars at the apical end. (Modified after Madhulata, 1960).

Male Cone and Male Flower:

The male flowers are arranged in definite rings above each collar on the nodes of the axis of male cone. The number of rings varies between 3-6. The male flowers in the rings are arranged alternately. There is a ring of abortive ovules or imperfect female flowers above the rings of male flowers.

Each male flower contains two coherent bracts which form the perianth (Fig. 13.11). Two unilocular anthers remain attached on a short stalk enclosed within the perianth. At maturity, when the anthers are ready for dehiscence, the stalk elongates and the anthers come out of the perianth sheath. In Gnetum gnemon a few (2-3) flowers are sometimes seen fusing each other (Fig. 13.12).

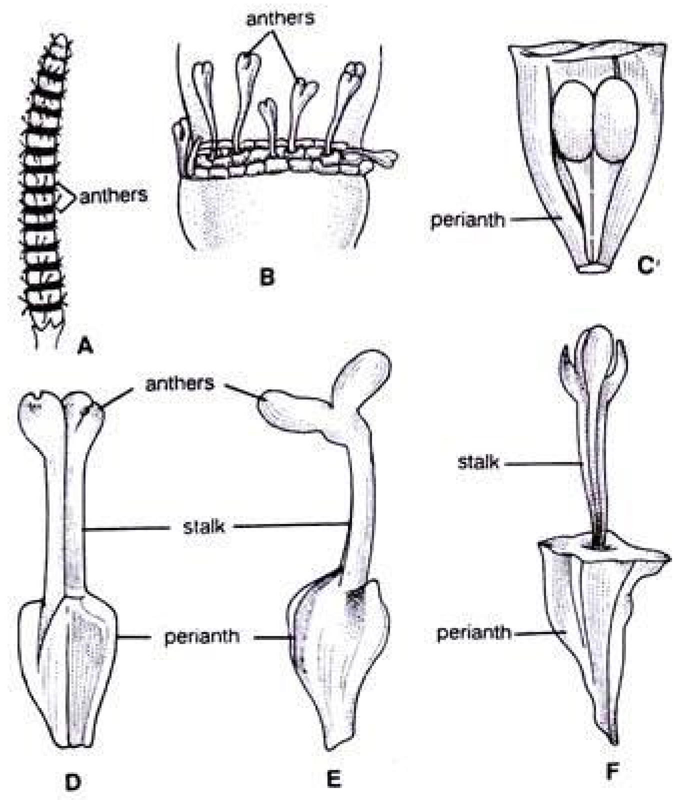

Fig. 13.11. *Gnetum ula.* A, A male cone; B, A part of 'A' showing male flowers; C, L.S. male flower; D-E, Male flowers with anthers emerged out of a perianth; F, A dehisced male flower.

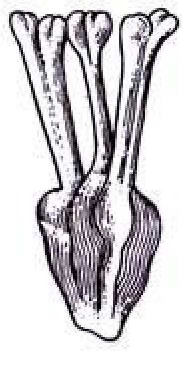

Fig. 13.12. *Gnetum gnemon.* Showing fusion of male flowers. (modified after Madhulata, 1960).

Development of Male Flower (Figs. 13.13, 13.14):

In very young cones, certain cells below each collar become meristematic. They divide repeatedly and form a small hump-like outgrowth. Certain cells on the upper side of this annular outgrowth start to differentiate into the initials of the ovules. They develop into abortive ovules which form the uppermost ring. The cells of the lower side of this annular outgrowth form the primordium of male flower.

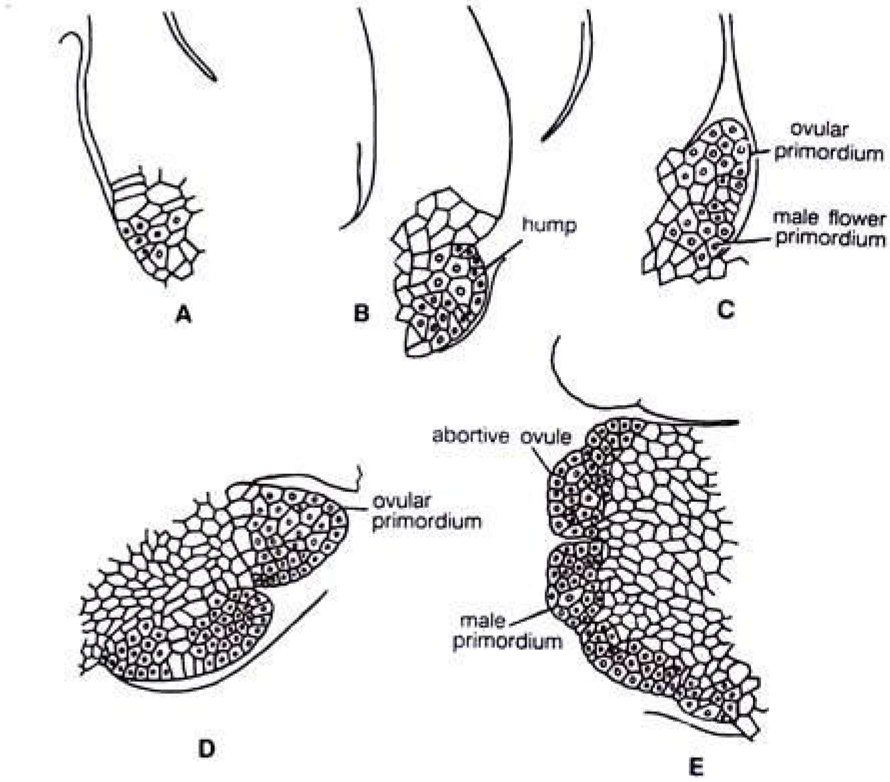

Fig. 13.13. *Gnetum ula*. Development of male flower (modified after Vasil, 1959).

