Tropic: Life history of *Pinus* sp.

Syllabus: **BOT-A-CC-2-4-TH**, Gymnosperm

1. Distribution of *Pinus* sp. In India

The conifers form a unique distinctive group among the gymnosperms and are largely confined to the hills and mountains of the tropics, subtropics, temperate and alpine climatic zones. Among the conifers, pines or the genus Pinus forms the largest and traditionally important group. For centuries pines have held economic, aesthetic and ecological importance. They provide forestation in areas where deciduous trees are unable to grow due to altitude and latitude. Pines also leach a sap called "Resin" that hosts different uses including sealant, glue and varnish. These resins are remedy for ulcer, smallpox and syphilis. Overall, Pinus species hold distinctive characters among gymnosperms with tremendous antioxidant potential that are explored herein.

In **India**, **Pinus** species are found in Jammu & Kashmir, Himachal Pradesh, Uttarakhand, West Kameng district of Arunachal Pradesh, Tenga valley of Arunachal Pradesh, North eastern regions of the country including borders of Tibet, Meghalaya, Indo-Burma border and West Bengal. In all these regions, occurrence of the plant is at different altitudes and climatic conditions. While near Indo-Tibet border in the north eastern region it is found at 1500-3600 m and prefers high moisture conditions to grow; in Jammu & Kashmir it grows in drier sunny slopes at an altitude of 2000-3350 meter.

Pinus is represented by 6 species in India. These are P. roxburghii, P. wallichiana, P. insular is, P. gerardiana, P.armandi and P.merkusii. They are distributed throughout in Himalayas. Pinus roxburghii (vern. Chir) grows at lower altitudes between 2000-5000 feet, whereas P. wallichiana grows in north-west Himalayas ranging from an elevation of 5000-12000 feet.

Pinus gerardiana (vern. Chilgoza) occurs on the Himalayan flanks extending from Punjab to Afghanistan and Baluchistan ranging within the altitudes of 5000 to 12000 feet.

Pinus roxburghii (popularly known as "Chir") grows from 460m to 1500m in Western Himalayas, extending to Bhutan and Eastern Nepal. (Figure – P. roxburghii whole plant, male and female cone.)

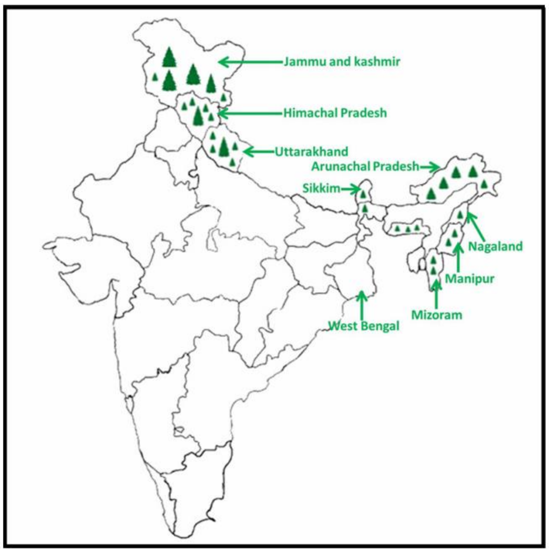
Pinus wallichiana (popularly known as "kail" or "blue pine" or '"Bhutan Pine") grows from 1500m to 3000m in Kashmir valley, Shimla, Mussoorie and Eastern Nepal.

Pinus insularis (popularly known as "Khasi pine") grows from 800m to 2000m in Garo, Khasi and Jaintia hills.

Pinus armandii (North-eastern Himalayas).

Pinus merkusii (Tenasarn Pine) is found in Andaman and Nikobar Islands and Myanmar.

Some other species, found in India but not indigenously, are Pinus canariensis (Kashmir), P.caribaea (Assam), P.halepensis (Srinagar), P.massoniana, P.patula, P.pinaster and P.taeda (Kulu, Manali), P. radiata (Nilgiris) and P.thunbergii (West Bengal).



Distribution of *Pinus* species in the Indian subcontinent

Pinus gerardiana	Jammu and Kashmir, Himacal Pradesh	2000m-3350m	Grows in drier sunny slopes	Farjon et al., 2013
Pinus roxburghii	Jammu and Kashmir to West Kameng district of Arunachal Pradesh	400m-2300m	Grows in drier and outer Himalayan valleys	Farjon et al., 2013
Pinus wallichiana	Jammu and Kashmir to West Kameng district of Arunachal Pradesh	Till 2700m	Occurs in drier region of Himalayas along with other species	Farjon et al., 2013
Pinus bhutanica	Tenga valley in Arunachal Pradesh	1000m	Drier and inner valleys along with other species	Farjon et al., 2013
Pinus insularis	North east India, Meghalaya	Upto 3000m	Prefer high moisture	
Pinus armandii	Extreme north eastern India bordering Tibet	1500-3600m	Prefers high moisture	Critchfield et al.,1996
Pinus mekusii	Indo Burma border	1500 m	Prefers high moisture	Bhatnagar et al., 1996

2. External Morphology of *Pinus* sp.

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).

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.

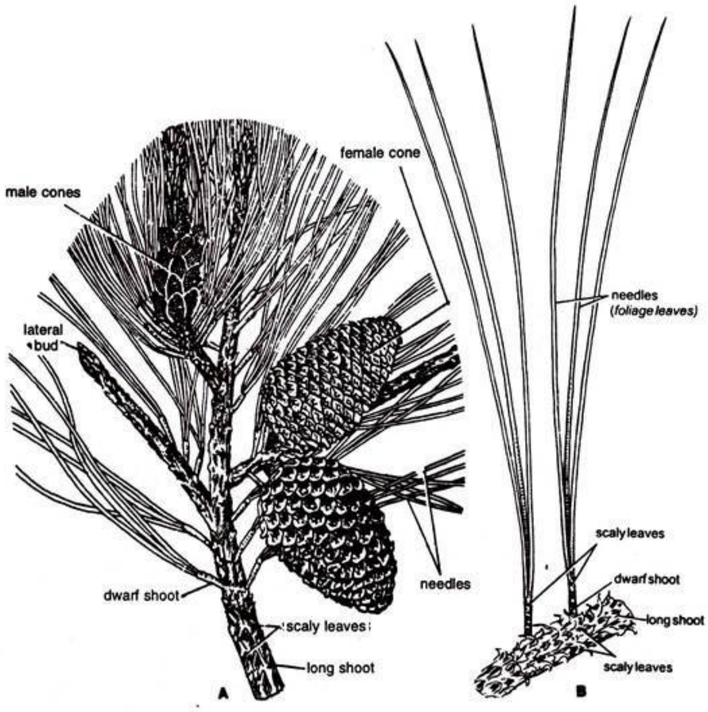


Fig. 26. Pinus gerardiana. A, Branch of a mature plant bearing male and female cones; B, A part of stem showing two types of shoots.

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.

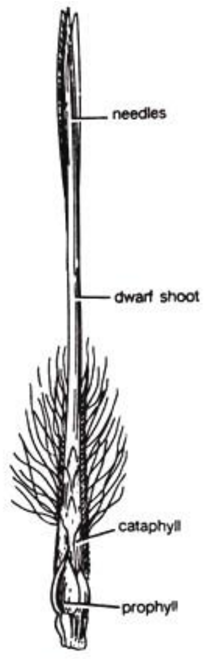


Fig. 27. Pinus roxburghii. A young dwarf shoot.

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 only.

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.

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).

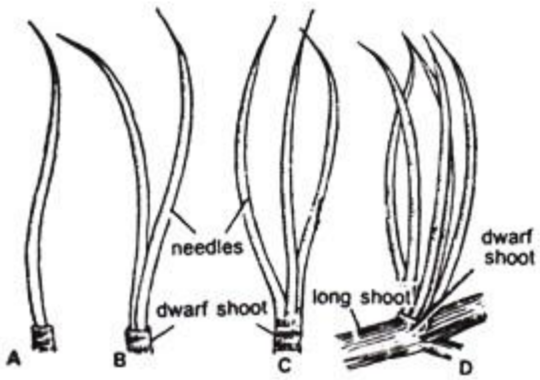


Fig. 28. Pinus. Spurs of different species. A, Monofoliar (Pinus monophylla); B, Bifoliar (P. sylvestris); C, Trifoliar (P. gerardiana); D, Pentafoliar (P. wallichiana).

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 hair.

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.

