Palissyaceae (genera : *Stachyotaxus, Palissya*); (4) **Cheirolepidaceae** (genus : *Cheirolepis*). (5) **Protopinaceae** (genera : *Protopodocarpoxylon. Protocedroxylon, Pinoxylon*, etc.) —Those five famillies include only fossil members; (6) **Pinaceae** (Syn. Abietaceae —This family contains 9 genera with about 145 species; important genera are *Pinus**, *Abies**, *Larix**, *Tsuga**, *Picea, Cedrus**, etc.), (7) **Taxodiaceae** (contains 10 genera with about 15 species —important genera: *Sequoia, Metasequoia, Taxodium, Cryptomeria*** etc.), (8) **Cupressaceae** (contains 16 genera with about 133 species —important genera : *Cupressus**, *Thuja****, *Libocedrus, Juniperus**, etc.), (9) **Araucariaceae** (contains 2 genera with about 35 species —genera : *Agathis* and *Araucaria* ***), (10) **Podocarpaceae** (contains 7 genera with 111 species—important genera: *Podocarpus**, *Phyllocladus, Pherosphaera*, etc.) and (11) **Cephalotaxaceae** (contains only one genus *Cephalotaxus** with about 6 species).

The last 6 families include both living and fossil members.

A. *PINUS*

Pinus belongs to the family Pinaceae, order Coniferales and the division Coniferophyta of Gymnospermae.

Distribution —*Pinus*, the most dominate genus of the order Coniferales is represented by about 90 species. The genus *Pinus* is widely distributed throughout the temperate and sub-alpine regions of the Northern hemisphere, and forms an evergreen forest-belt. It is widely distributed in the hills and is an important source of resin and timber. In India, 6 species of *Pinus* are found to occur in the North-West and North-East Himalayas (Raizada and Sahni, 1960).

(1) *Pinus gerardiana* Wall. (the Chilgoza Pine)—A tree (upto 22.0 m), found in the North-Western Himalayas at altitudes ranging from 1,800 to 3,500 m.

(2) *P. insularis* (syn. *P. khasya*), the Khasi pine —A tall tree (upto 45.0 m.), found in Eastern Himalayas, specially in the Khasia and Jaintia hills at an altitude of 1,000 to 2,500 m.

(3) *P. roxburghii Sarg.* (syn. *P. longifolia*), the Chir pine —A tall tree (upto 30.5 m), found in the Western and Eastern Himalayas between the altitude of 450 and 2,250 m.

(4) *P. wallichiana Jacks.* (syn. *P. excelsa, P. griffithii*), the Blue pine —A tree (upto 45.5 m), found in both the Western and Eastern Himalayas between an altitude of 1,800 and 3,000 m.

(5) *P. armandi Franch*, Armand's pine—A medium sized tall tree (upto 15 m), found in the NEFA above an altitude of 1500 m.

(6) *P. merkusii Jung.* (the Tenasserim Pine)—A small tree, hardly reaches a height of 3 m. Found to grow profusely on hillocks in Eastern India, Bangladesh; often

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[2] Placed under separate order Taxales. Genera endemic in India. ** Introduced in India from Japan.
*** Introduced in India from E. Asia, now cultivated in Indian gardens.

coming down to an altitude of 150 metres.

Structure of the Sporophyte

1. EXTERNAL MORPHOLOGY—A tall, evergreen and lofty tree with strong tap root system. The tree takes a pyramidal form (*excurrent*) due to development of racemose branching.

Stem—The stem is erect, stout, cylindrical and branched. The stem is covered with bark which is characteristic of different species. Branching is monopodial. Branches are of two kinds, viz. (a) short branches of limited growth (dwarf or spur shoots) and (b) long lateral branches of unlimited growth (long shoots). The dwarf shoots develop in the axils of scale leaves and are devoid of apical buds. These dwarf shoots possess scale leaves below and needle-like foliage leaves at their apices.

Root—*Pinus* has a strong tap root system, which may persist or may be associated with stronger adventitious roots. Root hairs are scanty and ectotrophic mycorrhiza occurs.