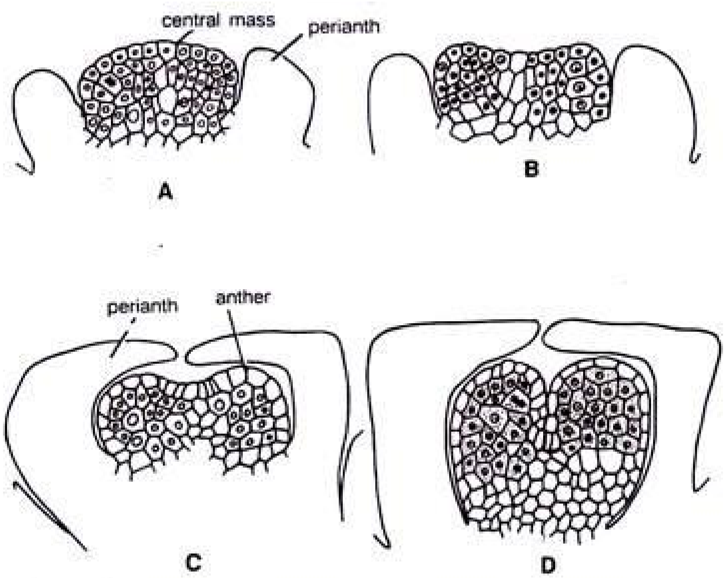

Fig. 13.14. *Gnetum ula*. Further development of male flower (modified after Vasil, 1959).

A central cushion of cells develops by the repeated divisions in the male flower primordium. This cushion gets surrounded by a circular sheath called perianth. The sheath-like perianth encloses the central cushion-like mass only partially. With the development of a depression or notch in the central mass two lobes differentiate and later on develop into two anther lobes.

With the help of many divisions the basal portion of this central mass of cells starts to differentiate into a stalk. This stalk elongates and pushes the anther lobes towards the outer side. Each anther lobe remains surrounded by an epidermal layer and a few wall layers which enclose a microsporangium.The innermost wall layer enclosing the sporogenous tissue is known as tapetum.

The sporogenous cells become loose, contract, round up and change into the spore mother cells. In the process of microspore formation the tapetum and two wall layers are used for the developing microspores. The spore mother cells undergo meiosis and ultimately the spore tetrads are formed.

The characteristic radial thickenings develop in the epidermal cells. They help in the dehiscence of microsporangium. The microspores are ornamented.

Female Cone:

The female cones resemble with the male cones except in some definite aspects. A single ring of 4-10 female flowers or ovules is present just above each collar (Fig. 13.15). Only a few of the ovules develop into mature seeds (Fig. 13.15B).

In the young condition, there is hardly any external difference between female and male cones. All the ovules are of the same size when young but later on a few of them enlarge and develop into mature seeds. All the ovules never mature into seeds.

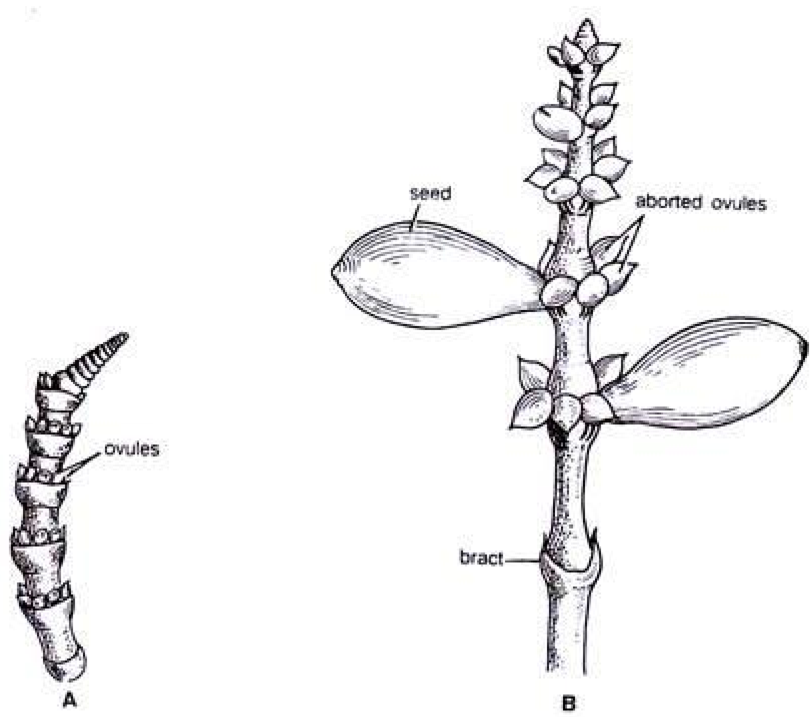

Fig. 13.15. *Gnetum*. A, An old female cone of *G. ula*; B, A female cone of *G. gnemon* bearing two seeds.

Ovule or Female Flower:

Each ovule (Fig. 13 16) consists of a nucellus surrounded of three envelopes. The nucellus consists of central mass of cells. The inner envelope elongates beyond the middle envelope to form the micropylar tube or style. The nucellus contains the female gametophyte. There is no nucellar beak in the ovule of Gnetum.

Stomata, sclereids and laticiferous cells are present in the two outer envelopes. Madhulata (1960) observed the formation of a circular rim from the outer epidermis of the inner integument in G. gnemon. Thoday (1921), however, observed the formation of a second such rim at a higher level. The ovules in G. ula are stalked.