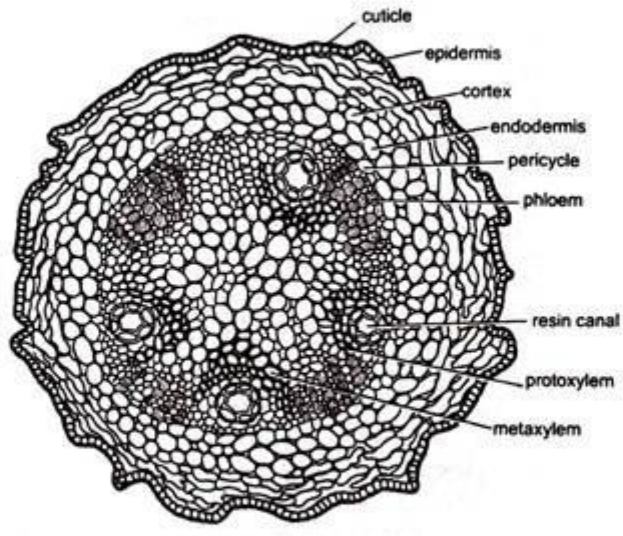


Fig. 29. *Pinus. T.S. young root (diagrammatic).*

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.

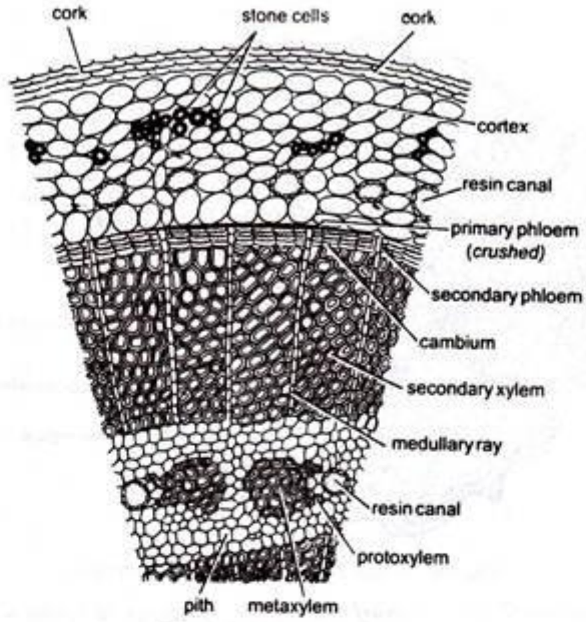


Fig. 30. *Pinus. T.S. old root.*

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.

T.S. Long Shoot (Young):

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

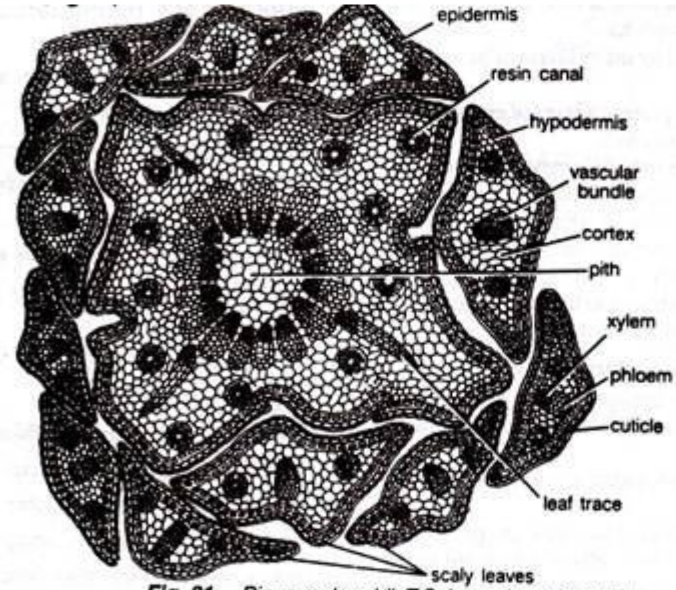


Fig. 31. Pinus roxburghii. T.S. long shoot (young).

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).

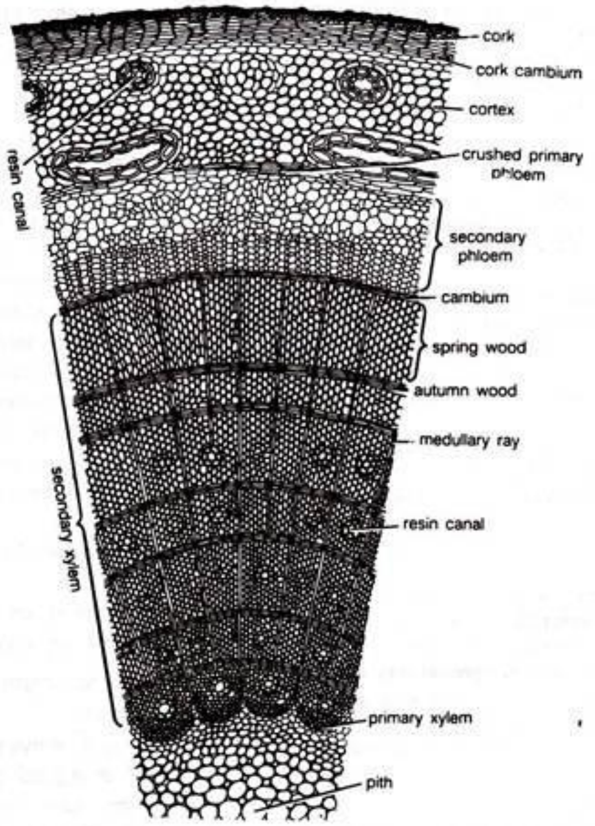


Fig. 32. Pinus. T.S. of a two-year old long shoot.

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).

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.

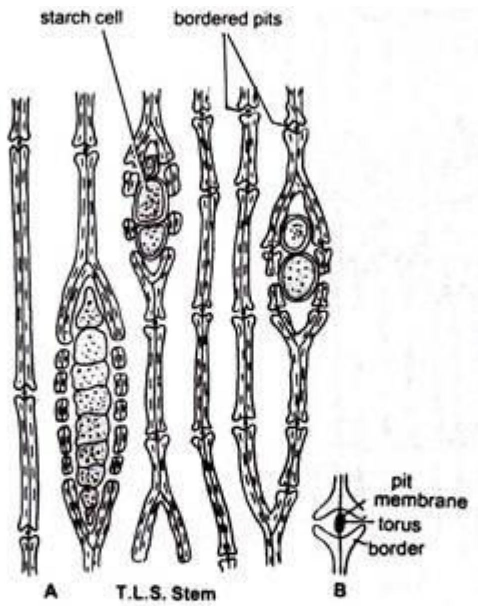


Fig. 33. Pinus. A, T.L.S. wood (a part); B, A magnified bordered pit.

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.

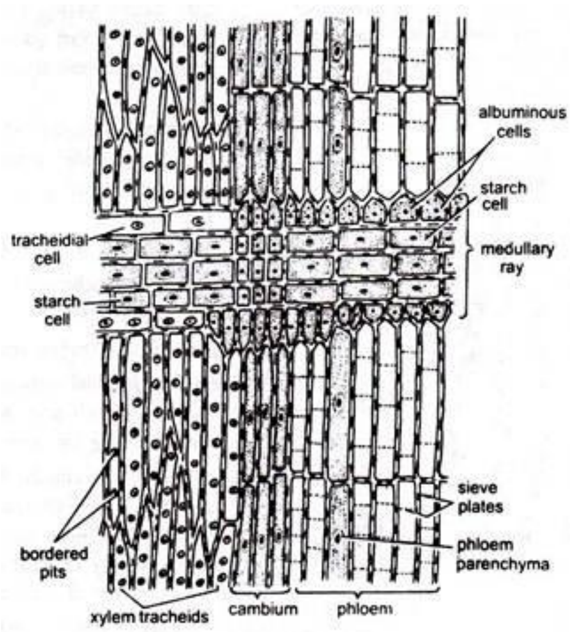


Fig. 34. Pinus. R.L.S. Stem.

4. In the xylem region thick medullary ray cells

are surrounded by ray tracheids (Fig. 34).

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:

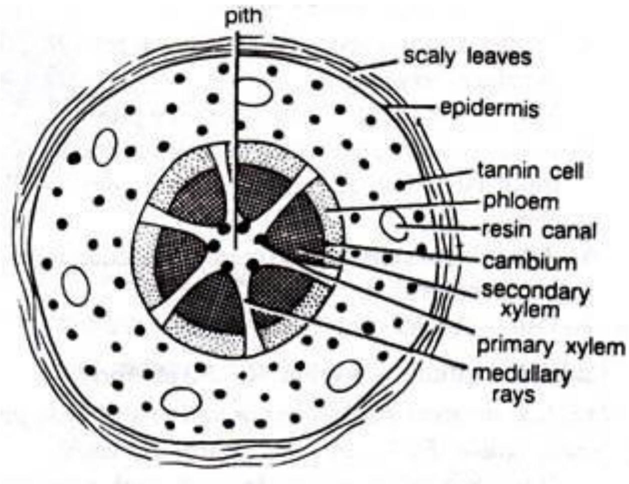


Fig. 35. Pinus. T.S. dwarf shoot.

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.

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.