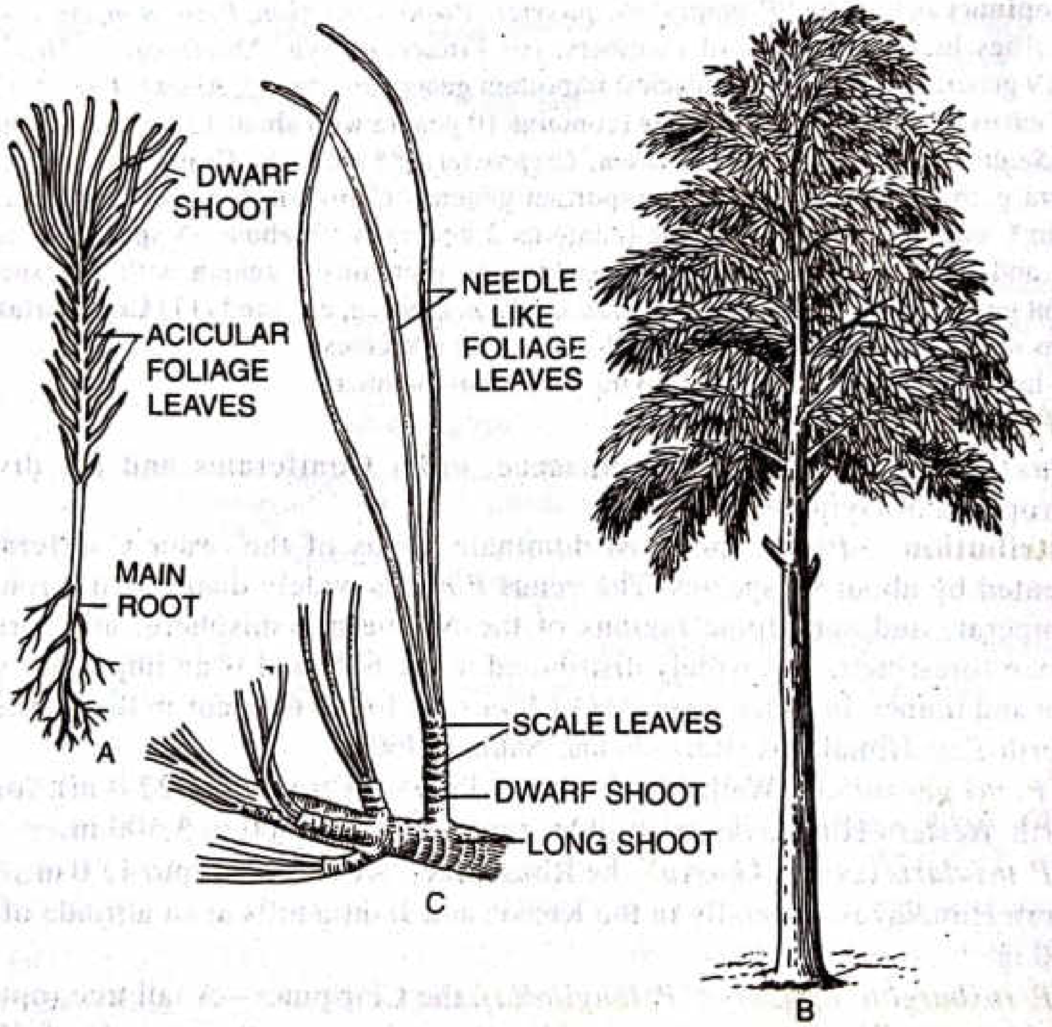


Fig. 3.10—*Pinus* sp. A. A young plant. A–Structure of a tree. B–Dwarf shoots bearing foliage leaves and scale leaves (only one shoot bears entire foliage leaves).

Leaves—Leaves are dimorphic i.e. (i) brown, small, thin scale leaves and (ii) needle-like green simple, foliage leaves developing in cluster at the apex of dwarf shoot. The number of mature needle-like foliage leaves varies from 1 to 5 in different species. Scale leaves occur on long and as well as on dwarf shoots and fall off as the branches attains maturity. But needle like foliage leaves are borne only on dwarf shoots. The main photosynthetic function is performed by the needle-like leaves.

2. Internal Morphology

Stem—In transverse section the stem shows a *thin cortex, a large zone of vascular tissues and a small pith* (Fig. 3.11).

