3. PINUS

Unit - III

3.1 SYSTEMATIC POSITION

Division	-	Gymnospermae
Class	-	Coniferopsida
Order	-	Coniferales
Family	-	Pinaceae
Genus	-	*Pinus*

3.2 GEOGRAPHICAL DISTRIBUTION

Pinus is the most dominant genus of the order *Coniferales*. The plants are widely distributed in the northern hemisphere. They usually grow on the slopes of hills and form dense and extensive ever green forests in the north - temperate and sub-alpine regions. The plant is introduced as ornamental and timber plant in much of the southern hemisphere. Many pines are fast growing species, tolerant of poor soils and relatively arid conditions. So they became popular in reforestation programmes.

The genus *Pinus* is represented by 90-110 species. Of these six species are indigenous to Indian sub continent. They are distributed in North - East and North - West Himalayas. The following species are known to occur in wild state.

1. ***P. roxburghii*** **(syn. *P. longifolia*) :** It is popularly known as '*chir pine*' and is the most important among Indian pines. It is very common and grows from 450 - 2250 m in the Western Himalayas, extending upto Bhutan. The plant attains a height of 50-60 metres and varies in diameter from 1.5 to 3 metres. Each foliar spur has **three needles** and the needles are triangular in cross section. Seed cones are shortly pedunculate and ovoid.

2. ***P. wallichiana*** **(syn. *P. excelsa*) :** It is commonly known as *Blue pine* or *Bhutan pine* and commercially known as '*Kail*'. It is found growing from 1800-2100 metres. It forms forests in the hills of Kashmir, Himachal Pradesh and Punjab. It is an ever green tree with glaucous bluish foliage. The leaves are **pentafoliate** and the female cones are cylindrical in shape.

3. ***P. insularis*** **(syn. *P. keysia, P. khasiana* and *P. khasya*) :** It is known as *Khasi Pine* and grows only in the khasya region of Assam at an altitude of 700-1850 metres. The plant attains a height of 75 feet to 100 feet and the foliage spurs are **trifoliate**. Seed cones usually solitary or paired, ovoid.

4. ***P. gerardiana*** **(Chilgoza pine) :** The species is common in drier arid ranges in Kashmir, Kinnaur district of Himachal Pradesh and Afghanistan. The plants prefer scanty rainfall and heavy snowfall. The seed cones ovoid, brown at maturity. The dwarf shoots bear **three needles**.

5. *P. merkusii* (Merkus pine) : The plants grow on the hillocks in Bengal, Assam and Arunachal Pradesh at an altitude of 150-600 meters. The plant is only 3-4 metres high with **bifoliate** spurs.

6. *P. armandi* (Armand's pine) : The plants are common in NEFA region at an altitude of 1500 metres. Leaves are **pentafoliate**. The plant attains a height of 35 metres, needles 5-7 per spur, needles sharply bent.

Richardson (1998) recognized three sub genera in this genus. They are :

(i) Subgenus **Pinus** - Typical or hard pines, includes about 73 species. Each needle shows two vascular bundles (Diploxylon), foliage shoots with 2-6 leaves.

e.g. *P. sylvestris, P. roxburghii.*

(ii) Sub genus **Strobus** - white or soft pines ; includes about 25 species. Each needle with single vascular bundle (Haploxylon), fascicles with 5 leaves.

e.g. *P. armandi, P. wallichiana.*

(iii) Subgenus **Ducampopinus** - Fox tail pines, includes about 20 species. Leaf vascular bundle single (Haploxylon), fascicles with 1-5 leaves.

e.g. *P. gerardiana, P. monophylla.*

3-3 EXTERNAL MORPHOLOGY OF SPOROPHYTE

Pinus is a beautiful tall tree, which varies in height from 70 feet to 200 feet. The horizontal branches are arranged in whorls, giving the tree a pyramidal appearance. The tree starts loosing its shape with age. The plant body is differentiated into root, stem and leaves.

(A) Root : The primary root is a typical tap root. It is short lived because the tree frequently grows on shallow soils of hill slopes. The lateral roots grow

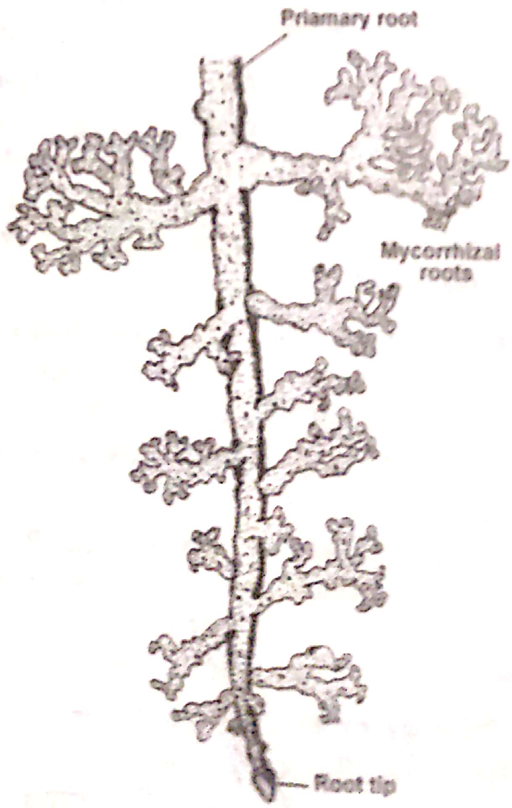


Fig. 3·1 : Mycorrhizal roots in *Pinus*

extensively and help the plant to keep firmly in the soil. Root hairs are poorly developed. The root lets are covered with fungal hyphae to form *mycorrhizal roots.* The fungi present in mycorrhizae are mainly the species of *Amanita, Boletus, Clavaria* and *Scleroderma* of Basidomycotina. They remain in symbiotic association with the roots and help in water absorption by the roots.

(B) Stem : The stem is erect, cylindrical, woody and branched. The main stem is covered with rugged scaly bark. The branches are monopodial and develop spirally in the axils of scale leaves. Such a branching gives a conical appearance to the plant. The stem is dichotomously branched in *P. sabiniana.*

In *Pinus,* the branches of two types viz., the long shoots and the dwarf shoots.

Long Shoots : These are the normal branches, which arise at regular intervals on the main trunk. They bear an apical bud enclosed in bud scales. Each long shoot arises as a lateral bud in the axil of a scale leaf. These lateral buds grow horizontally on the main stem to a certain length and is referred to as nodal growth. In some pines, this growth produces a single internode in a year (uninodal pines) or many internodes are formed in a year (multinodal pines). These branches bear only scale leaves.

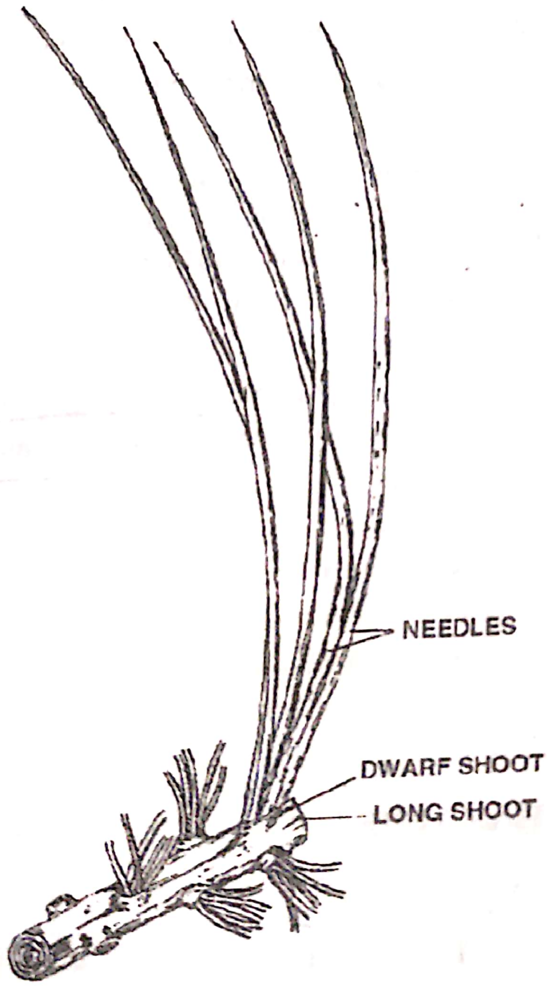


Fig. 3·2 : Vegetative branches of *Pinus*

Dwarf shoots : These branches arise in the axil of scale leaves on the long shoots. They have ephimeral apical buds and show only limited growth hence called **branches of limited growth.** Each dwarf shoot bears two opposite scaly leaves, called prophylls followed by 5-13 spirally arranged scaly, cataphylls in 2/5 phyllotaxy. The dwarf shoots terminate with a cluster of needle like foliage leaves. The dwarf shoots with their cluster of needles are known as *spurs*. The dwarf shoots are shed every 2-3 years, leaving scars on the stem.

(C) Leaves : The leaves are of two kinds *i.e.* dimorphic. They are the scale leaves and foliage leaves.