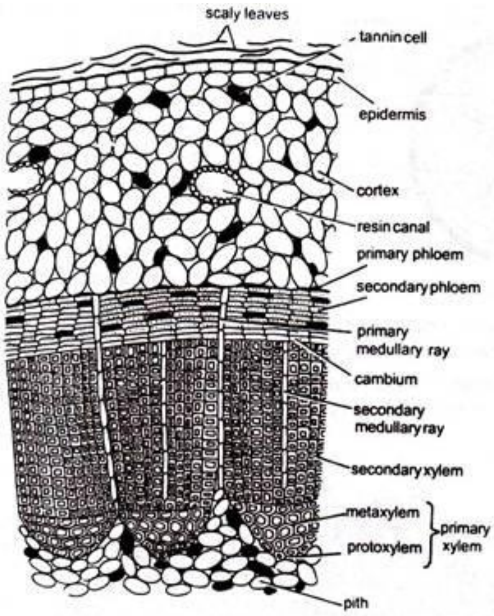


Fig. 36. Pinus. T.S. old dwarf shoot (a part cellular).

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

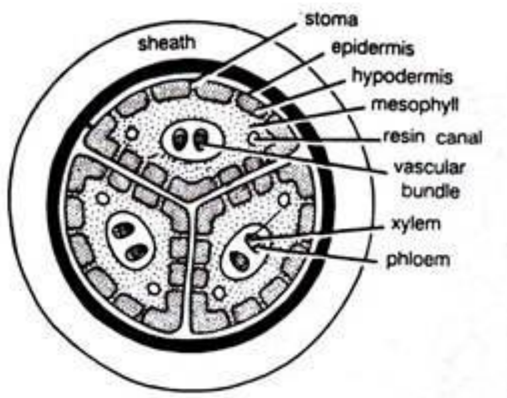


Fig. 37. Pinus. T.S. upper part of dwarf shoot showing the formation of three needles in a trifoliar spur.

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).

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).

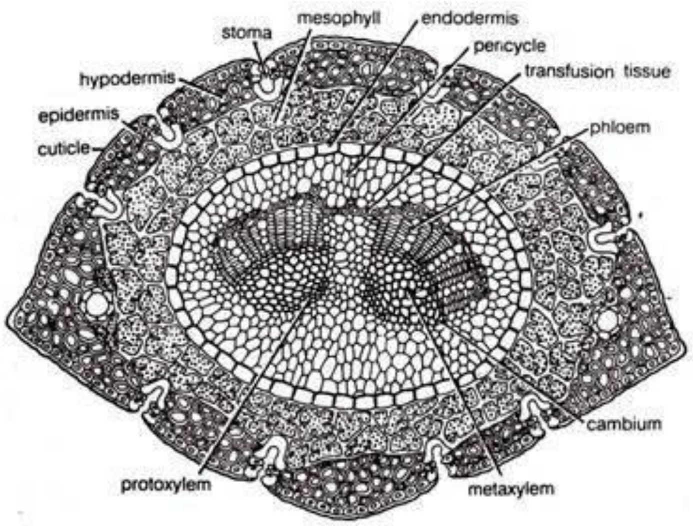


Fig. 38. Pinus. T.S. needle.

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.

Distinctions between Haploxylon and Diploxylon pines

Haploxylon pines	Diploxylon pines
1. They are the soft pines.	1. They are the hard pines.
2. There is a single vascular bundle in the needle.	2. There are two vascular bundles in the needle.
3. The umbo (tip of the apophysis of ovuliferous scale in the mature cone) is either terminal or dorsal.	3. The umbo is always dorsal.
4. In stem, ray tracheids have smooth walls and tangential pits are developed after one year's growth.	4. In stem, ray tracheids have dentate or reticulate walls and tangential pits are not formed at the end of a year's growth.

3. *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.

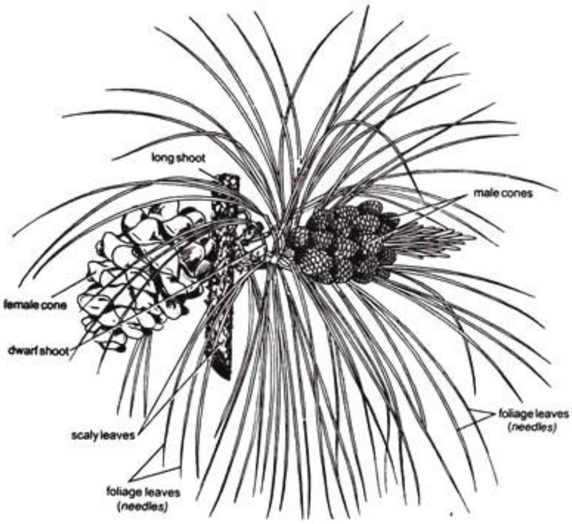


Fig. 39. Pinus. A long shoot bearing cluster of male cones and a mature female cone.

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

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).

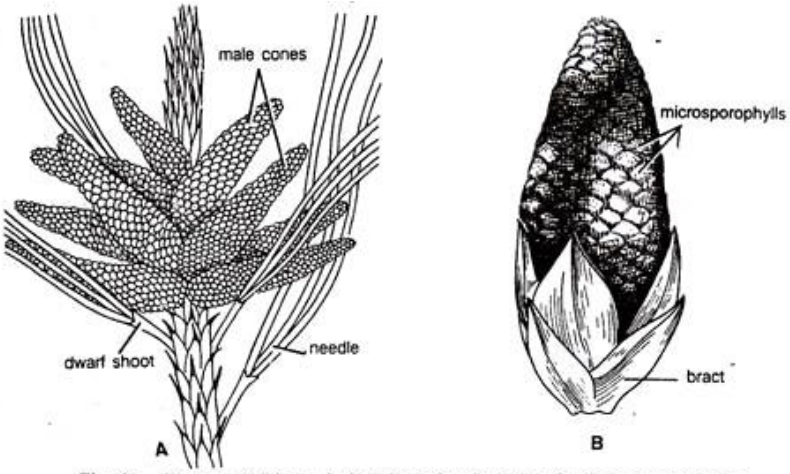


Fig. 40. Pinus wallichiana. A, A cluster of male cones; B, A single male cone.

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

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

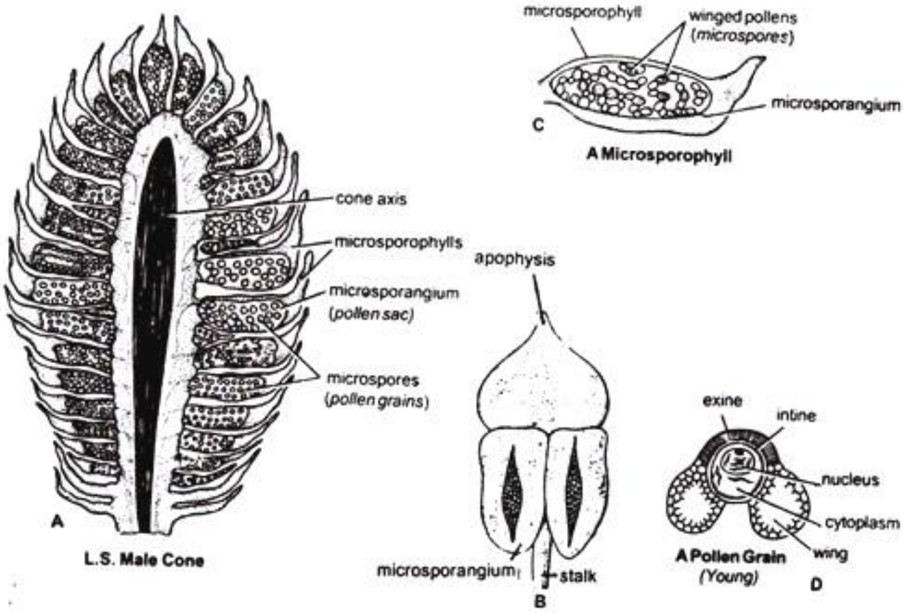


Fig. 41. Pinus. A, L.S. male cone; B, A single microsporophyll with microsporangia in surface view; C, A microsporophyll; D, A young pollen grain.

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).

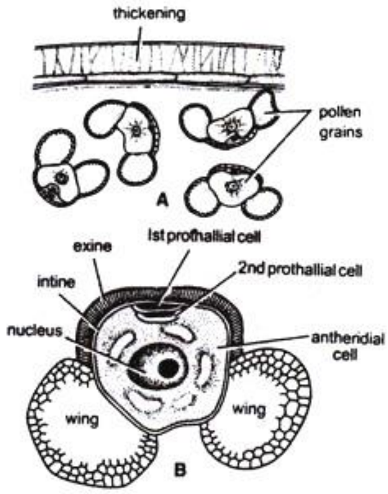


Fig. 42. Pinus. A few pollen grains and a mature winged pollen grain.

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).

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.

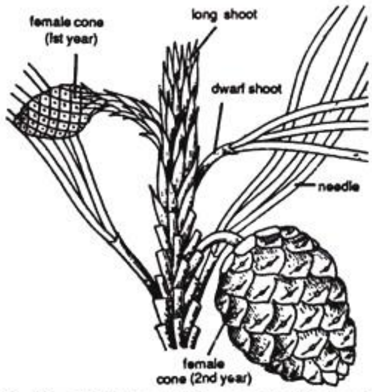


Fig. 43. Pinus. A fertile long shoot bearing 1st and 2nd year female cones.