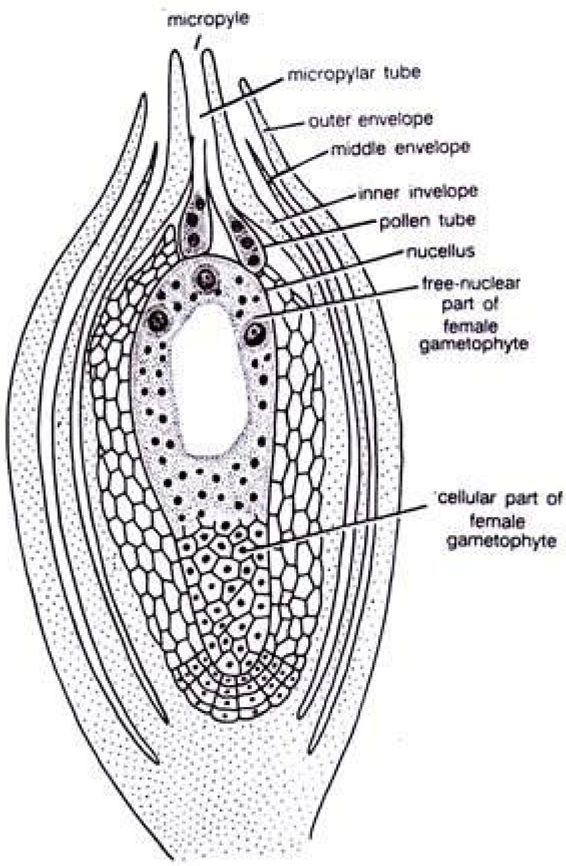

Fig. 13.16. *Gnetum*. L.S ovule.

Abnormal Cones:

More than one rings of ovules in the male cones in Gnetum gnemon have been reported by Thompson (1960) and Madhulata (1960). Collars, arranged spirally in the female cones of G. gnemon and G. ula have been observed by several workers including Maheshwari (1953).

Pearson (1912) reported some cones bearing only two collars in G. buchholzianum. Rarely, the lower collars in the male cones bear one or two fertile ovules whereas normal male flowers are present in the upper collars of the same cone.

Morphological Nature of Three Envelopes:

Several different views have been given by many different workers regarding the morphological nature of the three envelopes surrounding the nucellus.

A few of them are under mentioned:

(i) According to Strasburger (1872) three envelopes of nucellus are integuments developing from the differentiation of single integument.

(ii) Baccari (1877) opined that the outer envelope is a perianth while the inner two envelopes are integuments.

(iii) Van Tieghem (1869) considered the two inner envelopes as the integuments while the outer envelope as an ovary or analogous to it.

(iv) According to Lignier and Tison (1912), however, the outer two envelopes form a perianth while the inner envelope is equivalent to an angiospermic ovary. Vasil (1959) also supported the view of Lignier and Tison (1912) in case of Gnetum ula.

Mega-Sporangium, Mega-Sporogenesis and Female Gametophyte:

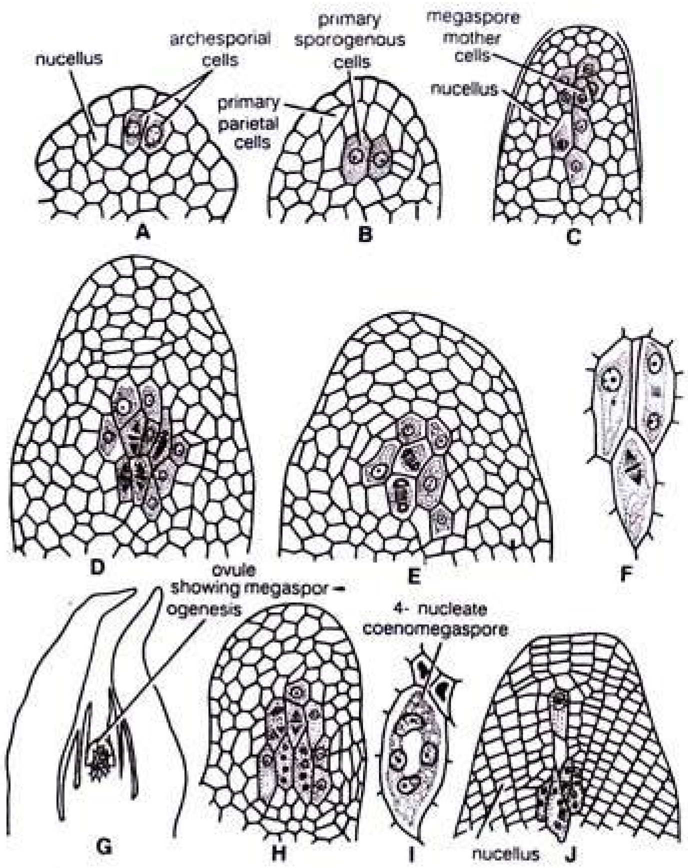

Fig. 13.17. *Gnetum*. Showing stages of megasporogenesis in different species. (A, C, D & E, in *Gnetum ula*; B, F to J in *G.gnemon*).

Four to ten ovular primordia differentiate on the annular meristematic ring. This ring develops below each collar of the female cone in the same manner as that of the male cone. The ovular primordium divides and re-divides several times to form a mass of cells.

All the three envelopes of the female flower develop around this mass of cells The innermost third envelope remains fused with the nucellus at the base while its upper portion remains free and form the long micropylar tube or **'style'.**

In the young conditions, an outer epidermal layer is distinguishable in the nucellus. Two to four archesporial cells develop below the epidermis at a later stage. The archesporial cells divide periclinally to form outer primary' parietal cells and inner sporogenous cells. The primary parietal cells and the epidermal layer divide periclinally and anticlinally several times resulting into a massive nucellus.

The sporogenous cells divide and re-divide to form megaspore mother cells which remain arranged in linear rows. All the megaspore mother cells may divide reductionally and form tetrasporic embryo-sacs but ultimately all, except one, degenerate.

As many as 256 (Gnetum gnemon) to 1500 (G. ula) free-nuclei are formed in the female gametophyte leaving a vacuole in the centre (Fig. 13.18). The female gametophyte is tetrasporic in development. It is broader towards the micropylar end and it tapers towards the chalazal end.

The nuclei near the chalazal end get surrounded by cell walls while those towards micropylar end remain free. Gametophyte is thus partly cellular and partly-nuclear. The archegonia are absent in Gnetum.