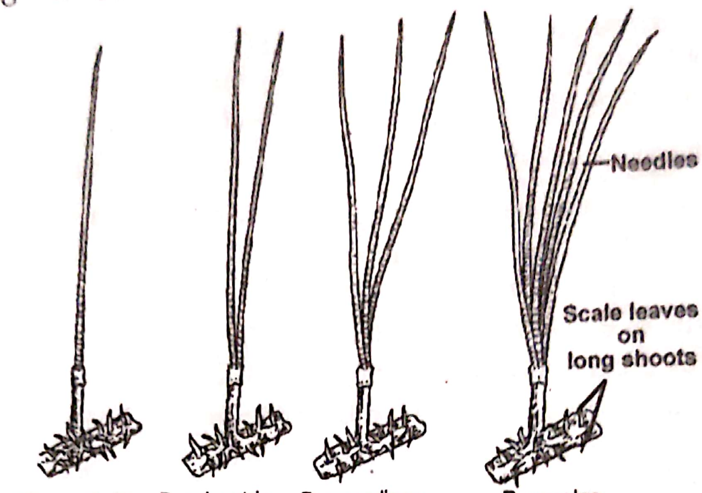


Fig. 3·3 : Various kinds of foliar spurs

(i) *Scale leaves* : The scale leaves are thin, membranous, flattened, dark brown structures. They are borne on both long and dwarf shoots. They fall off as the branches mature. Their main function is protection of young buds. The scale leaves on the dwarf shoots have a distinct mid rib and they are called *cataphylls*. Dwarf shoots, male and female cones arise in the axis of scale leaves on the long shoots.

(ii) *Foliage leaves* : The foliage leaves are green, long, narrow (acicular) and needle - like. So the foliage leaves are commonly known as needles. They are borne only on dwarf shoots in clusters of two (*P. sylvestris, P. merkusii*), three (*P. roxburghii*), four (*P. quadrifolia*) or five (*P. excelsa, P. armandi*). In *P. monophylla* only one leaf is produced on dwarf shoot. The dwarf shoots bearing the foliage leaves are known as "*Spurs*". The needles are persistent. They fall only when the spur is shed as a whole. Hence the *Pinus* tree is evergreen. The foliage leaves are photosynthetic. The needle - like nature of the foliage leaves indicates xerophytic adaptation of these plants.

3-4 INTERNAL STRUCTURE

A Anatomy of Root :

The primary root of *Pinus* resembles a dicot root in the arrangement of tissues. In consists of piliferous layer, cortex and stele.

(i) Piliferous layer : It is the outermost layer, which is composed of tightly packed cells. The cells give rise to unicellular root hairs. Root hairs are poorly developed, as the young root forms mycorrhizal association.

(ii) Cortex : Just beneath the piliferous layer, there lies a broad cortex. It consists of 4-5 layers of thin parenchymatous cells. The innermost layer or cortex is differentiated into *endodermis*. The endodermis consists of a single layer of brown suberised cells containing tannin in them.

(iii) Stele : The stele is surrounded by many layered pericycle. The cells contain resins and tannin. The second layer of the pericycle gives rise to the lateral roots.

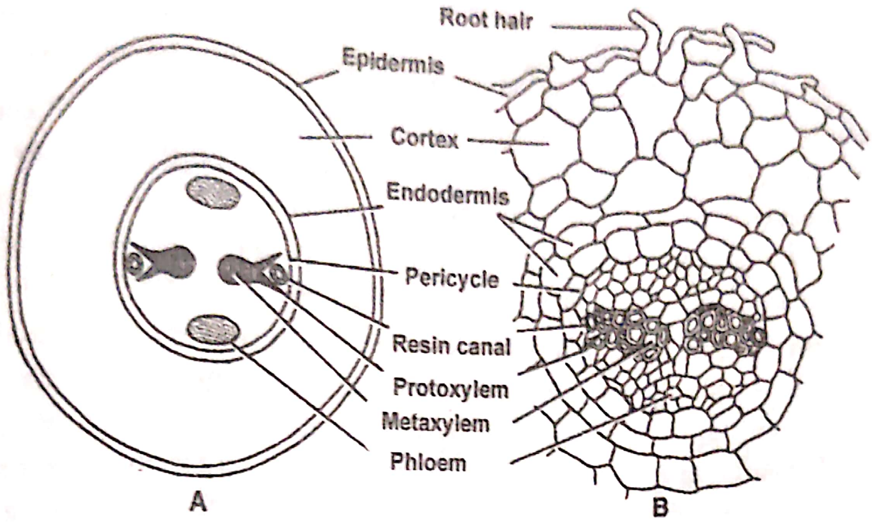


Fig. 3·4 : *Pinus* - Young root

(A) Diagrammatic representation of transverse section; (B) Sector enlarged

The roots are *diarch* to *tetrarch* with *radial* and *exarch* vascular bundles. The protoxylem bifurcates to form a y-shaped structure and a resin duct lies in between the two arms of the protoxylem. The xylem consists of only tracheids. Vessels are absent. Phloem strands alternate with the xylem strands. Phloem consists of sieve tubes and phloem parenchyma. Companion cells are absent. The pith cells are rich in starch. The primary medullary rays arise opposite to each protoxylem group. Secondary growth takes place in the manner similar to dicot root.

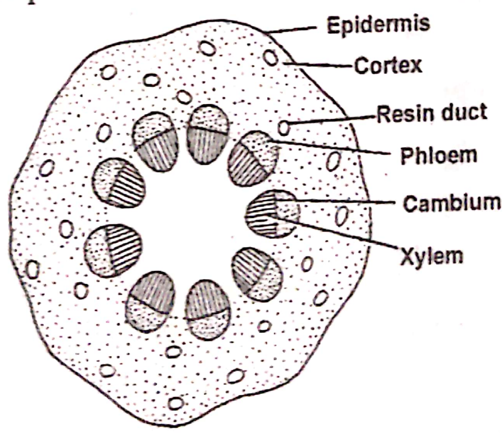


Fig. 3·5 : T.s. Young stem (diagrammatic)

B Anatomy of Stem :

Primary Structure : A young stem of *Pinus* is more or less identical to the dicot stem in the arrangement of tissues. The stem shows wavy outline due to the presence of leaf bases and dwarf shoots.

Epidermis : It is the outermost layer composed of compactly arranged and heavily cutinised cells. The epidermis bears, scattered stomata.

Cortex : The cortex is multilayered, but not extensive. The hypodermis is formed by a few layers of sclerenchyma cells. The inner cortex consists of thin walled parenchyma cells. Presence of resin canals is a characteristic feature of the cortex. Each resin canal is surrounded by a layer of glandular *epithelial cells*, which secrete resin. Each resin canal lies outside the vascular bundle.

The inner most layer of the cortex forms the endodermis, however it is not clearly demarcated. The pericycle is parenchymatous and inconspicuous.

Vascular Tissues : The vascular cylinder is of *eustelic* type. It consists of a ring of five to eight closely placed vascular bundles. The bundles are **conjoint, collateral, endarch** and **open.** The bundles are separated from one another by narrow medullary rays. Each bundle has primary phloem on the outside and primary xylem on the innerside with primary cambium in between the two.

The primary phloem consists of sieve tubes and phloem parenchyma. There are no companion cells. Some albuminous cells are also present in the phloem which are associated with sieve tubes like companion cells. The primary xylem contains tracheids. **Vessels are absent.** The protoxylem is *endarch*. The protoxylem elements have a loose spiral thickening with a few small bordered pits on its radial walls. The metaxylem elements are reticulate and pitted. The bordered pits on their radial walls are large and uniseriately arranged.

Pith : Centre of the stem is occupied by thin walled parenchymatous pith. Some of the pith cells are filled with resinous substances.

C Secondary growth in Stem :

The stem of *Pinus* grows in thickness by secondary growth, in the same way as in dicot stems. Interfascicular strips of cambium develop in the primary medullary rays in between the vascular bundles. The strips of interfascicular cambium join with the intrafascicular cambium in the vascular bundles and form a complete ring of cambium. The cambial cells cut off secondary xylem towards the innerside and secondary phloem to the outside. The secondary vascular tissues are added continuously due to the activity of the vascular cambium and as a result the stem increases in girth. The primary phloem and xylem are crushed due to the presence of secondary vascular tissues.

Secondary wood consists of tracheids, traversed by rays. The tracheids are about 4 mm long and pointed at both ends. Bordered pits occur on their radial and tangential walls. Bordered pits are uniseriate and are separated by crescent shaped structures called bars of sanio. If bordered pits are in two rows they are placed opposite to each other. Such pits are called *Abietinian pits*. Resin canals are also present in the secondary wood. Vessels and xylem fibers are absent.

The secondary phloem consists of sieve cells and phloem parenchyma. The sieve cells are elongated, taper at both their ends and possess sieve plates on their radial walls. The companion cells are absent, but phloem parenchyma and albuminous cells are present.