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.

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).

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.

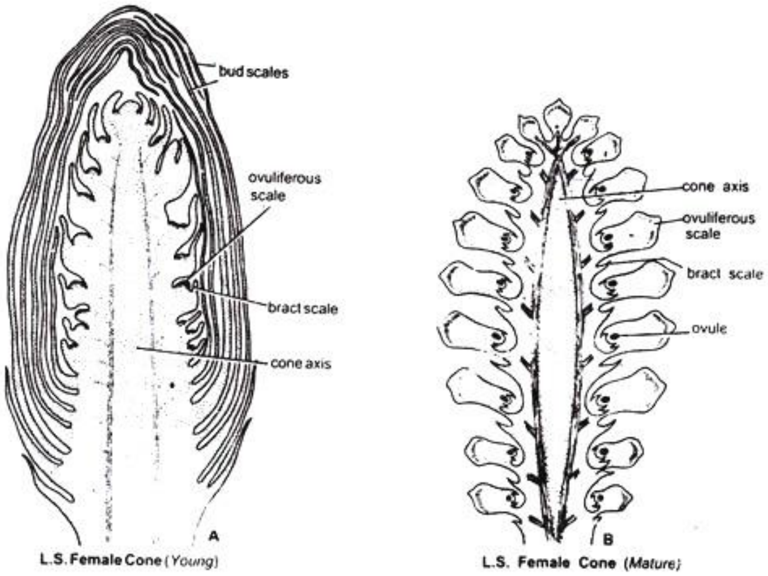


Fig. 44. Pinus. A, L.S. female cone (young); B, L.S. female cone (old).

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.

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.

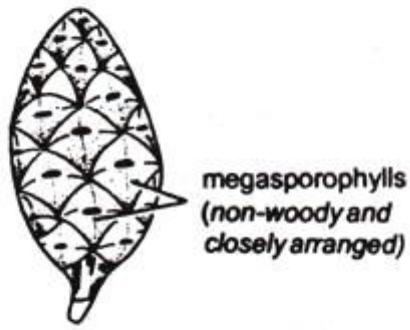


Fig. 45. Pinus. A 1st year female cone.

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.

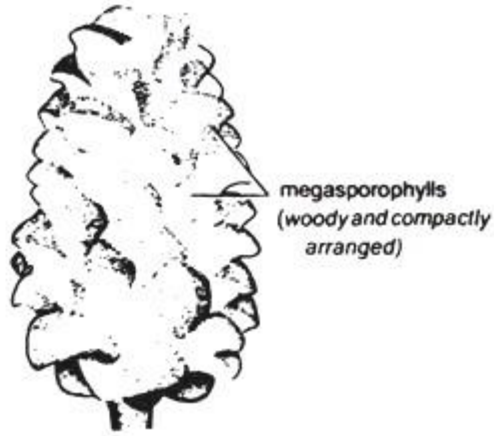


Fig. 46. Pinus. A 2nd year female cone.

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

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).

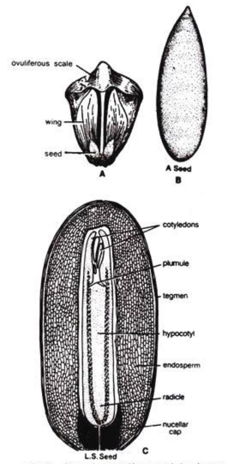


Fig. 48. Pinus. A, An ovuliferous scale bearing two winged seeds; B, A single seed; C, L.S. seed.

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.

(ii) Female cone is woody.

(iii) Presence of bract and ovuliferous scales in female cone.

(iv) Seeds are winged

(v) Polyembryony present.. Pinaceae

(e) (i) Plant conical in appearance.

(ii) Presence of ectotrophic mycorrhiza on roots.

(iii) Presence of monofoliar to pentafoliar spurs.

(iv) Leaves needle-like.

(v) Presence of resin canals in pith, cortex and wood.

(vi) Clusters of male cones present.

(vii) Winged pollen grains and winged seeds.

(viii) Many cotyledons are present........... Pinus.

Reproduction of *Pinus* sp.

Pinus is meoecious. Plant develops both male and female strobili on the same plant. The strobili are monosporous. There is no vegetative reproduction in Pinus.

Male Cone

The male cones are much smaller. They are produced in clusters near the tip of the long shoots. The male cones are produced in the spring. Each male cone has a central axis. It bears a nua Der of spirally arranged microsporophylls or stamens. Each microsporophyll has sac like microsporangia (pollen sacs) on the ventral side. Each microsporangium produces a large number of microspores (pollen grains). The wall of each microspore (pollen grain) consists of an inner Milne and an outer exine. It has balloon like wings. The wings help in the dispersal of spores by wind.

Fig: L.S of male cone

Development of Microsporangium (Stamen)

A number of hypodermal cells act sporangial initials. The sporangial initials divides to form outer wall initials and the inner archesporial. The wall initials divide to form a many layered wall of the sporangium. The archesporial initials also increase in number by the repeated divisions. The peripheral cells of the archesporium form the tapetum.

Some of the archesporial cells are transformed into microspore mother cells. The remaining archesporial cells and the tapetal layer provide nourishment to the developing microspore mother cells.

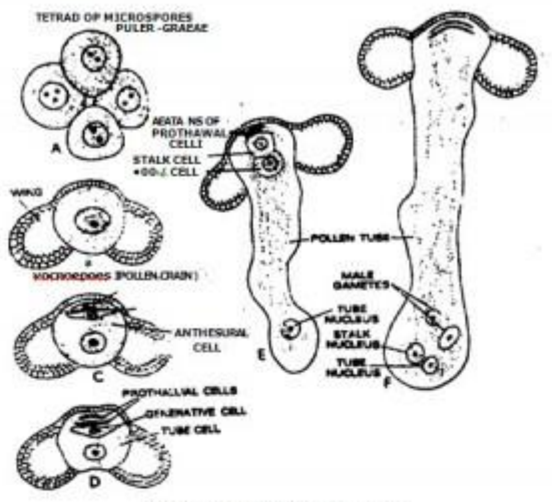


Fig: Germination of pollen grain

The microspore mother cell divides to form four microspores or pollen grains. The exine of spore forms wings. The pollen grain divides in to smaller and larger cells. The smaller cell again divides to form two small prothalial cells. The larger cell becomes antheridial cell. The sporangium splits and microspores are released from the microsporangia at this stage.

Female Cone

Female cones are produced in the axils of the scale leaves. The production of female cones is initiated in the winter. These become ready for pollination during the following spring. Each young female cone has a central axis. It bears spirally arranged scales. The scales are of two types. Some are thin membranous and are directly attached to the central axis. They are called bract scales. Woody ovuliferous scales are present on the ventral surface of each bract scale. The broader end of the ovuliferous scale has projection called the umbo. Each ovuliferous scale bears two ovules. They are situated side by side on upper side. Each ovule (megasporangium) has a mass of nucellar tissue. They are surrounded by a single integument. The micropylar end of the ovule is directed towards the central axis. A single megaspore mother cell is differentiated in the nuc,ellus near the micropylar end. This megaspore mother cell undergoes meiosis to form four megaspores. Only the lower most megaspore remains functional. The others disintegrate. Functional megaspore (embryo sac) increases in size. It occupies the major part of the nucellus. Pollination takes place at this stage.

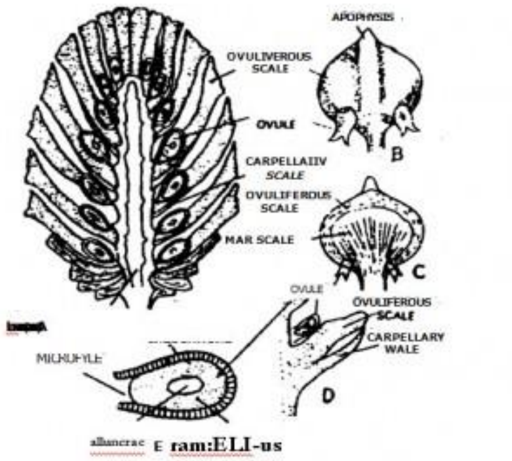


Fig: Section of female cone

Female Prothallus

The megaspore divides many times to form female prothallus. Megaspore wall encloses the female prothallus. Three archegonia are produced towards the micropylar end. Each archegonium develops from a single prothalial cell. Archegonia consist of a large venter and a short neck. The oosphere or egg is very large. It is bounded by the prothalial cells.

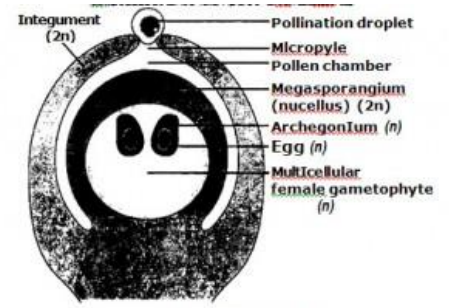


Fig: Ovule with female gametophyte

There is a small ventral canal cell below the neck. The neck is without any neck canal cells. The prothalial tissue enlarges very much in size. It crushes all nueellar tissue except a small amount near the micropylar end.