Certain nuclei near the micropylar end start to function as egg nuclei. According to Swamy (1973) the only nucleus in a uninucleate cell or one of the nuclei in a multinucleate cell enlarges and functions as the egg in G. ula. The nucellar beak is absent in Gnetum.

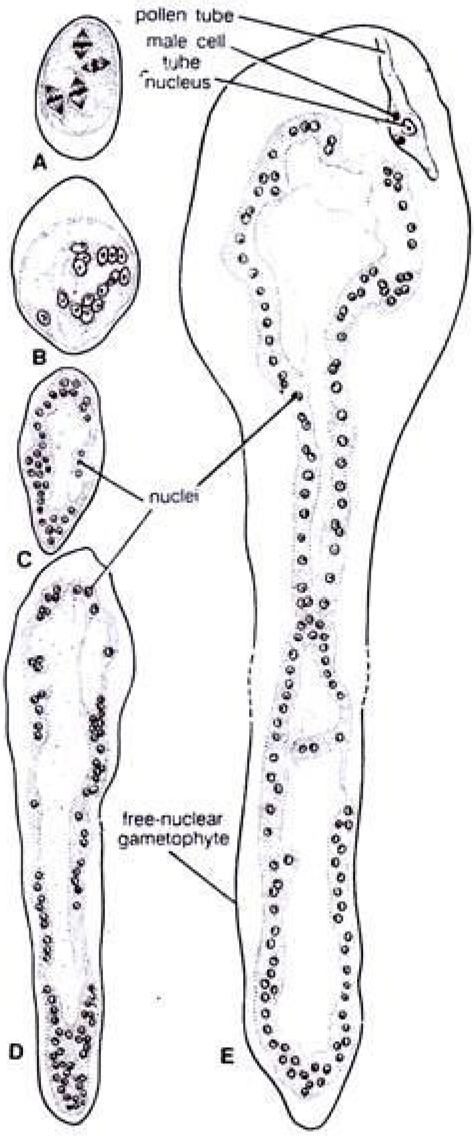

Fig. 13.18. Development of female gametophyte in *Gnetum ula* (modified after Vasil, 1959).

The megaspore mother cell divides reductionally and forms four free haploid nuclei in the mother cell. Megaspore tetrads are never formed in Gnetum.

Microsporangium and Micro-Sporogenesis:

Development of the microsporangium (Fig. 13.19) can be studied only in young anthers. Two archesporial cells are distinguished below the epidermal layer (Fig. 13.19A). Archesporial cells divide and re-divide to form many-celled archesporium (Fig. 13.19B). The outermost layer of the archesporium divide periclinally to form an outer layer of parietal cells and inner layers of sporogenous cells (Fig. 13 .19C).

The parietal cells form the wall layers and tapetal layer by periclinal divisions (Fig. 13.19D). The sporogenous cells develop into microspore mother cells by some irregular divisions. Tapetal cells later on become bi-nucleate (Fig. 13.19D, E). Microspore mother cells divide reductionally to form haploid microspores.

The microspores may be arranged in isobilateral, decussate or tetrahedral manner in their earlier stages. Side by side the wall cells and the tapetal cells degenerate and ultimately dis-organise. The epidermal cells become thick, cutinized and radially elongated.

Many fibrous thickenings also develop in these cells (Fig. 13.19H). Small globular structures are present on the inner surface of the epidermis in Gnetum ula and G. gnemon. Anthers dehisce along a double row of small cells which extends from the tip towards the base.

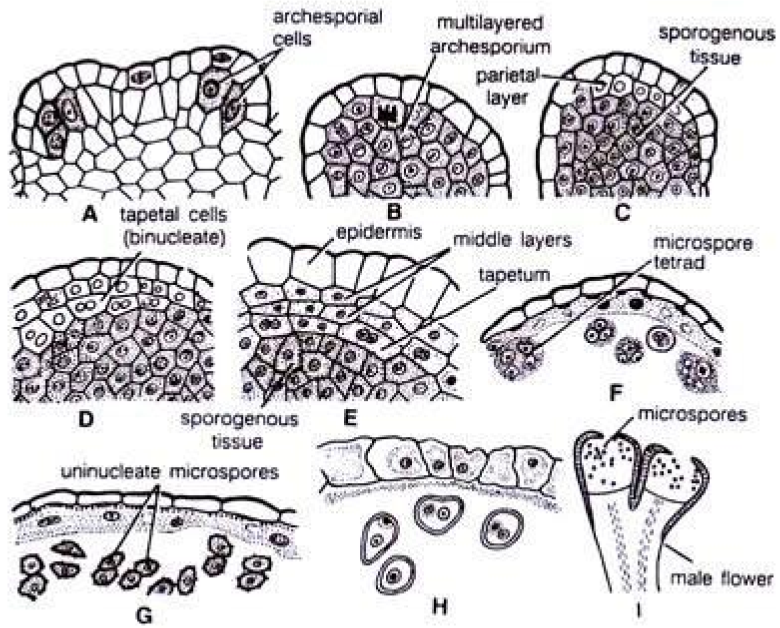

Fig. 13.19. Development of microsporangium in *Gnetum*.

Male Gametophyte:

Pollen grains or microspores are roughly spherical in outline. They are uninucleate and remain surrounded by a thick and spiny exine and thin intine. Mature pollen grains are shed at three-nucleate stage. These include prothallial nucleus, tube nucleus and generative nucleus (Fig. 13.20, Upper) in Gnetum Africanism and G. gnemon according to Pearson (1912, 1914).

This three-nucleate stage is reached by first dividing the microspore nucleus mitotically into two and then one of them again gets divided. Further development is affected only in the pollen chamber. The intine comes out by rupturing the exine and forms a pollen tube.

The tube nucleus migrates into the pollen tube. The generative nucleus also adopts the same course and divides into two unequal male gametes in the tube. Prothallial nucleus does not enter the pollen tube.