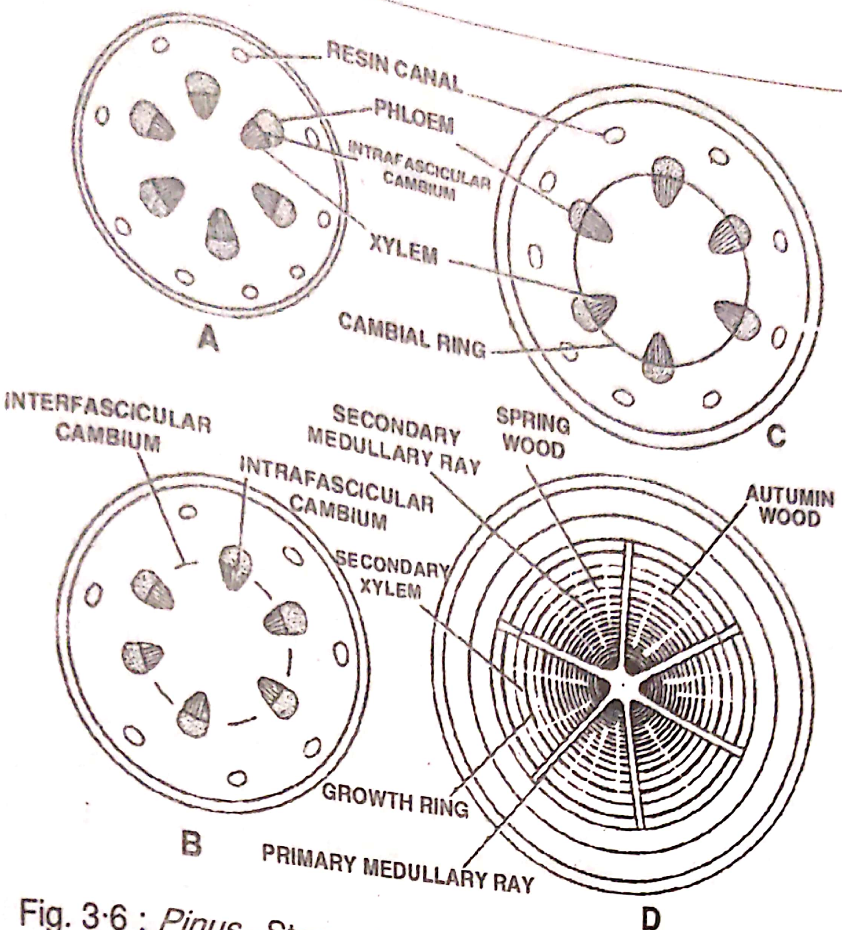


Fig. 3·6 : *Pinus* - Stages in secondary growth of a long shoot

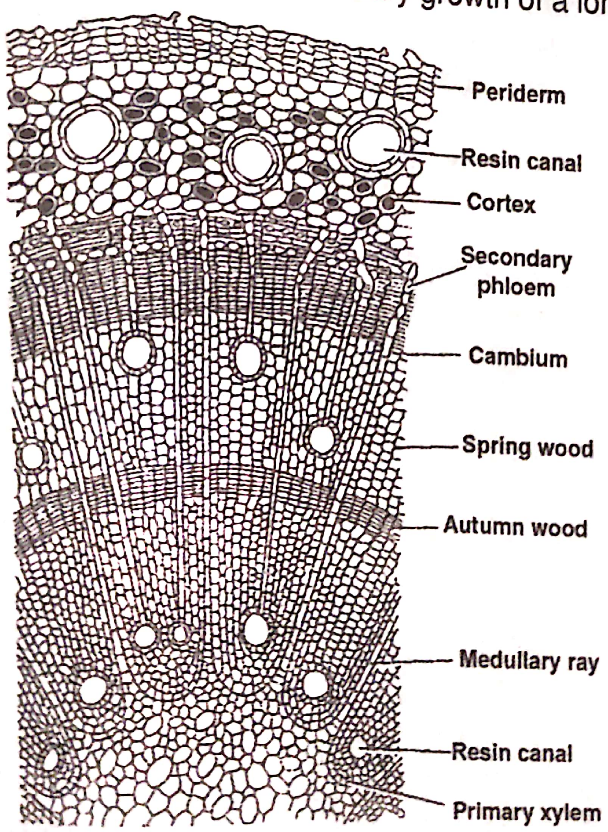


Fig. 3·7 : *Pinus* - T.s. of mature long shoot

Annual rings : Every year (winter - spring summer - autumn) the cambium forms a band of secondary xylem and secondary phloem. The successive bands of secondary xylem are quite distinct from each other. In a cross section it appears as a series of concentric layers. Each layer or band represents a year's growth and is commonly called as an *annual ring*. The annual rings are formed due to the difference in the size of tracheids formed in the spring as compared with those formed in the autumn. In spring season (warm weather) new leaves and branches are formed and thus there is active translocation of water and nutrients. Hence the tracheids formed in this season are broad, polygonal, thin - walled with large bordered pits. In autumn (cool weather) when there is leaf - fall, active transportation of water and nutrients is not required. Hence, the trancheids formed in this season are squarish with narrow lumen, thick - walled, with small bordered pits.

Autumn wood and spring wood formed in a year constitute an *annual ring*. The age of a plant can be calculated with help of these annual rings.

Periderm or york : Concurrently with the secondary growth in the vascular region, a lateral meristem known as *phellogen* or *cork cambium* develops in the outer region of the cortex. The phellogen divides periclinally to cut off *cork cells* (phellem) towards the outerside and secondary cortex (phelloderm) towards the innerside. As the stem increases in girth, the epidermis ruptures and the cork cells form a protective covering. The cork cells are impervious to water and check transpiration from the stem surface. The phellem, phellogen and phelloderm together form the *periderm* or *bark*.

Secondary Medullary Rays : During secondary growth, the primary medullary rays are replaced by secondary medullary rays. They are formed from the fascicular cambial cells. They traverse the secondary xylem and phloem zones at certain places. They vary is size from 2-12 cells in height and are only one cell broad (uniseriate). However the rays associated with the resin canals are multiseriate.

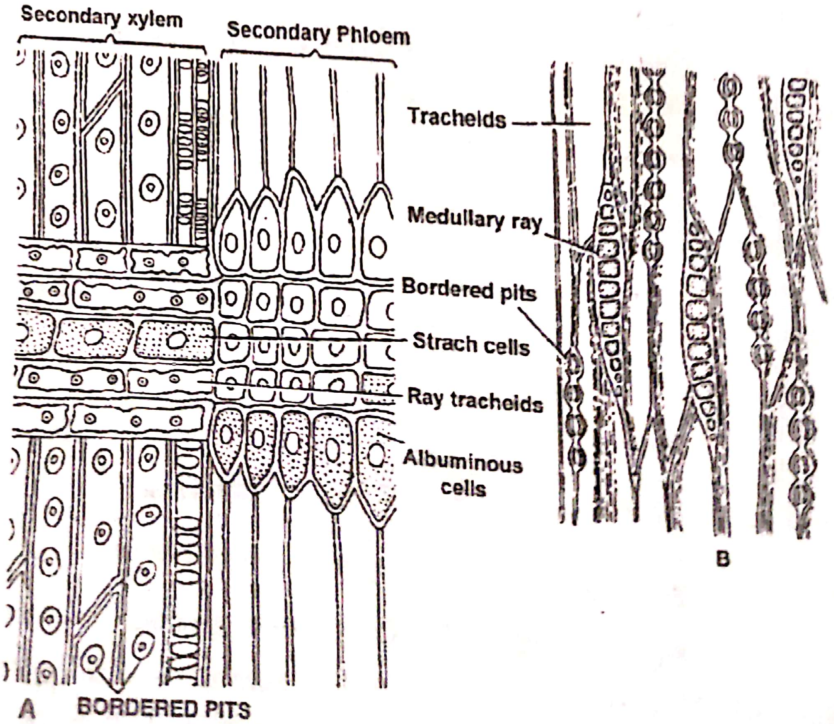


Fig 3.8 : Secondary wood - (A) Radial longitudinal section, (B) Tangential longitudinal section

New medullary rays are formed each year, alternating with those previously laid down. The secondary wood consists of exclusively dead tracheids. It lacks wood parenchyma. So the radial diffusion of food materials become a matter of difficulty. The secondary medullary rays have a significant role in this connection.

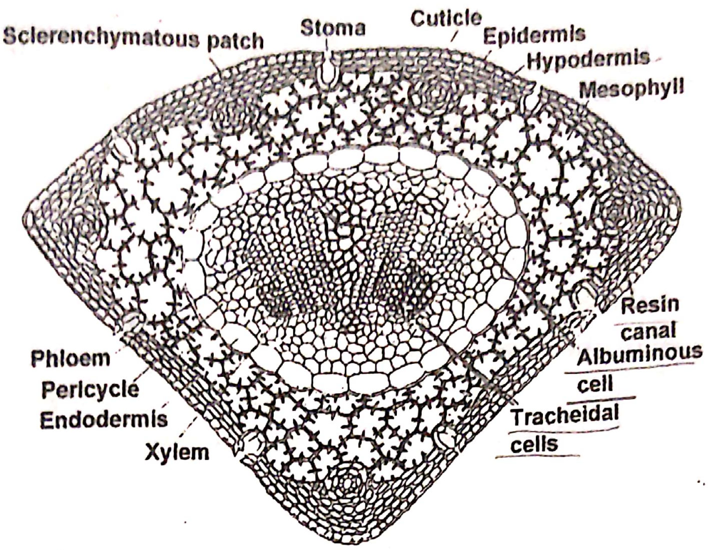


Fig. 3·9 : *Pinus* - T.s of Needle

Structurally the medullary rays are much more complex than those of the dicotyledons. The rays in the secondary wood consists of thin walled rectangular parenchymatous cells containing cytoplasm, a nucleus and starch grains. They possess simple pits. The starchy layer is surrounded on either side with 2-3 layers of dead *tracheidal cells*. They are elongated, horizontally situated in one or two rows and are called *marginal ray tracheids*. The marginal ray tracheids have bordered pits on their lateral and end walls. Thus, they allow radial diffusion of fluids and compensate the lack of wood parenchyma. The areas of mutual contact between the medullary ray tracheids and the tracheids of the wood communicate with each other by simple pits. They are known as the *pits in the field*.

The medullary rays in the secondary phloem region also consists of living starch - filled parenchymatous cells. But in this region, marginal ray tracheids are absent. Their place is taken up by large thin walled cells which are elongated vertically. They are commonly called the *albuminous cells*. They contain protein.