Pollination

Each ovule secretes a mucilaginous drop at the micropylar end. A gap is produced between the ends of the ovuliferous scales. It forms a passage for the entry of pollen grains. Wind carried pollen grains. The mucilage drop entangles the pollen grain. Pollen grain is carried through the micropyle to the surface of the nucellus.

Male Prothallus

The pollen grain has two prothalial cells and an antheridial cell. These cells soon disintegrate. Further development of the pollen grain takes place at the surface of the nucellus. The antheridial cell cut off second prothalial cell. It also cut off generative cell adjacent to the prothalial cells. The remaining large cell is known as the tube cell. Its nucleus is called tube nucleus. Tube nuclers controls the growth of the pollen tube. Exine of the pollen grain ruptures. Intine grows out to form the pollen tube. It grows through the nucellus. But its activity stops till spring. Female cone enlarges very much in size after pollination. Outer ends of the ovuliferous scales increase very much. They meet each other to close the gaps in between them. The cone is covered with a lot of resinous secretions.

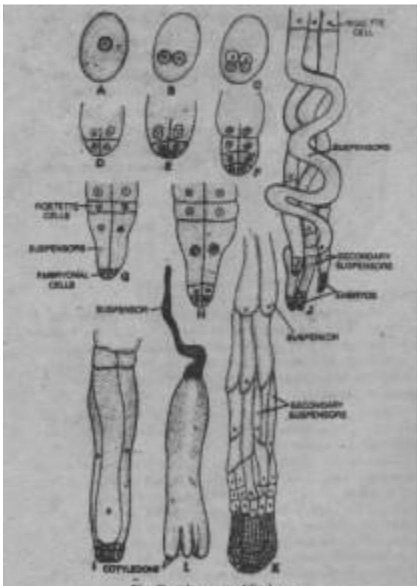


Fig: Development of Embryo

The pollen grain resumes its activity in the spring. Generative cell divides into two cells: stalk cell and a body cell over the stalk cell. Body cell divides into two unequal male cells or sperms. Male cells pass down to the tip of the pollen tube. The pollen tube grows through the nucellus. It passes through the neck of the archegonium and touches the oosphere. One male nucleus fuses with the oosphere to form oospore. The other degenerates. Fertilization is completed in the June of second year.

Formation of Embryo and Seed

Diploid nucleus divides thrice to form eight cells. The lower four cells becomes proembryonal cells. The upper four nuclei are separated by incomplete cell walls. Four proembryonal divides to produce three tiers of cells:

1. **Embryonal cell**: The cells of the lower tier become embryonal cells. The four embryonal cells separate from each other. Each develops into a separate embryo independently. Each embryonal cell forms secondary suspensor cells. The formation of more than one embryo from a single fertilized oosphere is called polyembryony. Only one embryo reaches maturity. The rest are aborted.

Suspensor cells: The cells of the middle tier become suspensor cells. Suspensor cells elongate very much. It pushes the developing embryos into the prothalial tissue for nutrition.

Rosette cells: The cells of the upper most tiers are called the rosette cells. These cells do not take part in the development of the embryo.

A fully developed embryo is in the form a short straight axis. Its radicle is present towards the micropylar end. Plumule is present towards the inner side. Plumule is surrounded by ten cotyledons. The unutilized prothalial tissue forms the endosperm. The persistant nucellus tissues near the micropylar end form the perisperm. The integument becomes hard testa. Some part of the ovuliferous scale fuses with the developing seed. It makes a large wing for dispersal of seed. The axis of the female cone rapidly increases. It produces gaps in ovuliferous scales. The cone becomes woody for the dispersal of seeds.

Germination of Seed

The radicle grows out. It splits the testa at the micropylar end. This radicle grows down into the soil and forms the primary root. The hypocotyl elongates to form a loop. Then it becomes straight. It carries with it the plumule and the cotyledons. The testa is also carried up with the cotyledons.

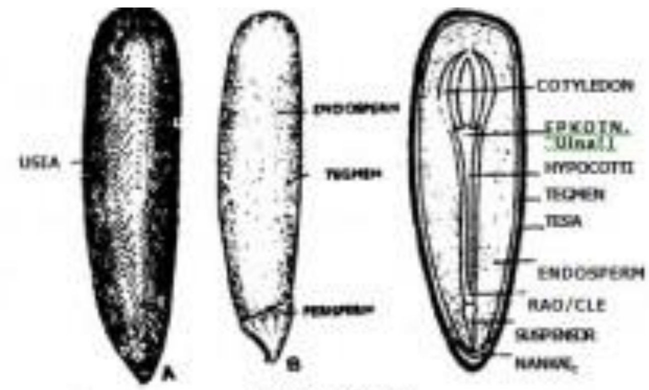


Fig: Seed of pinus

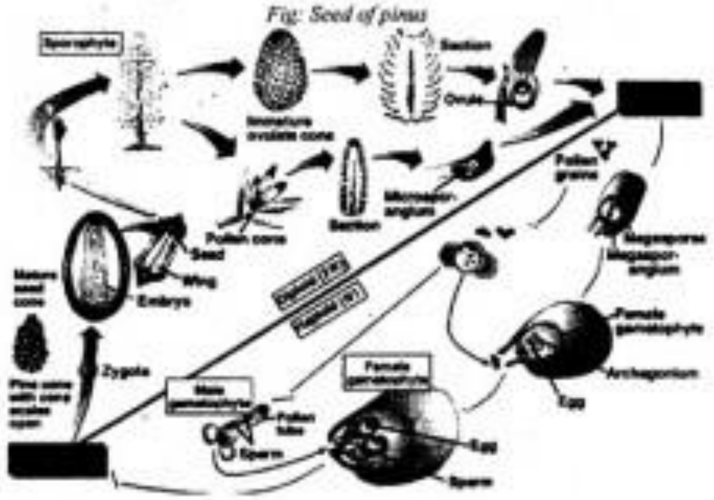


Fig: Life cycle of Pinus

Another note on reproduction of Pinus. You can Read this also….

Ovule:
The ovules of Pinus are anatropous, unitegmic and crassinucellate (Fig. 1.64). The sin-gle integument is free from the nucellus except at the chalazal end. There is a fairly broad micropylar tube which becomes inwardly curved during pre-pollination stages and becomes outwardly curved at the time of pollination.
The integument is three-layered, the outer fleshy, the middle stony and the inner fleshy.

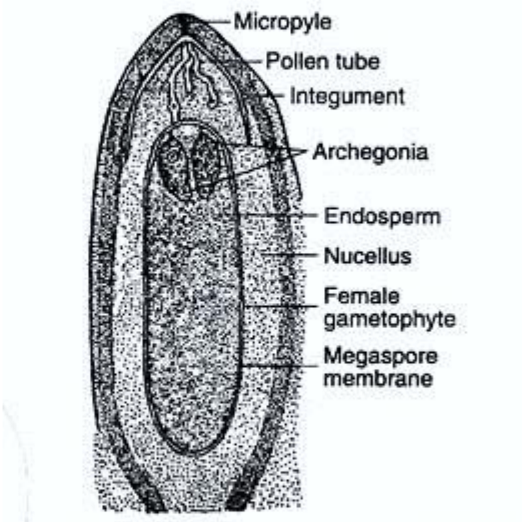


Fig. 1.64 : *Pinus* : Median L.S. of a mature ovule

Megasporogenesis:
A hypodermed cell in the nucellar tissue at the micropylar end is differentiated into an archesporial cell. It divides periclinally to form an upper parietal cell and a lower megaspore mother cell. The parietal cell further divides to form tapetal layer. The megaspore mother cell undergoes meiotic division to form a linear tetrad of four megaspores.
The outer three megaspores degenerate, while the lowermost megaspore becomes functional (Fig. 1.66A). The upper free opening of the integument forms the micropyle and a concavity in between the integument and nucellus in the upper part of the ovule forms the pollen chamber. After pollination the pollen grains are stored in the pollen cham-ber and further development of pollen grains takes place in the nucellar tissue.