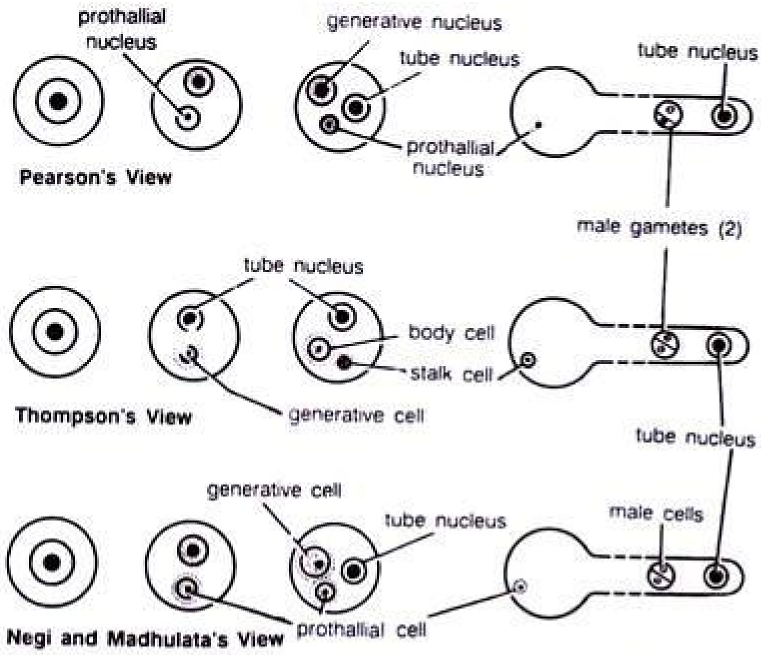

Fig. 13.20. Diagrammatic representation of different views on the development of male gametophyte in *Gnetum*. (modified after Negi and Madhulata 1957)

Thompson (1916) opined that the prothallial cell does not form at all in the male gametophyte (Fig. 13.20, Middle). The microspore nucleus divides into a tube nucleus and a generative cell. The latter divides into a stalk cell and body cell. The tube nucleus and body cell enter in the pollen tube where the body cell divides into two equal male gametes.

According to Negi and Madhulata (1957) the microspore nucleus in Gnetum gnemon and G. ula divides into a small lenticular cell and a large cell (Fig. 13.20, Lower). The lenticular cell does not take part in the further development and ultimately disappears.

The other large nucleus divides into a tube nucleus and a generative cell, both of which pass into the tube. The generative cell divides into two equal male gametes in the tube. A stalk cell is never formed in these species.

Pollination:

Wind helps in carrying the pollen grains up to the micropylar tube of the ovule. The micropylar tube secretes a drop of fluid in which certain pollen grains get entangled and reach up to the pollen chamber. The nucellus cells below the pollen chamber are full of starch.

Fertilization:

The fertilization in Gnetum has been studied only by a few workers. Vasil (1959) studied this phenomenon in G. ula. At the time of fertilization, the pollen tube pierces through the membrane of the female gametophyte just near to a group of densely cytoplasmic cells. The tip of pollen tube bursts and the male cells are released. One of the male cells enters the egg cell.

The male and female nuclei, after lying side by side for some time, fuse with each other and form the zygote. According to Swamy (1973), the only identifying features of the zygote are its spherical shape and dense cytoplasm. Both the male cells of a pollen tube may remain functional if two eggs are present close to the pollen tube.

Endosperm:

In all gymnosperms, except Gnetum, a cellular endosperm (Fig. 13.21) develops before fertilization. In Gnetum, the cell formation, although starts before fertilization, a part of the gametophyte remains free-nuclear at the time of fertilization.

After fertilization the wall formation in the female gametophyte starts in such a way that the cytoplasm gets divided into many compartments. Each of these compartments contains many nuclei (Fig. 13.21C).

All the nuclei of one compartment fuse and form a single nucleus. The wall formation starts from the base and proceeds upwards. The wall formation varies greatly in Gnetum. Only the lower portion of the gametophyte may become cellular leaving the remaining upper portion free-nuclear. Sometimes the entire gametophyte may become cellular.

In some cases the upper portion may become cellular instead of the lower portion. Sometimes only the middle portion may become cellular and in still other cases there may not be any wall formation at all. The characteristic triple fusion of the angiosperms is, however, absent in Gnetum.

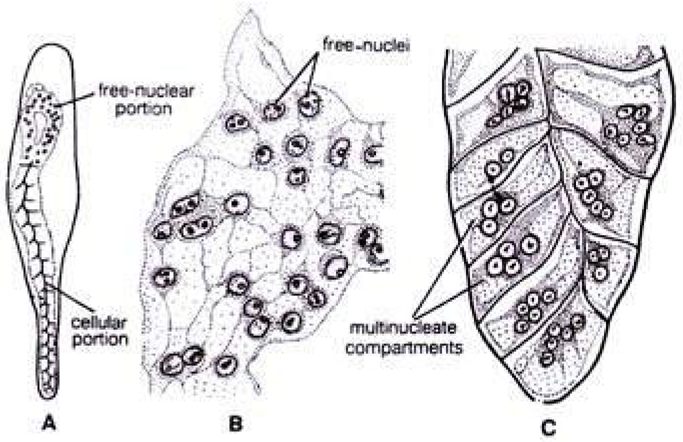

Fig. 13.21. *Gnetum ula*.. A, Female gametophyte showing the development of endosperm; B, A part of upper portion of 'A'; C, A part of lower portion of 'A'. (modified after Vasil, 1959).

The Embryo:

The embryo development in several species of Gnetum has been studied by many different workers including Lotsy (1899), Coulter (1908) and Thompson (1916), but the details put forward by these wokers are highly variable.

Maheshwari and Vasil (1961) have stated that in all the angiosperms the first division of the zygote is accompanied by a wall formation but in all gymnosperms, except Sequoia sempervirens, these are free-nuclear divisions in the zygote. Gnetum in this respect forms a link in between gymnosperms and angiosperms by showing both free-nuclear divisions as well as cell divisions.