In a radial longitudinal section (R.L.S) of the wood, the medullary rays are cut length wise and their height and length can be observed. The ray is seen crossing the tracheids in a horizontal direction. The bordered pits are seen in surface view on the radial walls of the tracheids. The pits are uniseriate. A tangential longitudinal section (T.L.S) of the wood cuts across the medullary ray. So this section shows the height and width of the ray. The bordered pits are seen in section on the radial walls of the tracheids which are cut through in this case. The rays with a single row of cells are called *linear vascular rays*. The rays which include a resin canal become multiseriate and fusiform. Such rays are called *fusiform vascular rays*. The rays vary in size from 2-12 cells in height.

D Anatomy of Foliage Leaf :

The foliage leaf (needle) of *Pinus* reveals a structure that makes it adaptable to with stand the low temperature and scarcity of water supply. It is therefore spoken of as *xeromorphic*.

The outline of needle in a transverse section depends on the number of needles present in a spur. For example it is circular in *P. monophylla* (with one needle), semi - circular in *P. sylvestris* (with two needles) and triangular in *P. roxburghii* and *P. wallichiana* with three needles in a spur.

The transverse section of the needle shows the following structure.

1. **Epidermis :** The epidermis consists of a single - layer of thick - walled cells, covered by a thick cuticle. Sunken stomata are present on all sides of the leaf (diploxylon pines) or they may be absent on the outer surface of the needle as in some haploxylon Pines. The stoma are developed in longitudinal rows. Each stoma consists of two guard cells, situated well below the level of the epidermis. It opens internally into a sub-stomatal cavity.

2. **Hypodermis :** The epidermis is followed by 2 - 3 layers of sclerenchymatous hypodermis. It is well developed at the corners. The hypodermis is frequently interrupted by airspaces beneath the stomata.

3. **Mesophyll :** The mesophyll is parenchymatous and is not differentiated into palisade and spongy tissues. It consists of thin - walled polygonal cells with abundant chloroplasts and starch grains. The walls of the mesophyll cells give rise to many peg - like or plate - like infoldings which increase the photosynthetic area of these cells. These are known as arms, flanges or simply folds. They increase the internal photosynthetic and respiratory area and in a way compensate for the reduction of the leaf surface.

Beneath the hypodermis, 2 - 3 resin canals are present. Each resin canal has a layer of secretory epithelial cells, which is surrounded on outside by a sclerenchymatous sheath.

4. **Endodermis :** Inner to mesophyll, there is a layer of barrel - shaped cells forming the endodermis. These cells are without chloroplasts but starch may be present. The endodermal cells are devoid of casparian strips.

5. **Pericycle :** The pericycle is multilayered and consists of four types of cells.

(i) Parenchymatous cells : Most of the pericycle is made up of ordinary parenchyma cells, containing starch grains. They form the *transfusion tissue.*

(ii) Albuminous cells : These cells occur above the phloem of vascular bundles. They are also parenchyma cells but are filled with proteins and starch grains.

(iii) Tracheidal cells : These are tracheid - like cells which occur close to the xylem of vascular bundles. The cells possess bordered pits and help in conduction of water and nutrients to mesophyll.

(iv) Sclerenchymatous cells : These cells form a T- shaped girdle above the two vascular bundles.

6. **Vascular bundles :** The number of vascular bundles vary in different species of *Pinus*. As early as 1893, Koehne divided the genus *Pinus* into **haploxylon** (with one bundle) and **diploxylon** (with two bundles) by studing the anatomy of the needle. When there is only one bundle (*P. wallichiana*) it is medianly placed. In those species, where there are two vascular bundles (*P. roxburghii*) they are placed at right angles to each other. The vascular bundles are collateral, open and endarch. Xylem consists of radial rows of tracheids, alternating with rows of parenchyma cells and albuminous cells. Phloem consists of sieve cells and parenchyma. Cambium is present in the vascular bundle. It cuts off secondary phloem and little or no secondary xylem. One or two layers of secondary phloem is formed every year.

Xerophytic characters of *Pinus* needle :

1. The needles are needle - like and acicular.
2. Epidermal cells are thick - walled and covered by thick cuticle.
3. Sclerenchymatous hypodermis.
4. Sunken stomata.
5. Presence of resin ducts.
6. Peg - like infoldings of the walls in mesophyll cells.
7. Presence of sclerenchymatous tissue over the vascular bundles.
8. Presence of peculiar transfusion tissue.
9. Presence of simple vascular system.

microsporogenesis - male cone
megasporogenesis - female cone

3-5 REPRODUCTION

heterosporous

The adult plant of *Pinus* is a sporophyte. It forms two types of spores - microspores and megaspores which develop into male and female gametophytes respectively. The plants are *monoecious i.e.*, male and female cones are formed on different branches of the same plant. The male cones arise on the lower and the female cones on the upper branches. Bisporangiate cones occur occasionally in some species. *e.g. P. montana, P. roxburghii, P. maritima.*

A Male cone :

The male cones are also known as staminate cones. They develop in the axils of scale leaves on the branches of unlimited growth. As the dwarf shoots are normally produced in the axils of scale leaves, the male cones are considered as modified dwarf shoots.

The male cones develop in groups of 15 to 140, just behind the apical bud on the branches of unlimited growth. The main shoot thus continues to grow further. The male cones can be seen on the Pine tree in the beginning or middle of March in the hills and in January or February in the plains. The shedding of pollen grains starts towards the end of April and continue, till the beginning of June. The young cones are green or reddish purple, but becomes yellow at the time of shedding. After the pollen is shed, the male cone withers and falls off.

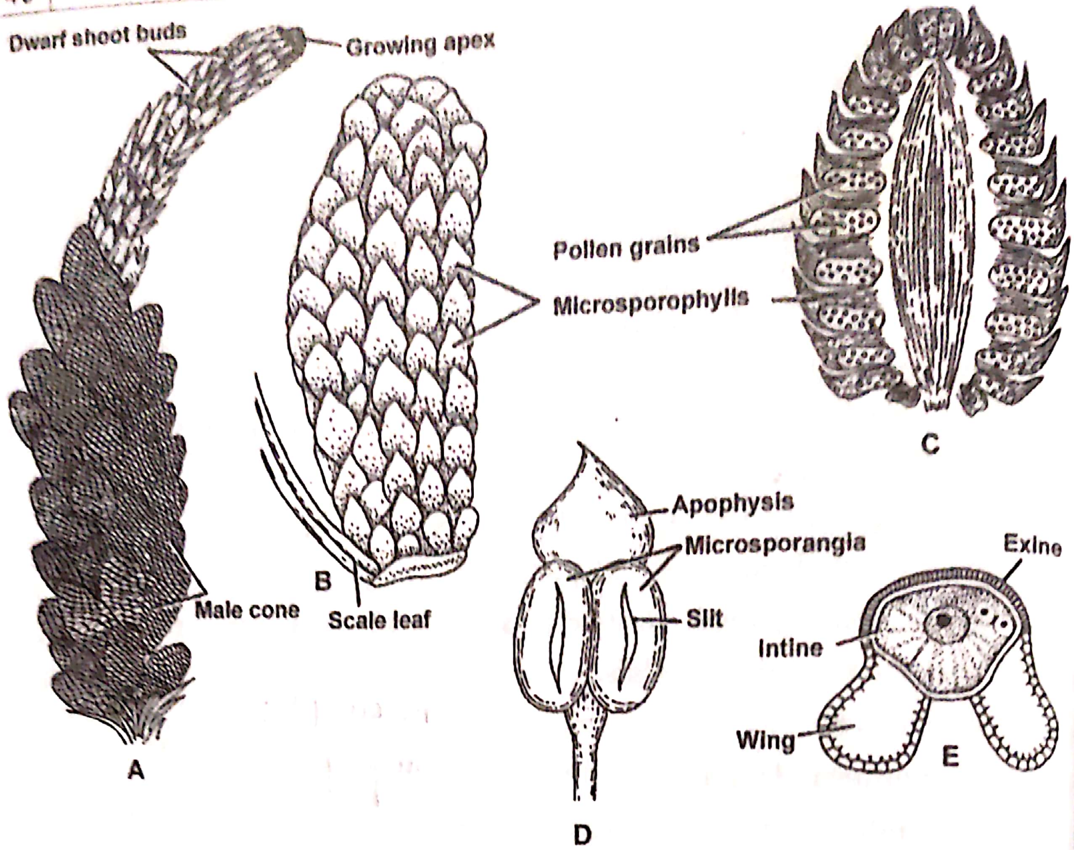


Fig . 3·10 : *Pinus* - Male cone. (A) A group of male cones,(B) A single male cone, (C) Longitudinal section of male cone, (D) Microsporophyll, (E) Pollen grain

The male cone is ovoid in outline and measures about 3-4 cm long and 0.64 cm diameter. At the base of the cone there is an involucre consisting of a number of small imbricate bracts. The microsporophylls are borne spirally on a central axis, which is devoid of bracts. The male cone, therefore, becomes homologous to a male flower of Angiosperms, and not to an inflorescence.

Microsporophylls : The microsporophylls (Stamens) are arranged spirally at right angles to the cone axis. Each sporophyll is triangular in outline and consists of a short stalk and a leaf like expanded structure. Two pollen sacs or microsporangia are present on the lowerside (abaxial surface) of the sporophyll. Each sporangium is filled with numerous **winged microspores**. The scales situated at the base of the cone are sterile.

Development of Microsporangium : The development of microsporangium is of *eusporangiate* type and superficial. A group of hypodermal cells take part in the sporangium development. These cells divide periclinally to form the outer *parietal cells* and inner *archesporial cells*. The parietal cells divide and produce a 4 - layered wall of the microsporangium. The wall consists of epidermis, two middle layers and a glandular tapetum. (Fig. 3·11)

The inner archesporial cells divide to form *sporogenous cells* which ultimately differentiate in to *microspore mother cells*. These cells are polygonal in outline and contain prominent nuclei and dense cytoplasmic contents. The microspore cells under go meiosis to form tetrads of *microspores*. Later the spores separate from the tetrads. According to Sethi (1928) in *P. roxburghii*, meiosis takes place during the last week of January.