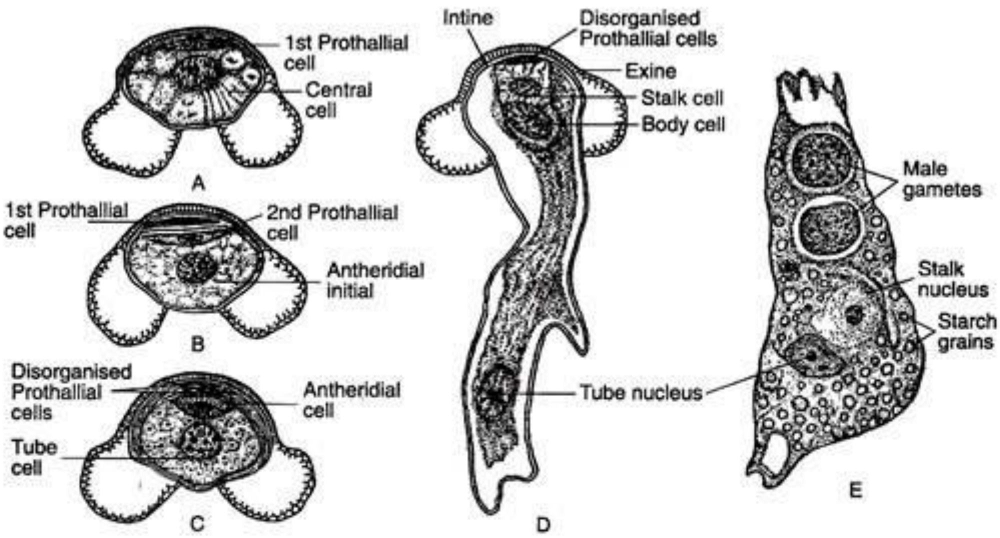


Fig. 1.65 : *Pinus* : A–E. The stages in the development of male gametophyte

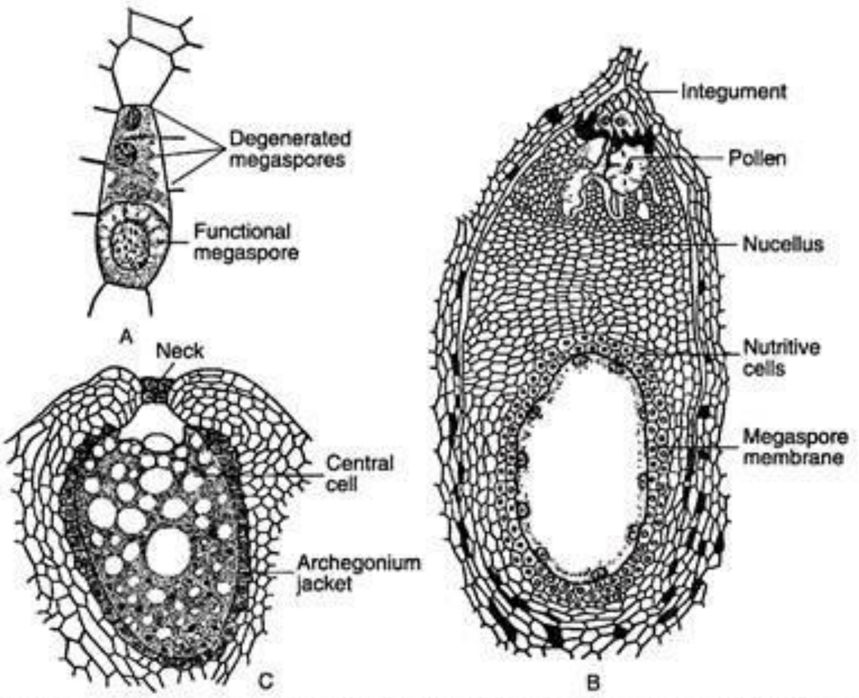


Fig. 1.66 : *Pinus* : A. Linear tetrad showing large functional megaspore, B. Free nuclear stage of female gametophyte, C. An archegonium

Morphological Nature of Ovuliferous Scale:

There is a great controversy regarding the morphological nature of ovuliferous scale and several hypotheses have been put forward.

Some of the earlier theories which have only a historial values are briefly discussed:

1. According to Robert Brown (1827), the ovuliferous scale represents an open foliar carpel bearing naked ovules, present in the axil of bract scale.

2. According to Schleiden (1839), the ovuliferous scale represents an axillary placenta which is situated in the axil of an axillary leaf (bract scale).

3. According to Alexander Brown (1842), the ovuliferous scale is equivalent to the first two leaves of an axillary shoot which had fused.

4. According to van Tieghem (1869), the ovuliferous scale represents a single leaf branch, present in the axil of a leaf (bract).

5. According to the foliar theory of Delpino (1889), both the ovuliferous scale and the bract scale are the parts of a tripartite bract, where the two lateral fertile lobes of the bract were fused to form ovuliferous scale and the median sterile part formed the bract scale.

6. According to ligular or excrescence theory of Sachs (1882) and Eichler (1889), the female cone represents a simple flower where the cone axis is equivalent to recep-tacle or thalamus and bract scale to free carpels. The ovuliferous scale represents an outgrowth of the carpel (bract scale) as in ligule of Selaginella or the placenta of angiosperms.

7. According to brachyblast theory of Braun, the female cone is equivalent to an inflore-scence, where ovuliferous scale represents a determinate axillary shoot bearing two fertile leaves with a single ovule on the dorsal surface of each leaf.

8. Modern hypothesis: On the basis of the comparative studies of the fossil Cordaitales and Voltziales members, Florin (1951) intro-duced a terminology ‘seed-cone complex’ for ovuliferous scale and bract scale, According to Florin, the female cone of Pinus represents an inflorescence where cone axis is the peduncle, bract scale is a true bract and the ovuliferous scale is a rudi-mentary female flower i.e., a modified reproductive shoot.

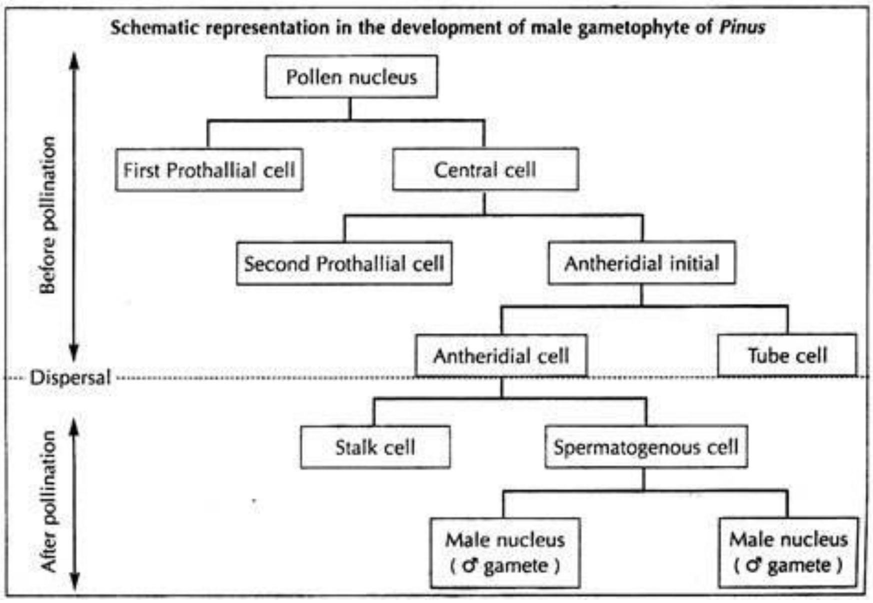
This hypothesis has been substantiated by fossil evidences. The occurrence of several Upper Carboniferous to Triassic seed-cone com-plex in the members of Cordaitales and Voltziales supports the above hypothesis (Fig. 1.56A-D). In Cordaianthus, Emporia and Ernestiodendron of Upper Carboniferous, the cone axis bears several secondary female reproductive shoots in the axils of bracts.

Each secondary shoot consists of many spirally-arranged sterile and fertile (with terminal ovule) scales (showing radial symmetry).

The further evolution took place in the Triassic Voltziales like Glyptolepis, Wallchiostrobus, etc. where the scales were planated (showing bilate-ral symmetry) and tangentially fused to form a rudimentary ovuliferous scale following Telome hypothesis. Thus, it confirms that the ovuliferous scale is a modified reduced secondary female reproductive shoot and bract scale is actually a reduced bract.

Gametophyte of *Pinus*:

The spore is the first phase of gametophyte generation. The microspore or pollen grain represents the male gametophyte, while the megaspore represents the first stage of female gametophyte which develops into a female gametophyte.



i. Development of Male Gametophyte before Pollination:

The basic pattern of the development of male gametophyte of Pinus is similar to that of Ginkgo. The pollen grains undergo endosporic development. The pollen nucleus divides mitotically to produce a small lens-shaped first pro-thallial cell towards the proximal end and a large central cell on the distal end (Fig. 1.65A).

The central cell again cuts off a second prothal-lial cell and an antheridial initial (Fig. 1.65B). Both the prothallial cells are ephemeral and the second prothallial cell remains attached to the first prothallial cell.

The antheridial initial divides to form a small antheridial cell and a large tube cell (Fig. 1.65C). The pollen grains are released from the microsporangium at the 4- celled stage (2 prothallial cells, an antheridial cell and a tube cell).

ii. Development of Male Gametophyte after Pollination:

After pollination, the 4-celled pollen stores in the pollen chamber and remains ungerminated for about 11 months. The pollen develops the next spring. The tube cell of the pollen comes out through the pollen aperture in the form of a pollen tube. The pollen tube proceeds towards the archegonium, penetrating the nucellar tissue of the ovule. The antheridial cell within the pollen tube divides to form a stalk cell and a spermatogenous (body) cell (Fig. 1.65D).