Thompson (1916) opined that a two-celled pro-embryo is formed (Fig. 13.22 A). From each of these two cells develops a tube called suspensor (Fig. 13.22B). Now the nucleus divides and one of the two nuclei undergoes free-nuclear divisions forming four nuclei. The embryo gets organised by these four nuclei (Fig. 13.22C, D). There is no division in the other larger nucleus..

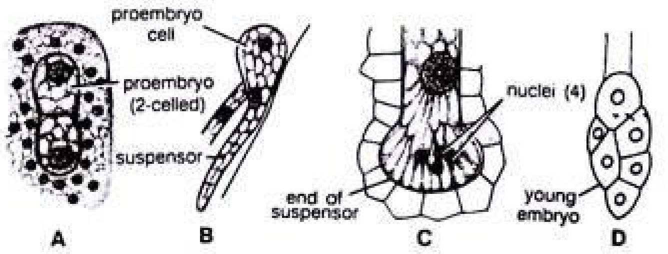

Fig. 13.22. *Gnetum.* Development of embryo. A-B, *G. gnemon*; C-D, *G. maluccense* (after Thompson,1916).

Madhulata (1960) has worked on the zygote development in Gnetum gnemon. According to her 2-4 or sometimes up to 12 zygotes may develop in a gametophyte, of which normally one remains functional. From the zygote develops generally one or sometimes 2-3 small tubular outgrowths.

Only one of these tubes receives the nucleus and survives while the remaining tubes disintegrate and soon die. The surviving outgrowth elongates, becomes branched and grows into different directions through the intercellular spaces of the endosperm. All the primary suspensor tubes usually remain coiled round each other.

A small cell is cut off at the tip of the primary suspensor tube in Gnetum gnemon. It soon divides first transversely and then longitudinally resulting into four cells. Now irregular divisions take place forming a group of cells. Some of these cells divide and elongate to form secondary suspensor (Fig. 13.23). The remaining cells at the tip form the embryonal mass.

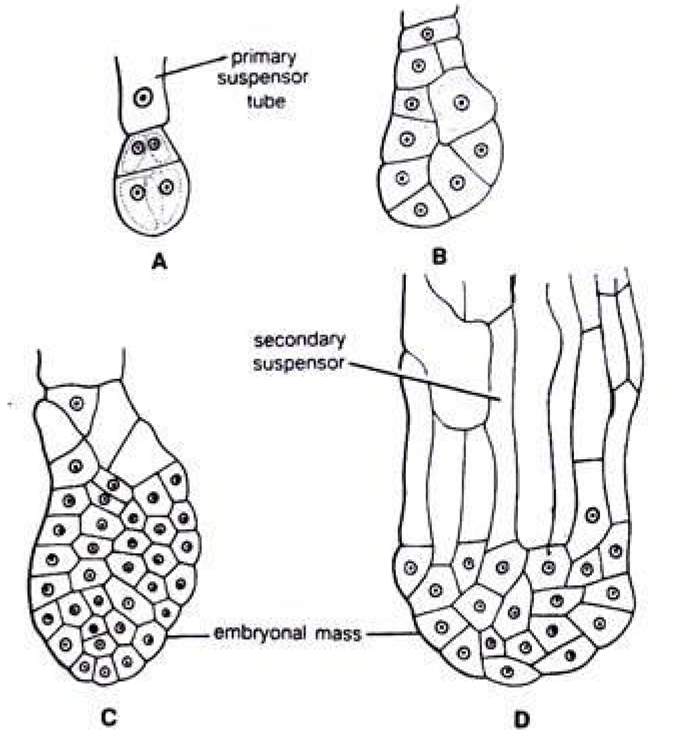

Fig. 13.23. *Gnetum gnemon.* Development of embryonal mass.

In Gnetum ula a small cell is cut off at the tip of the tube called peculiar cell. This peculiar cell soon divides and forms a group of cells. The secondary suspensor and embryonal mass are differentiated (Fig. 13.24) from this group of cells. By this time, the wall of the tube starts to become thick.

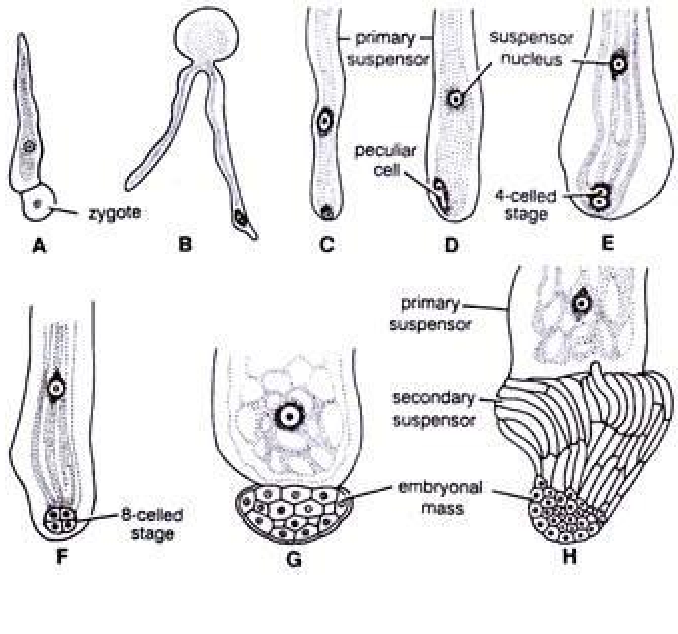

Fig. 13.24. *Gnetum ula.* Development of embryonal mass. A-B, Germination of zygote; C-D, Formation of peculiar cell; E-F, Formation of 8-celled stage of embryonal mass; G, Embryonal mass formed by peculiar cell; H, Formation of secondary suspensor.

What so ever may be the pattern of formation of the embryonal mass and secondary suspensor, the cells of the former are small, compact, dense in cytoplasm and develop into embryo-proper while that of the latter (i. e. secondary suspensor) are thin-walled, uninucleate and highly vacuolated.