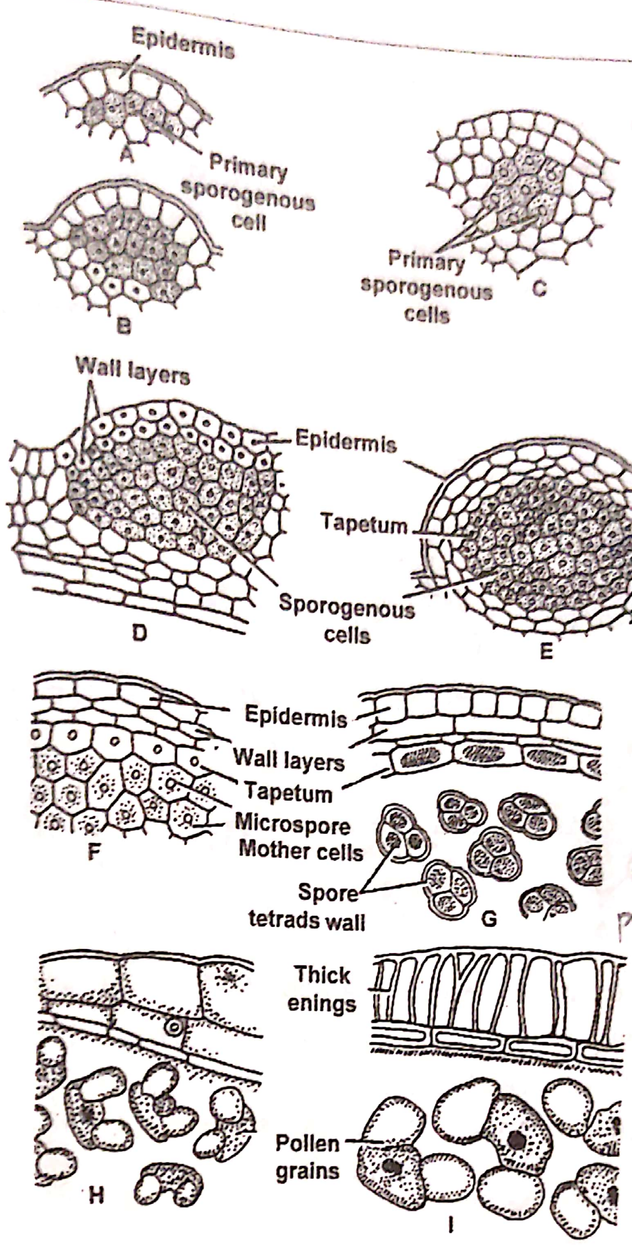


Fig. 3·11 : *Pinus* - Development of microsporangium and microspores

Dehiscence of Microsporangium : At maturity, the sporangial wall splits longitudinally on the dorsal surface. The pale yellow coloured pollen grains are released through the slit in the form of a dust. In India, dehiscence of microsporangia takes place in warm and dry environmental conditions during March - June period. The microspores are liberated in such a large number that pine forests appear yellow at the time of dehiscence. This is called '*shower of sulphur*'. After the pollen is shed, the male cone withers and falls off.

B Female Cone :

Female cones are also known as '*ovulate strobili*'. They are fewer in number and arise single or in a small cluster of two to four. They arise as a bud in the axil of a scale leaf towards the end of the new shoots of unlimited growth. They replace the branches of unlimited growth. The female cones take about three years to mature. The young cones are small, compact, erect, reddish to pinkish in colour.

The second year cones are large and woody with sporophylls still compactly arranged. The third year cone becomes loose and the sporophylls separate from one another due to the elongation of the cone axis.

The female cones are much larger than the male cones. They are usually 15 - 20 cm long and 3 - 4 cm in diameter. The cones may attain a length of about 60 cm in *P. lambertiana*. The female cones are initiated in the month of February in hills and March in plains. They are protected by an involucre of bract scales. The cone axis elongates in April and the cone thus protrudes out of its involucre of bracts. The seeds are shed when the cone is 22 months old.

female cones are larger

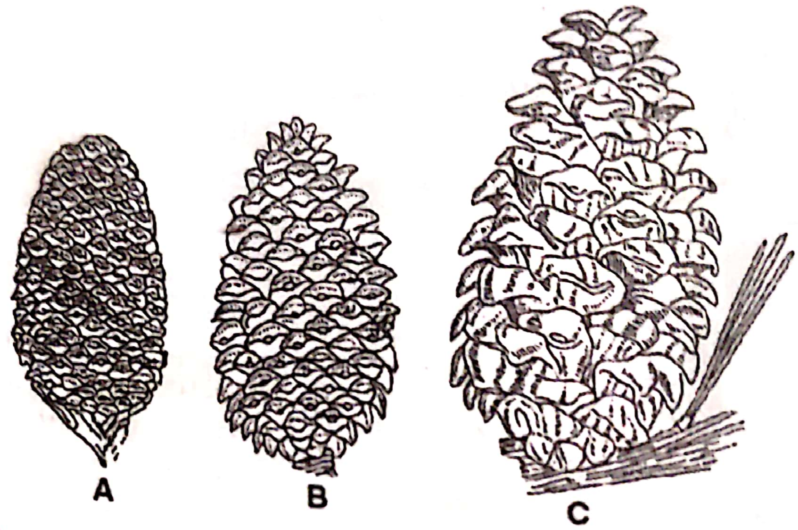


Fig. 3·12 : *Pinus* - Female cone. (A) 1st year cone, (B) 2nd Year cone, (C) 3rd year cone

The female cone is much complicated in structure. Like the male cone, it consists of a central axis, which bears paired scales (20-80) in a close spiral. The lower scale of the pair is small. It is called is the *bract scale*. It is leathery and

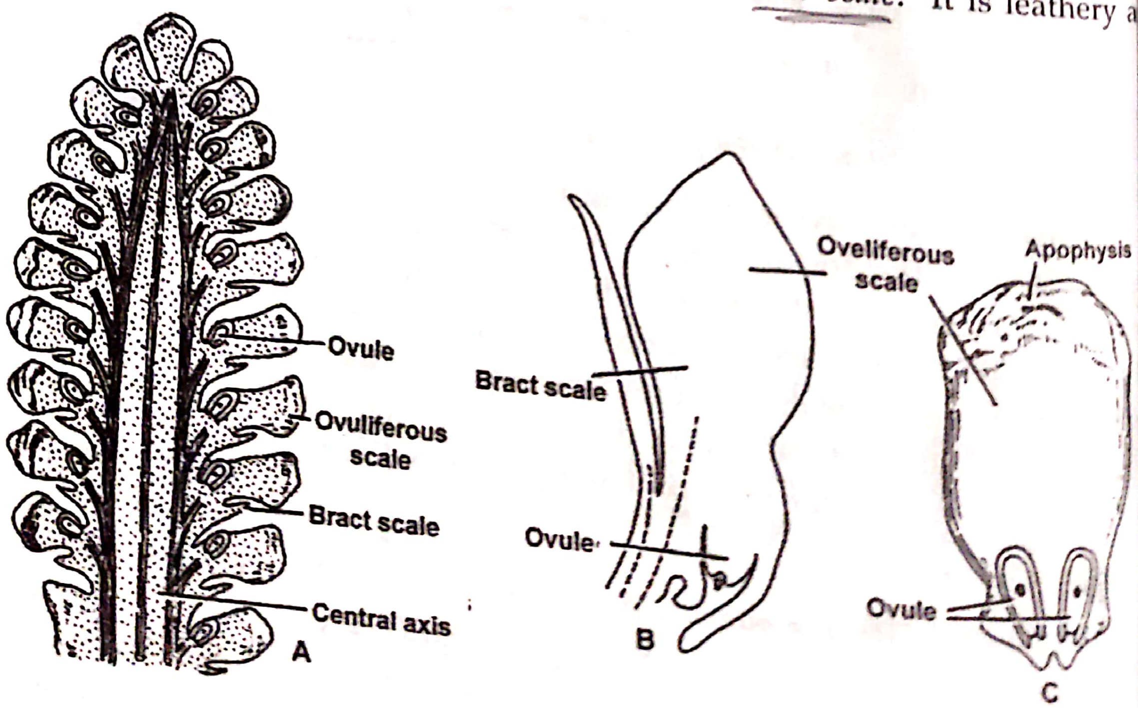


Fig 3.13 : *Pinus* - Female cone
(A) Longitudinal section, (B) Megasporophyll, (C) Ovuliferous scale

directly attached to the cone axis. Each bract scale has a single vascular bundle with xylem oriented towards the upper side as in a normal leaf. The upper scale of the pair is larger, thicker and stouter. It is called the *ovuliferous scale*. It develops for the upper surface of bract scale and bears two ovules side by side on its upper (dorsal) surface as two small white swellings. The micropyles of the ovules are directed towards the axis of the cone. The ovuliferous scale is woody and wedge - shaped (triangular) and its upper broad sterile part is known as *apophysis*. The apophysis is directed upwards. The surface of the cone is marked by rhomboidal areas each with a small central conical point - the *umbo*. The rhomboidal areas are the outlines of the broad sterile apophysis of the ovuliferous scales and the tips of apophysis is the **umbo**. The umbo in all diploxylon pines is dorsal in position, whereas it is terminal or dorsal in haploxylon pines.