The spermatogenous cell divides to form two male nuclei just prior to fertilisation (Fig. 1.65E). The male nuclei are actually the male gametes which are non-motile and ephemeral.

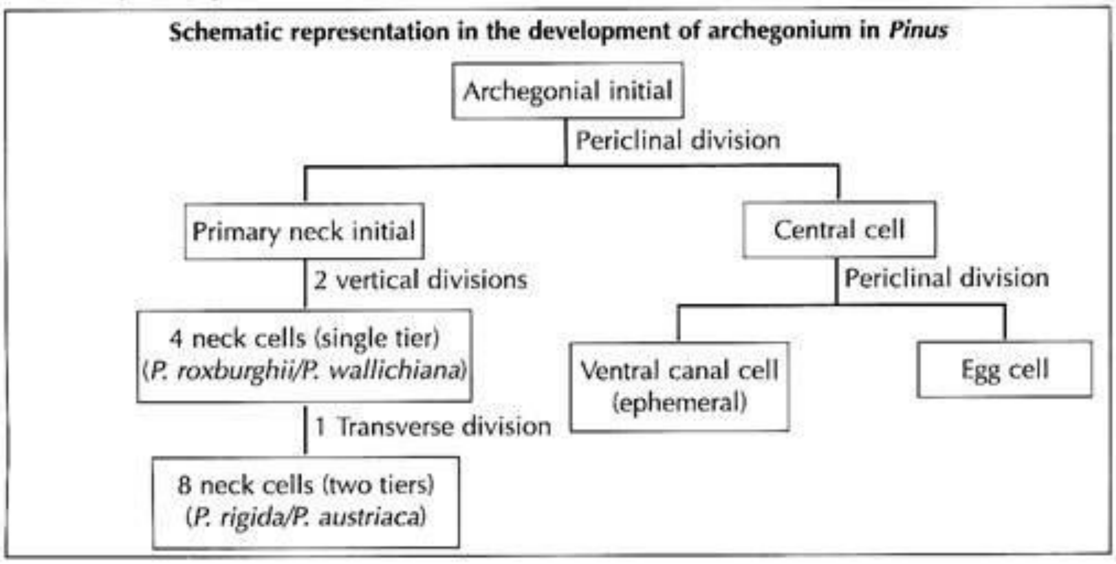
iii. Development of Female Gametophyte:

The female gametophyte of *Pinus* develops from the functional megaspore which enlarges considerably (Fig. 1.66A). The nucleus of the megaspore divides mitotically forming a large number of nuclei unaccompanied by wall for-mation.

The number of free nuclei is constant for a particular species; say for example, it is 2,000 for *P. gerardiana* and 2,500 for *P. roxburghii* and *P. wallichiana*. With the increase in size, the megaspore develops a vacuole at the centre which forces by cytoplasm along with nuclei towards the periphery.

Thus, the nuclei lie in a thin film of cyto-plasm around the vacuole (Fig. 1.66B). There-after, the cell wall formation starts in a centripetal fashion, from periphery inwards. At this stage, numerous radially elongated multinucleate tube--like cells called alveoli are formed and the wall formation takes place through alveoli. Each alve-olus containing a nucleus at its mouth directs its growth.

Then, cross-walls are laid down on each alveolus to form uninucleate cells. In this way, the entire gametophyte becomes cellular and the tissue thus formed represents endosperm or female prothallus (Fig. 1.64).



iv. Development of Archegonia:

The development of archegonia in Pinus is similar to that of Ginkgo. Two to four cells of the female gametophyte at the micropylar end enlarge in size and have dense cytoplasm and prominent nuclei. These cells function as archegonial initials. Each archegonial initial divides periclinally to form an outer small primary neck initial and a large central cell.

The primary neck initial divides by two vertical walls at right angles to each other forming a neck of four cells. Thus, the four neck cells are arranged in a single tier as in P. roxburghii and P wallichiana. However, in P. rigida, P. austriaca the four neck cells again divide transversely to form eight cells which are arranged in two tiers. The central cell enlarges very rapidly and its cyto-plasm becomes vacuolated (Fig. 1.66C).

The nucleus of the central cell divides into an upper ephemeral ventral canal cell and a large egg cell. A nutritive layer called archegonial jacket is differentiated around the archegonium. The nucellar tissue above the archegonia disorga-nises to form an archegonial chamber.

v. Pollination:

Pinus is anemophilous i.e., wind-pollinated. The pollen grains are dispersed and remain sus-pended in the air for some time. At the same time, the nucellar beak in the ovule disorganises form-ing a viscous sugary liquid containing glucose, fructose and sucrose. This fluid comes out in a cyclic phenomenon (24 hr. cycle) through the micropyle in the form of a pollination drop either at night or in the early hours of morning. The pollen grains are caught in the pollination drop and are collected in the pollen chamber as a result of drying off the fluid. The mouth of the micro-pyle is then sealed from the outer environment.

vi. Fertilisation:

The fertilisation takes place after one year of pollination. The pollen tube enters the tip of the archegonium by forcing itself between the cells of the nucellus. The pollen tube wall is disinte-grated by the enzymes secreted from the egg and eventually two male nuclei are released. One of the male nuclei fuses with the egg cell and thus a zygote is formed.

vii. Development of Proembryo:

The zygote nucleus divides by two mitotic divisions forming four nuclei which move to the base of zygote (Fig. 1.67A). All the four nuclei are arranged in one plane and only two nuclei are thus visible in lateral view. A synchronous division gives rise to eight nuclei arranged in two tiers of four each (Fig. 1.67B).

Thus, the upper group of four cells forms the primary upper tier (these cells have no wall towards upper side) and lower group of four cells forms the primary embryonic tier (these cells are bounded by wall all around).

The internal division in both the tiers forms four tiers of four cells each (Fig. 1.67C), and the proembryo thus consists of 16 cells. The lowest tier is known as embryonal tier, (Fig. 1.67D) which further divides to form embryo. The next tier, called suspensor tier, elongates considerably to form the embryonal suspensor.

The third tier is known as dysfunctional suspen-sor (earlier known as rosette tier) which shows abortive meristematic activity. The uppermost or the fourth tier is called upper tier or nutritive tier which provides nutrition.

viii. Embryogeny:

The developing embryonal cells are deeply embedded into the gametophyte by the seven-fold elongation of embryonal suspensor (Fig. 1.67E). Thus the several embryonal suspensors (designated as Es1, Es2, Es3 and so on) are formed. Proximal cells of the embryonal mass elongate unequally to form embryonal tubes.

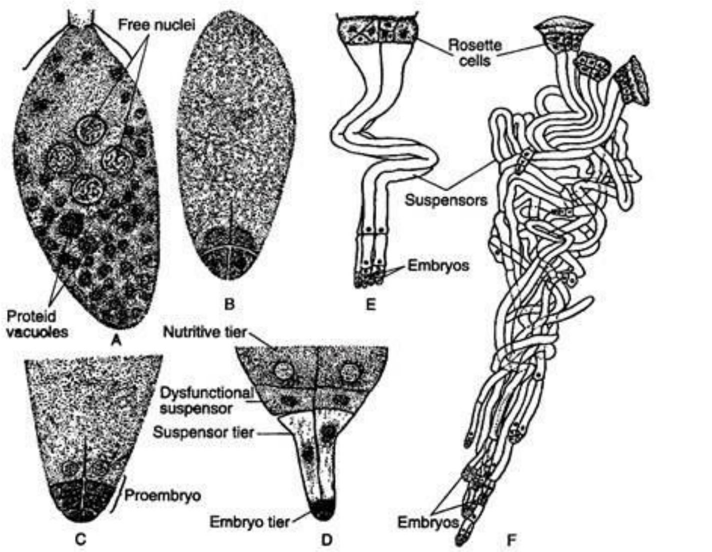


Fig. 1.67 : *Pinus* : A–D. The stages of development of proembryo, E–F. The stages of development of embryo

The cells of the embryonal tier are separated from each other at the time of embryonal suspensor elongation, thus four independent embryos are formed (Fig. 1.67E). This phenomenon is known as polyembryony, because more than one embryo is formed from a zygote (Fig. 1.67F).

As the polyembryony occurs due to the splitting of a zygote, it is called cleavage polyembryony. Only a single deep-seated proembryo develops into an embryo and the growth of other embryos is arrested at different stages of development.

The proembryo divides transversely to form two cells which by further repeated divisions form an embryo. The embryo is comprised of 3- 18 cotyledons, a distinct epicotyl root axis and a hypocotyl shoot axis with remnants of suspen-sor (Fig. 1.68A). Both the two-year and three- year reproductive cycles are exemplified by Pinus species.

In two-year type, the pollination and fertilisation take place in late spring of first and second year, respectively. In three-year type the pollination takes place in spring of first year, and fertilisation in the spring of third year, a lapse of two years. The seeds shed in autumn.