The primary and secondary suspensors help in pushing the embryo into the endosperm. Soon a stem tip with two lateral cotyledons form in the tip region of the embryonal mass. On the opposite side develop the root tip with a root cap.

A feeder develops after the formation of stem and root tips (Fig. 13.25). The feeder is a protuberance-like structure present in between root and stem tips. Thus, the stem tip, two cotyledons, feeder, root tip and root cap are the parts of a mature embryo.

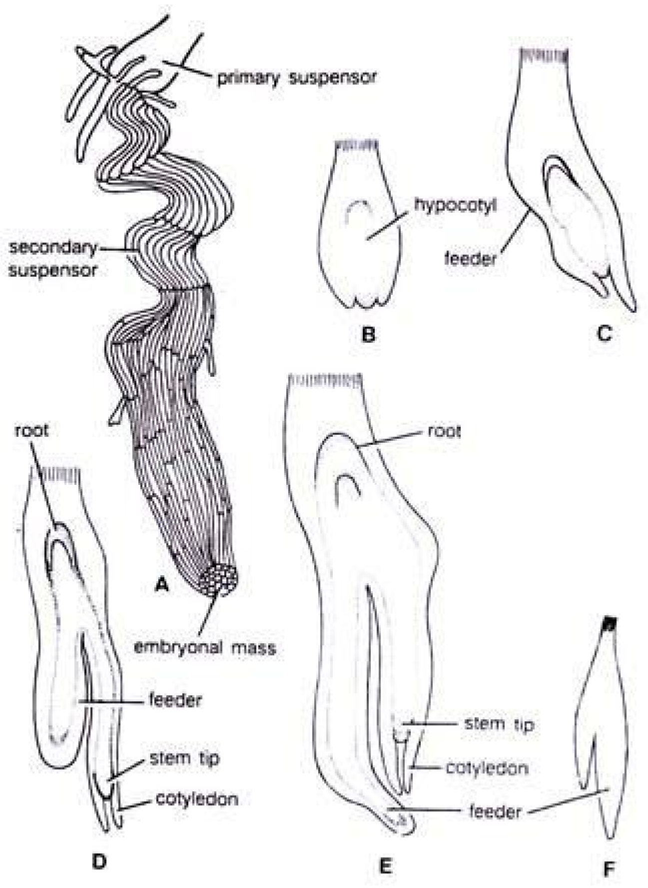

Fig. 13.25. *Gnetum ula.* Development of embryo

Seed:

Gnetum seeds (Fig. 13.26) are oval to elongated in shape and green to red in colour. It remains surrounded by a three-layered envelope which encloses the embryo and the endosperm. Outer envelope is fleshy, and consists of parenchymatous cells. It imparts colour to the seed.

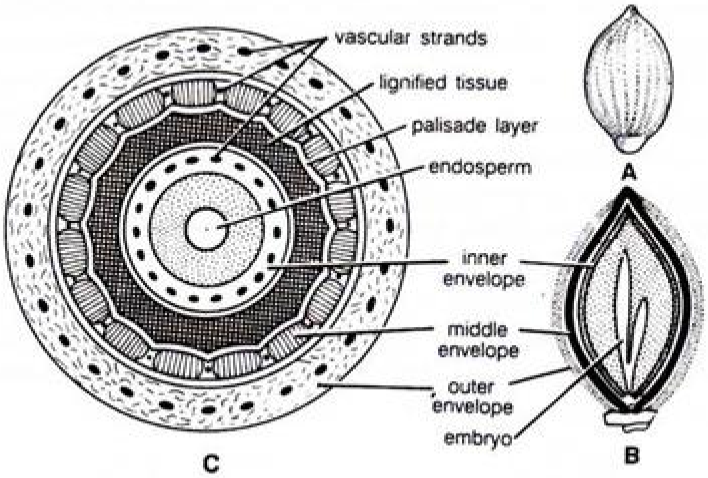

Fig. 13.26. *Gnetum*. A, An entire seed; B, L.S. seed; C, T.S. seed.

The middle envelope is hard, protective and made up to three layers, i.e., outer layer of parenchymatous cells, middle of palisade cells and innermost fibrous region. The inner envelope is parenchymatous. Branched vascular bundles traverse through all the three envelopes.

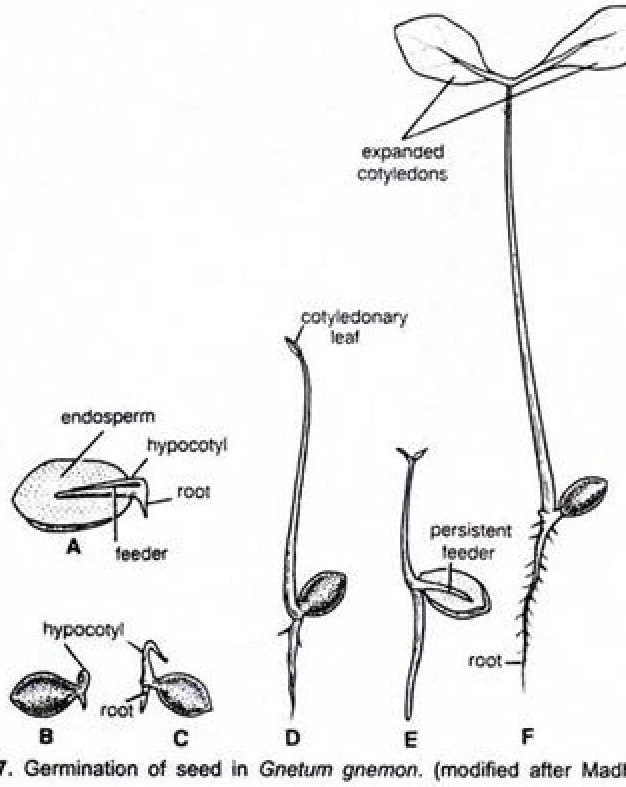

Fig. 13.27. Germination of seed in *Gnetum gnemon*. (modified after Madhulata, 1960).