C Morphology of the Bract and Ovuliferous scale :

The morphological nature of the paired scales has long been a debated question.

(1) Robert Brown (1827) explained that the ovuliferous scale is an *open carpel*, arising in the axil of the bract scale.

(2) Sachs and Eichler (1868) looked upon the female cone as a simple *female flower* with the central axis comparable to receptacle or thalamus of the angiospermic flower. According to their view, the ovuliferous scale corresponds to the *ligule* (similar to the ligule of *Selaginella*) or placenta of angiosperms.

(3) Alexander Braun (1842) considers that the ovuliferous scale is formed by the fusion of the first two leaves of an axillary shoot. The **bract scale represents the leaf**. The growth of the axillary shoot stopped after the formation of first two leaves.

(4) Florin (1951, 54) considers the female cone of *Pinus* is comparable to the *inflorescence* of angiosperms. The cone axis represents the **peduncle**, the bract scale is a **true bract** and the ovuliferous scale developed in its axil represents the rudimentary **female flower**. It is thus, the female cone is a *compound strobilus*, resembling an inflorescence. He introduced, a combined term *seed - scale complex* for the bract scale and the ovuliferous scale.

On the basis of epidermal features and the developmental order of the various zones of the scale, Lemoine - Sebastin (1973, 75) discussed the problem of seed - scale in the pines. She visualised that the complex seed - scale is composed of an axial portion (corresponding to the body) possessing the ovules and a foliar part (corresponding to the apophysis).

From the foregoing discussion it appears that morphologically the ovuliferous scale is a **reduced shoot** and the female cone is an **inflorescence**.

D Structure and development of Ovule :

The ovules arise as a small, round white swelling on the upper surface, near the base of ovuliferous scale. The nucellus increases in size and soon a ring-like outgrowth of cells arises from its base and grows up around it to form the integument.

Each ovule consists of a central mass of tissue called the nucellus, which is covered by an integument. The integument leaves an opening, the micropyle at the top of the ovule. The integument continues into a long tube beyond the nucellus, to form micropylar canal.

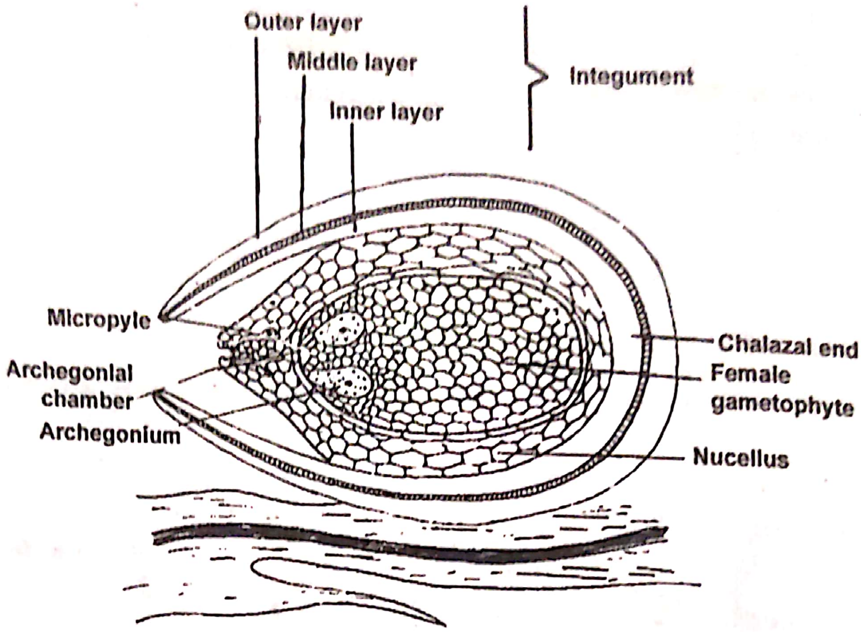


Fig. 3.14 : *Pinus* Sp. Mature ovule V.S.

The nucellus does not protrude into the micropyle to form the nucellar beak. A prominent pollen chamber also is absent. Their absence is related to the production of non-ciliated male gametes.

Megasporogenesis : At the apex of nucellus, a hypodermal cell enlarges and acts as the **archesporial cell**. It divides periclinally into **tapetal cell** and **megaspore mother cell**. The tapetal cell, forms the tapetum, a nourishing layer. The megaspore mother cell divides meiotically to form a linear tetrad of haploid megaspores. The upper three megaspores disorganise and the **chalazal one enlarges in to a functional megaspore**.

The megaspore is the first cell of female gametophytic generation. It is homologous with the "embryosac" of angiosperms.

3-6 GAMETOPHYTIC GENERATION

The pollen grain and the megaspore are in haploid condition. They represent the begining of male and female gametophytic generations respectively.

I Male Gametophyte :

(A) Microspore (Pollen grain) : The pollen grain is the first cell of the male gametophyte. The pollen grain is a unicellular and uninucleate structure. It is surrounded by a three layered wall. The exine is the outermost cuticularised layer. It is formed only on one side of the spore. The inner layer, intine, is thin and soft. The middle layer called exo-intine is inflated with air and forms two balloon like outgrowths or wings. The wings aid the pollen grains to float in the air and the dispersal by wind.

(B) Development before liberation : The pollen grain starts germinating about a month before it is liberated. The pollen grain divides and cuts off 2 small **prothallial cells** and a single **antheridial cell**. The two prothallial cells represent the vegetative tissue of the male gametophyte.

The antheridial cell then divides into a small **generative cell** and a large **tube cell**. The pollen grains are shed at this *four celled* stage. Further development of the male gametophyte stops till the pollen grains reach the nucellus of the female plant.

(C) Pollination : In *Pinus* the pollen grains are carried to the nucellus through wind. Hence the pollination is anemophilous. Pollination occurs in the month of May or June in the hills and in February or March in the plains. The pollen-sacs dehisce by longitudinal slits and clouds of yellow pollen grains are seen in pine forests. The pollen grains are very minute and are buoyant due to the wings. They are easily blown by wind on liberation and are carried to the young female cones.

Pollination takes place when the female cones are in their first year of growth. Prior to pollination, the female cones are erect and the bract scales are tightly arranged. Just before pollination, the bract scales become incurved, separating the ovuliferous scales. This will allow the pollen grains to reach the ovules directly.

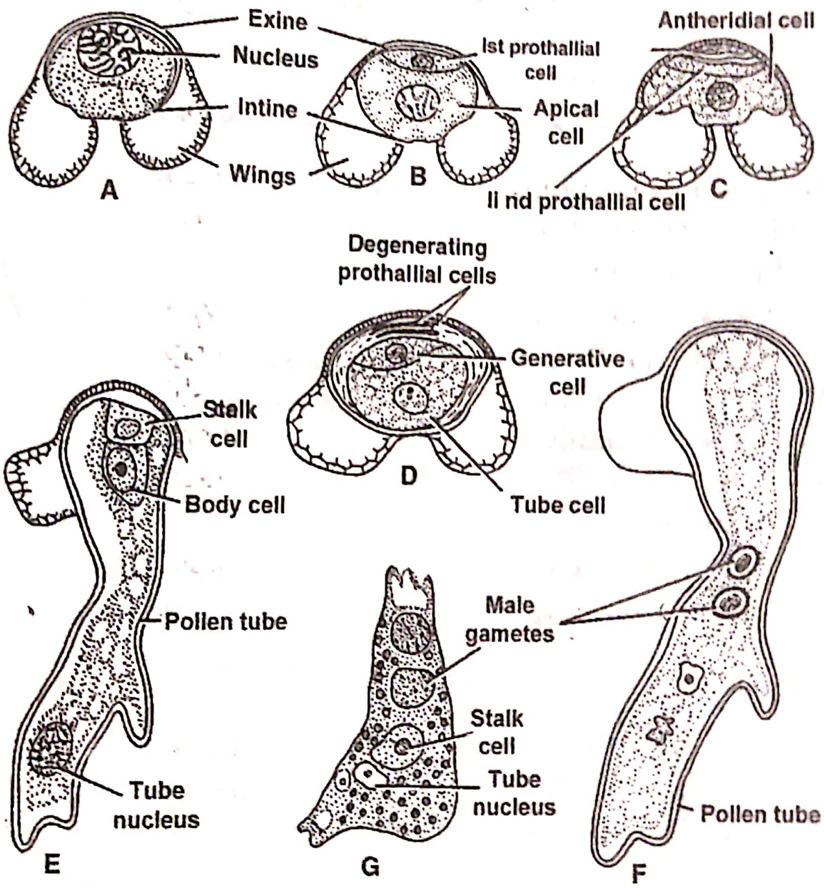


Fig. 3·15 : *Pinus* Sp. Development of male gametophyte - (A-D) Stages before pollination; (E-G) Stages after pollination

A little mucilage in the form of a pollination drop oozes out through the micropyle. The pollen grains get entangled in this fluid. After the pollination is over, the mucilage drop dries up, drawing the pollen grains to the apex of the nucellus.

After pollination, the bract scales close tightly and the cone becomes inverted.

(D) Development after pollination : After the transfer of pollen grains to the nucellus, further development of male gametophyte occurs. The pollen grains resume activity in the following spring season (April or May).

The exo-intine ruptures between the two wings. The tube cell protrudes and grows out to form a delicate pollen tube. In this condition the pollen-grains rest for one season. The pollen tube resumes growth in April of the second year in the hills but two months earlier in plains.