Seeds of Pinus:

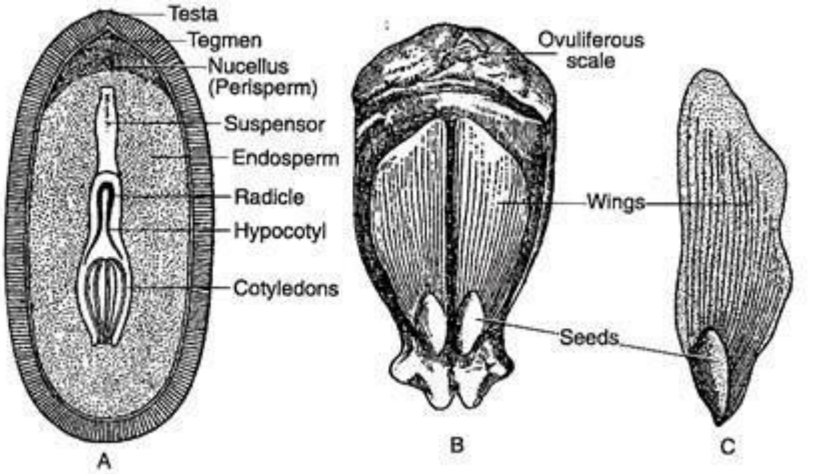


Fig. 1.68 : *Pinus* : A. L.S. of seed, B. An ovuliferous scale bearing seeds, C. A seed with wing

The seeds are endowed with a well-developed wing which is thin and papery and is easily detachable at maturity (Fig. 1.68B). The outer fleshy layer of integument and part of ovuliferous scale contribute to the wing forma-tion (Fig. 1.68C). The seeds are usually dispersed by wind. The embryo remains embedded within the endosperm.

The seeds of Pinus remain viable for a long time. The germination of seed is epigeal.

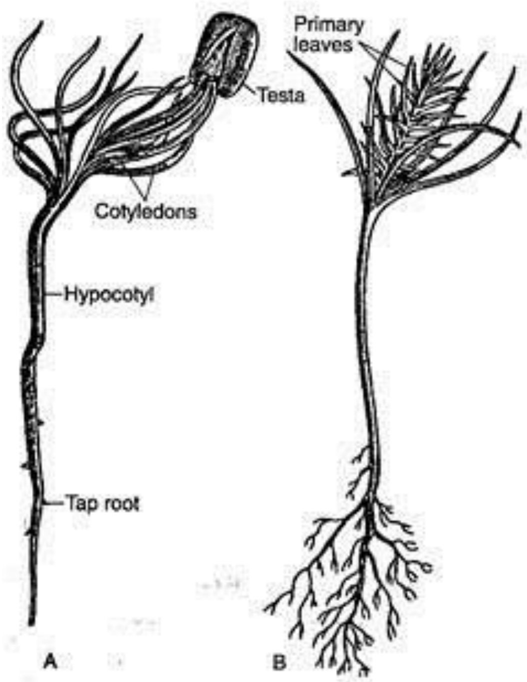


Fig. 1.69 : A–B. The stages in germination of seed

Origin and Relationship of Pinus:

The conifers are large and diversified group of extant gymnosperms. The Pinaceae is the largest family of the modern conifers. The conifers had evolved from the members of Permo-Carboniferous Voltziales, commonly known as "transition conifers". They reached their climax in mid-Mesozoic forming extensive forests in Northern Europe.

Among the living families, Pinaceae and Araucariaceae are more primitive, probably evolved during the Triassic age. On the other hand, Cupressaceae and Cephalotaxaceae are comparatively younger which have evolved probably during Upper Jurassic to Lower Cretaceous period.

Pinus is the large and well-representative genus of the family Pinaceae. It indicates relationship with Cycadales, Ginkgoales and Cordaitales.

Relation to Cycadales:

The similarities between Pinus and Cyca-dales are:

i. The stem anatomy shows a broad pith, large cortex and centripetal wood.

ii. The presence of haplocheilic, sunken sto-mata in leaves.

iii. The presence of leaf sclerenchyma.

iv. The seeds are with three-layered integu-ment.

v. The presence of free-nuclear divisions in the development of female gameto-phyte.

Relation to Ginkgoales:

The resemblance between Pinus and Ginkgoales are:

i. The plants are profusely branched showing excurrent habit.

ii. The shoots are dimorphic, bearing long shoots and dwarf shoots

iii. The wood is pycnoxylic.

iv. The leaves are with haplocheilic sunken stomata.

v. The mature wood shows pitting and Bars of Sanio.

Relation to Cordaitales:

Conifers have derived from the members of Voltziales which are considered as 'transition conifers' between Cordaitales and Conifers. Thus, Pinus shows striking similarities with Cordaitales.

These include:

i. The plants are tall-branched trees.

ii. The leaves are sample with paralled veins.

iii. The presence of sclerenchymatous hypoder-mis in the leaves.

iv. The presence of pycnoxylic wood.

v. The pollen grains are winged.

vi. The ovules are bilaterally symmetrical.

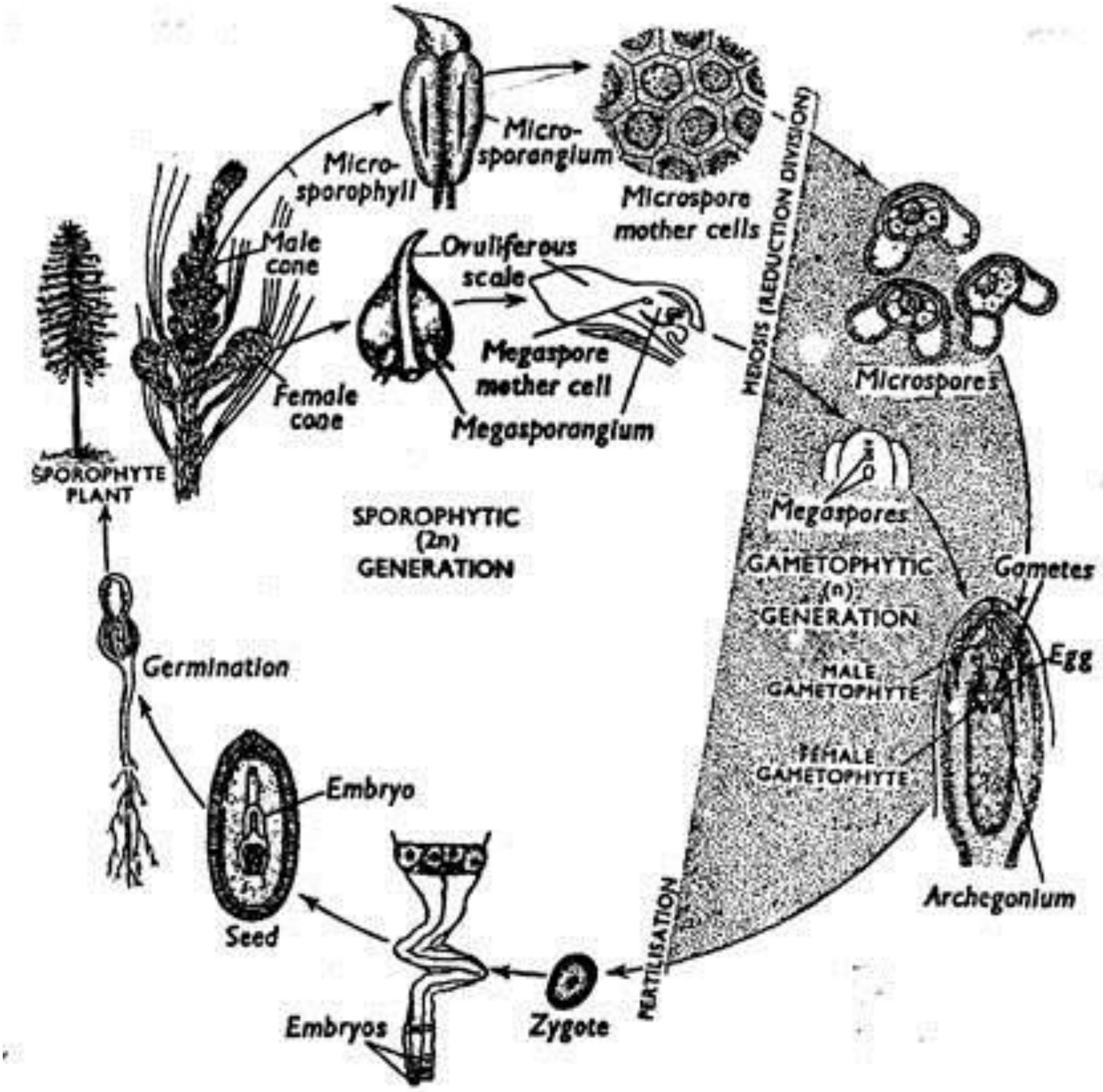


Fig. 1.70 : Life cycle of *Pinus*