Germination of Seed:

Germination is of epigeal type (Fig. 13.27). The cotyledons are pushed out of the seed. The hypocotyl elongates, and this brings the cotyledons out of the soil. The first green leaves of the plant are formed by the cotyledons. The first pair of foliage leaves is produced by the development of plumule. A persistent feeder is present up to a very late stage in the seed.

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5. Relationships of Gnetum:

Gnetum and Other Gymnosperms:

Gnetum shows several resemblances with gymnosperms and has, therefore, been finally included under this group.

Some of the characteristics common in both Gnetum and other gymnosperms are under mentioned:

1. Wood having tracheids with bordered pits.

2. No sieve tubes and companion cells are present.

3. Presence of naked ovules.

4. Absence of fruit formation because of the absence of ovary.

5. Anemophilous type of pollination.

6. Development of prothallial cell.

7. Cleavage polyembryony.

8. Resemblance of the vascular supply of the peduncle of the cone of Cycadeoidea wielandii with that of a single flower of Gnetum.

9. Resemblance of the structure of basal part of the ovule in Gnetum and Bennettites.

Gnetum and Angiosperms:

A key position to Gnetum has been assigned by scientists while discussing the origin of angiosperms. Both Gnetales and angiosperms originated from a common stalk called “Hemi-angiosperm”.

Thompson (1916) opined that the ancestors of both Gnetum and angiosperms were close relatives. Some other workers have gone up to the extent in stating that Gnetum actually belongs to angiosperms. Hagerup (1934) has shown a close relationship between Gnetales and Piperaceae.

In a beautiful monograph on Gnetum, Maheshwari and Vasil (1961) have stated that **“Gnetum remains largely a phylogenetic puzzle. It is gymnospermous, but possesses some strong angiospermic features”.**

Some of the resemblances between Gnetum and angiosperms are under mentioned:

1. The general habit of the sporophyte of many species of Gnetum resembles with angiosperms.

2. Reticulate venation in the leaves of Gnetum is an angiospermic character.

3. Presence of vessels in xylem is again an angiospermic character.

4. Clear tunica and corpus configuration of shoot apices is a character of both Gnetum and angiosperms.

5. Strobili of Gnetum resemble much more with angiosperms than any of the gymnosperms

6. Micropylar tube of Gnetales can be compared with the style of the angiosperms because both perform more or less similar functions.

7. Tetrasporic development of the female gametophyte is again a character which brings Gnetum close to angiosperms.

8. Absence of archegonia again brings Gnetum and angiosperms much closer.

9. Dicotyledonous nature of the embryo of Gnetum brings it quite close to the dicotyledons.

Resemblances Between Gnetum, Ephedra and Welwitschia:

All the three genera of Gnetales show following resemblances:

(1) Opposite leaves;

(2) Vessels in their secondary wood,

(3) Similar structure and development of perforation plates in their vessels;

(4) Similar Gnetalean mode of development of their vessels i.e. by the dissolution of torus and middle lamella of the bordered pits;

(5) Almost similar structure of their sieve cells and phloem parenchyma;

(6) Spiral or annular elements in their protoxylem;

(7) Arrangement of their flowers in compound strobili;

(8) Unisexual flowers;

(9) Dioecious plants;

(10) Stalked male flowers bearing synangia made of 1-6 or more sporangia;

(11) Almost consistent structure of the wall of their microsporangia;

(12) Wingless pollen grains;

(13) Orthotropous ovules;

(14) Ovules surrounded by several envelopes which are interpreted variously as integuments or perianth;

(15) Extremely elongated micropylar tube;

(16) Formation of unicellular primary suspensors;

(17) Dicotyledonous embryo;

(18) Simple type of polyembryony.

Economic Importance of Gymnosperms

1.Ornamental value:A number of gymnosperms are grown as ornamental plants,e.g.,Cycas,Araucaria,Thujae

2.Food Value

i. 'Sago 'starch obtained from pith and cortex of stem of C.revolute,C.rumphietc.

ii. 'Seed starch'obtained from seeds of Cycas rumphi etc.It is prepared into flour and cooked before eating.

iii.Seeds of Pinus gerardiana(chilgoza)are edible.

iv.'Kaffirbread 'prepared from the stem pith of Encephalartos.

v.Young leaves of Cycas cooked as vegetables.

3.Medicinal value.

i. Ephedrine(alkaloid)extracted from Ephedra used in treating asthma,cough,cold,bronchitis etc.

ii. Tincture of Ephedra is a cardiac stimulant.•

iii.The juice extracted from young leaves of Cycas revoluta is used for curing blood vomiting and flatulance.

.4. Industrial uses.

i. Gum-Cycas gum used as adhesive antidote for snake bites and using malignant ulcers.

ii. Tannins–Tannins extracted from bark of Araucaria ,Pinus,Sequoia etc . used in leather industry.

iii.Canadabalsam–It is turpentine obtained from Abies balsamea and used as a mounting medium in biological preparations.

iv.Amber(fossilresin)obtained from Pinus succinifera . Wood of Pinus is used for doors, poles, beams, railway wag on flooring etc

V.Plywood prepared from Podocarpus.

VI.Papers like news prints,writing and printing papers are being prepared from the woodpulp of Pinus, Picea, Abeis, Gnetum etc.

vii.The leaves of cycads are used for preparing baskets, mats,hats,brooms etc.

viii.The fibres obtained from the leaves of Cycas and Macrozamia are used for stuffing pillows and making mattresses.

5. Source of oils

i.Oils extracted from seeds of C.revoluta, Macrozamiareidlei,Pinus cembra and Cephalotaxus drupacea are used as edible oils.

ii.Red cedar wood oil extracted from the heart wood of Juniperus virginiana is used for cleaning microscopic preparations and for oil immersion lenses.

iii.Oils obtained from Cedrusdeodara, Ciyptomeria japonica and Cupressus serm-perivirens are used in preparations of perfumes.