In the mean time, the generative cell divides into a barren **stalk cell** and a **body cell**. The body cell becomes free and passes into the pollen tube. It is accompanied by the nucleus of the stalk cell. The pollen tube reaches the archegonium at the begining of July. Just before fertilization, the **body cell forms two male gametes which are non-ciliated.**

II Female Gametophyte :

After pollination, the female cone increases in size and becomes inverted. This increase in size is due to enormous growth of the axis and of the ovuliferous scales. Ovuliferous scales on maturity turn hard and brown while the bract scales remain small in size.

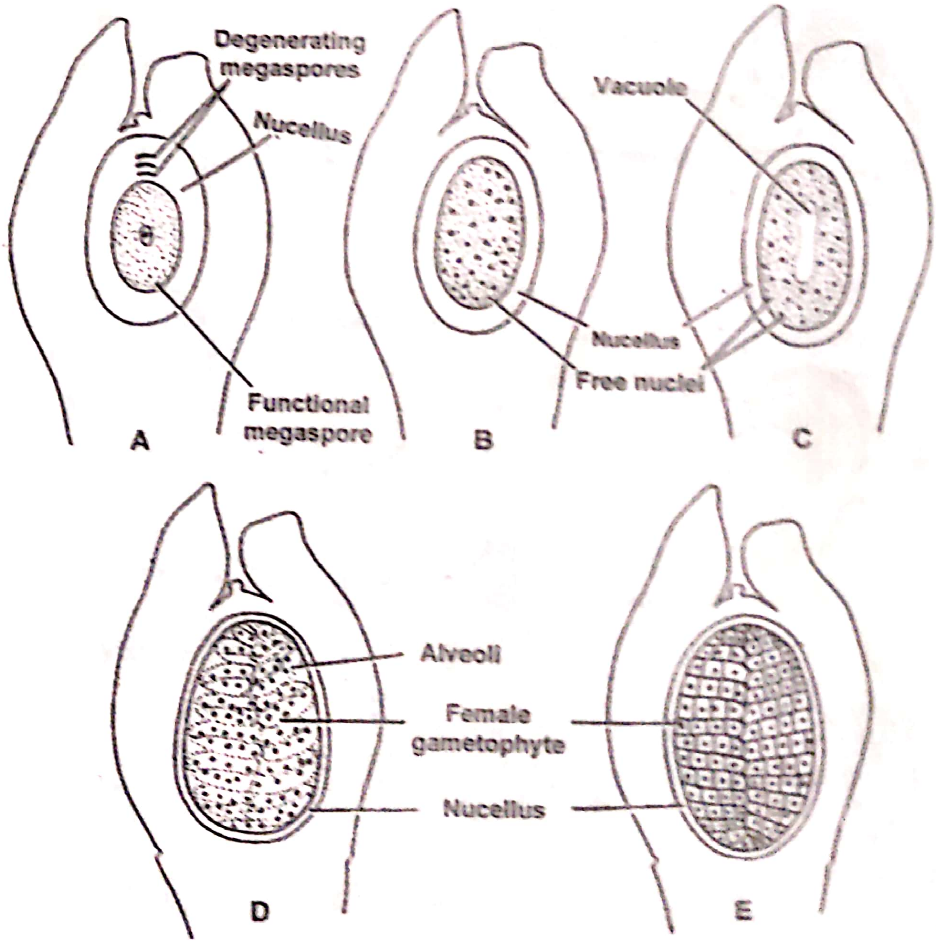


Fig 3.16 : *Pinus* - (A-E) Development of female gametophyte

The functional megaspore is the initial cell of the female gametophyte. There is an interval of about 13 months between the origin of megaspore and the development of mature female gametophyte. The megaspore enlarges in size and vacuole appears in the centre. The nucleus within the megaspore enlarges and begin to divide. Free nuclear divisions takes place and about 2,000 small nuclei are formed without walls. Each nucleus later gets a wall, and the wall formation starts from the periphery towards the centre.

There after the embryosac is cut into a number of radial spaces in the form of long tubes. They are known as **'alveoli'**, each containing several nuclei. The alveoli project towards the centre of the germinating megaspore. Cross walls divide the alveoli into uninucleate cells. The massive tissue thus formed is called the **endosperm** or **female prothallus.**

The cells of the nucellus form a two- layered nutritive tissue around the female prothallus. This tissue is called the *'Spongy layer'* and corresponds to a tapetum.

Development of archegonia :

At the micropylar end of the ovule, 3 to 5 archegonia are produced from superficial cells of the female prothallus. Each archegonium is quite simple in structure and consists of a short neck and a large venter. There are **no neck canal cells.**

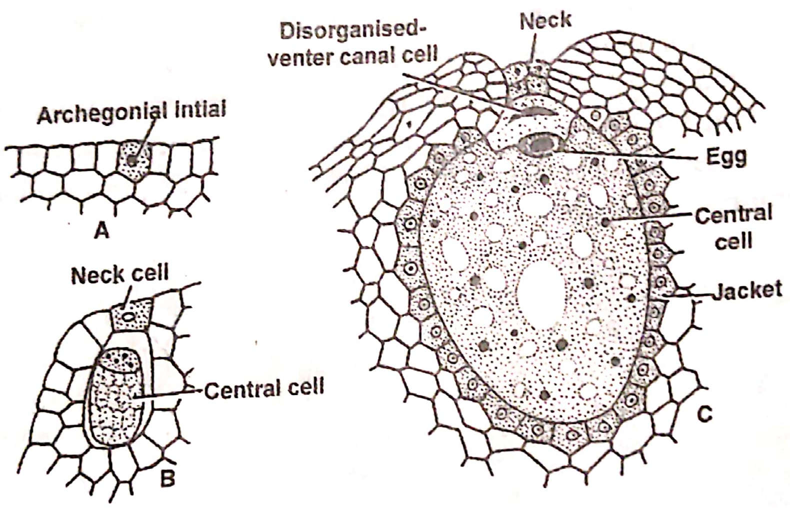


Fig. 3·17 : *Pinus* - Archegonium

(A, B) Stages in the development of archegonium, (C) Matrue archegonium

Each archegonium develops from a single superficial cell near the micropylar region. The archegonial initial divides producing two cells-the ***primary neck* cell and the central cell.** The primary neck cell divides thrice successively producing eight cells. These cells constitute the neck with two tiers of four cells each.

The central cell divides to produce an *egg* and the *ventral canal cell*. This division takes place appoximately at the same time when the body cell of the male gametophyte divides to form male nuclei. The cells surrounding the archegonium forms a jacket which supplies food to the developing egg. The cells of the female prothallus surround the archegonium more vigorously than the neck cells so that an archegonial chamber is resulted.

III Fertilization :

After an year of pollination, fertilization takes place. The generative cell divides in to two cells, a *stalk cell* and a *body cell*. The body cell divides and forms two male gametes.

By this time the pollen tube pierces through the nucellus and reaches the neck of the archegonium. The pollen tube bursts at the apex of the archegonium and both the male gametes are liberated. Only one of the male gametes fuses with the egg nucleus and forms the oospore (zygote). Fertilization usually occurs at the end of the June. Oospore being diploid, represents the begining of a new sporophytic generation. More than one archegonium may be fertilized in a single ovule, but only one comes to maturity.

3-7 EMBRYOGENY

Development of embryo can be studied in the following two stages.

1. Development of Proembryo : The zygote is the first cell of the new sporophytic generation. The diploid nucleus migrates towards its base and then divides by two mitotic divisions to form four haploid nuclei. All the four nuclei thus formed get arranged in one plane at the base of the zygote. Thus only two nuclei are visible in lateral view. These nuclei divide again and form eight nuclei which are arranged in two ties of four each. There after wall formation takes place in such a way that four complete cells are formed only in the lower tier, and four cells with incomplete walls are formed in the upper tier. The incomplete cells do not take part in embryo formation.

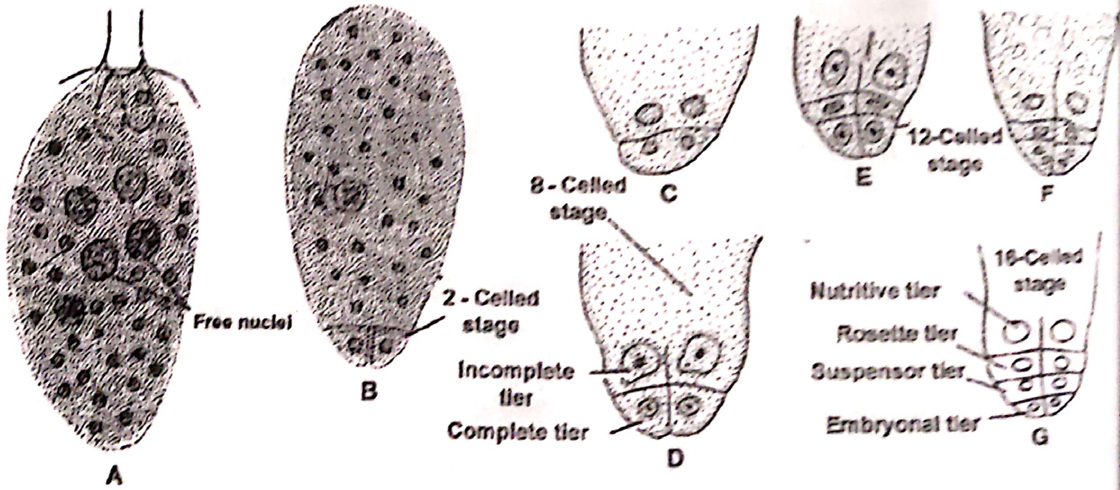


Fig. 3·18 : *Pinus* - Early Stages in the development of embryo

The cells of the lower tier divide twice to form three tiers of four cells each. This sixteen celled stage is known as ***proembryo***. Each tier has a specific function. Embryo develops from only a part of the embryo. This type of development is called as **meroblastic**.

(i) The lowermost tier is known as the *embryonal tier*, these cells divide to form embryo.

(ii) The cells of the next tier (middle) is known as the *suspensor* tier. These cells from the suspensor.

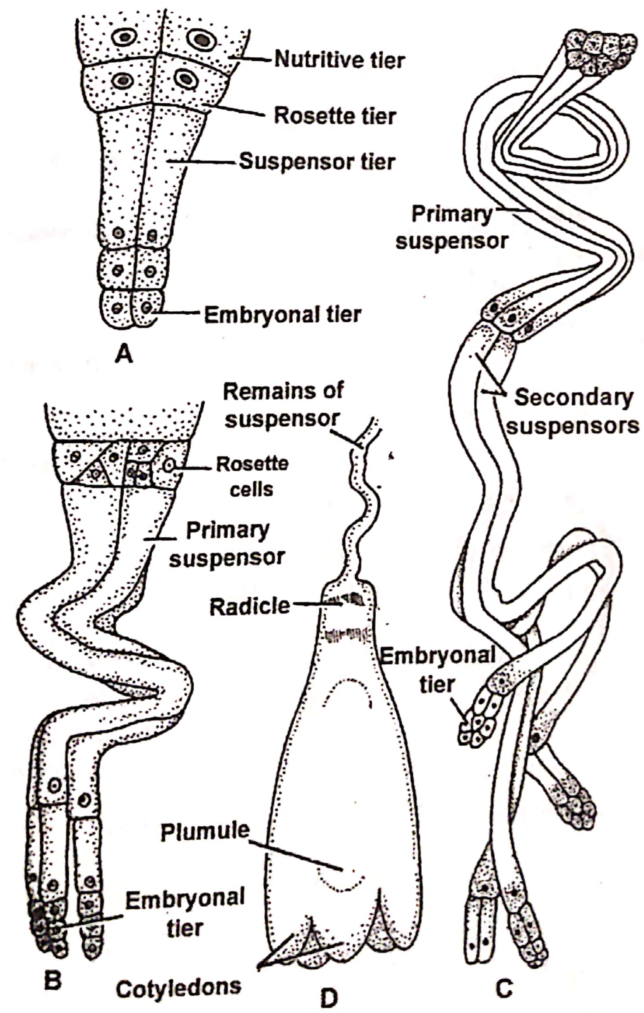
(iii) The third tier from below is called the rosette tier. These cells have no function.

(iv) The upper most tier consists of incomplete cells and is known as *nutritive tier*, as it provides nutrition.

2. Development of Embryo : The suspensor cells elongate considerably and push the embryonal cells out of the archegonium and deep into the tissue of the female prothallus, at the expense of which they grow. Due to the limitation of space in the endosperm, the primary suspensor cells become coiled to each other. At this stage, the cells of the embryonal tier divide transversely and form *secondary suspensor cells* and *embryonal tier*.

The cells of the embryonal tier separate from each other and form four independent embryos. Thus in *Pinus*, a single zygote forms more than one embryo, it is known as *cleavage polyembryony*. Sometimes cells of rosette tier may develop embryo and then it is called *rosette polyembryony*. However, due to limited nutrients available, only a single proembryo develop into mature embryo and the rest degenerate.

The mature embryo consists of a short axis with *radicle* directed towards the micropyle and *plumule* or shoot apex, with usually more than two cotyledons.



female cone is also called as ovulate strobili

Fig. 3·19 : *Pinus* - Later Stages in the development of embryo

3-8 STRUCTURE OF THE SEED

After fertilization, the ovules get transformed into seeds, and the female cone turns into a brown woody structure. The seed contains the following structure.

(a) Embryo : A seed contains a single mature embryo. The mature embryo consists of a short axis with the radicle towards the micropylar end and a small plumule downward. The plumule is surrounded by a number of cotyledons. The suspensor remains attached as a small coil to the tip of the radicle.

(b) Endosperm : It is a nutritive tissue which surrounds the embryo. It is white and oily in nature.

(c) Perisperm : It is a thin, membranous cap like structure which helps in serving as a nutritive tissue to the developing embryo. It is the remnant of the nucellar tissue.

(d) Testa (Seed coat) : The integument of the ovule becomes the seed coat or testa. The testa is hard and stony as it develops from the middle stony layer of the integument. The inner integument is present as a thin membrane.

(e) Wing : The seed has a thin membranous wing. It is derived from a thin layer of tissue on the upper surface of the ovuliferous scale. It helps the seed in the dispersal by wind to longer distances.

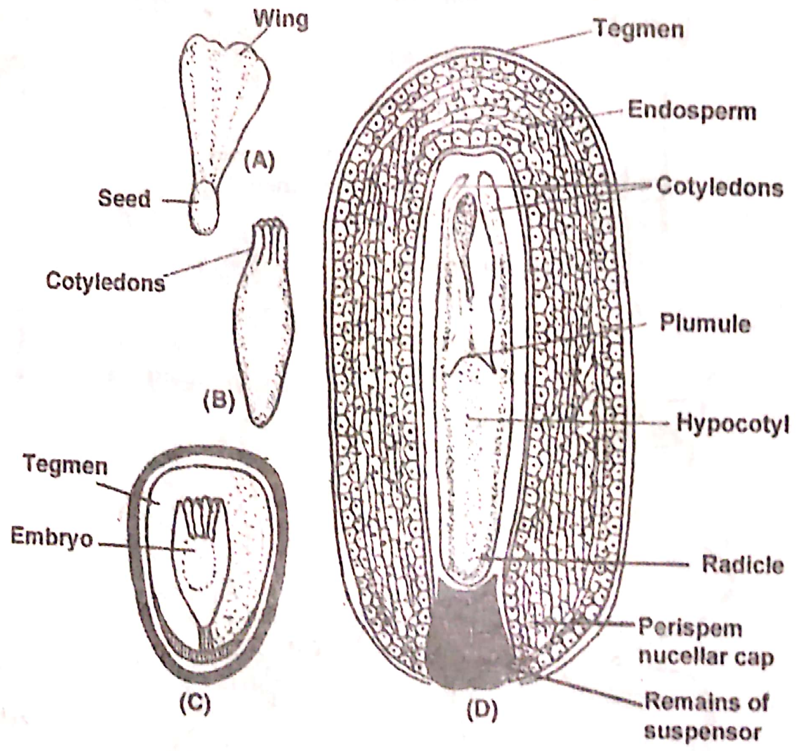


Fig. 3·20 : Structure of Pinus seed

Within the seed three distinct generations are distinguishable.

(I) Seed coat and perisperm - have diploid number of chromosomes (2n = 24) and represent the sporophytic generation.

(II) Endosperm - is the gametophytic tissue (n = 12)

(III) Embryo - is a new sporophytic generation (2n = 24)

Dispersal of Seeds : In the third year, when the female cone reaches maturity, the cone becomes dry, brown and woody. Each ovuliferous scale bears two mature seeds placed side by side on its upper surface. When the seeds mature, the cone axis elongates and the scales are separated from each other leaving spaces among them. The seeds are liberated and they are blown away by wind. The wings of the seeds aid in their dispersal.

Germination of Seed :

The pine seeds germinate immediately after they fall on moist soil. The seeds may remain dormant for sometime in unfavourable conditions.

The germination is **epigeal** i.e., the cotyledons come above the ground by the elongation of hypocotyl. The seeds absorb water and the seed coat splits up. The radicle grows downward into the soil and forms the primary root. The plumule grow towards the light carrying cotyledons which are already green. The plumule grows upwards and produces a shoot of unlimited growth. 8 to 14 cotyledonary leaves are spirally arranged on the shoot.

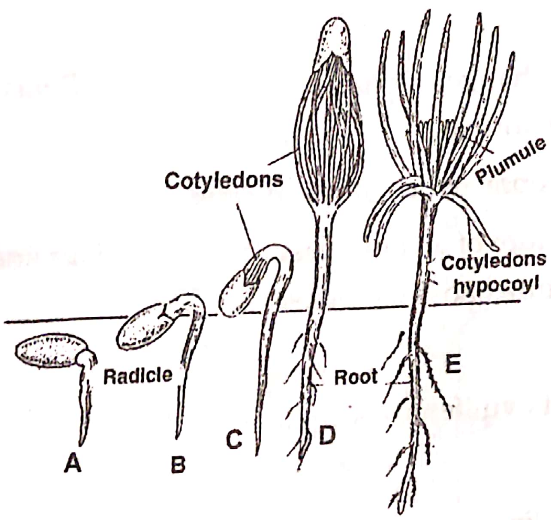


Fig. 3·21 : Stages in the germination of Pinus seed

These leaves become smaller and smaller till they are reduced to small papery brown structures, the scale leaves. Dwarf shoots bearing needles arise in the axils of scale leaves.

3·9 ECONOMIC IMPORTANCE

Several species of *Pinus* yield **wood** which is used as building material, furniture, poles, match boxes and other articles. The wood of *P. excelsa* and *P. longifolia* yield good timber. The wood is also used as fuel as it can be easily ignited due to the presence of resin.

The plants yield large amount of **resin** which is used in resin and turpentine industry. Resin and turpentine are used to make paints, varnishes and medicines.

The roasted seeds of *P. gerardiana* are edible. They are sold in the market under the name 'Chilgoza". The seeds of *P. roxburghi* are also edible.

Many species of *Pinus* are important as cheep sources of cellulose which is used for various industrial purposes.

Pine forests usually surround the T.B. Sanitòria and make the surroundings attractive and healthy.