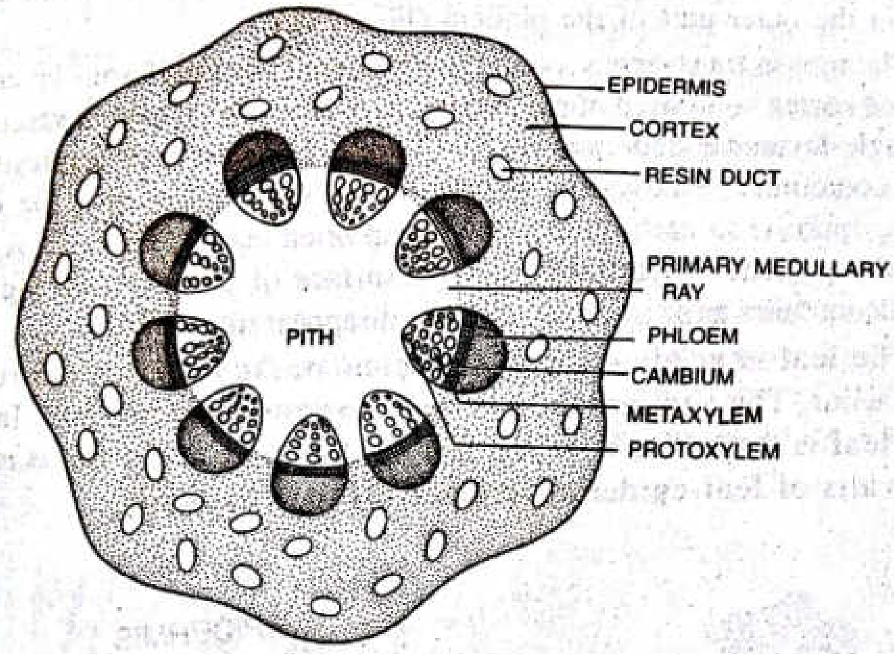


Fig. 3.11—*Pinus* sp. T.s. of young stem (diagrammatic).

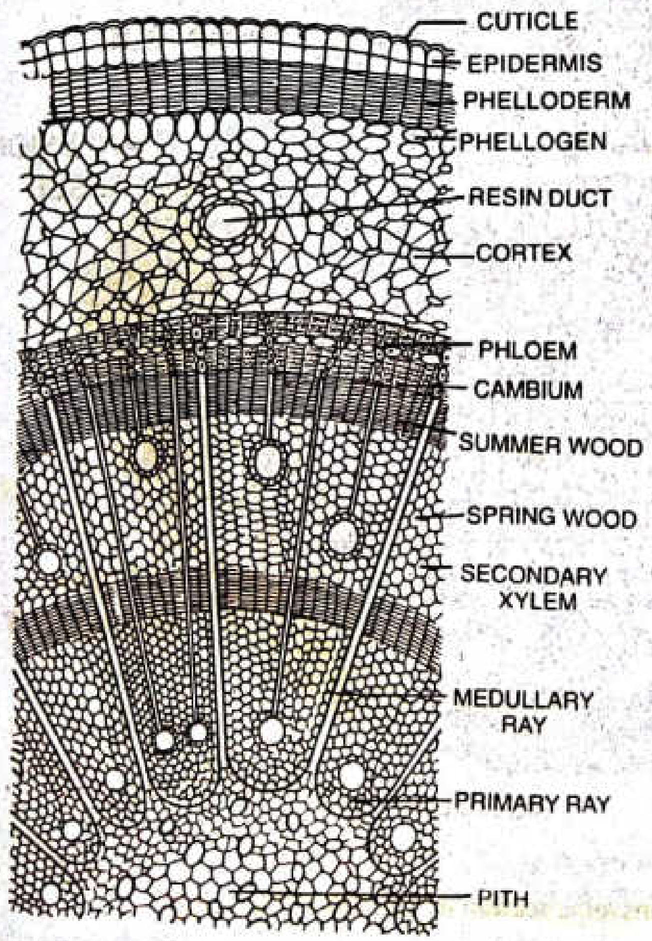


Fig. 3.12—*Pinus* sp. A portion of a stem (two years old) in transverse section.

The stem is differentiated into outer cortex and stele i.e. central cylinder. Epidermis and pericycle are not very distinct. The pith is parenchymatous.

The epidermis is one-cell layer thick and consists of tubular, close compact cell— the outer walls are cutinised. The cortex is composed of parenchyma cells, Resin ducts are present in the cortex. The vascular bundles are conjoint, collateral, open and endarch (i.e., the protoxylem is directed towards the pith). The primary permanent tissue and secondary tiissues are developed in the same way as in dicotyledons of angiosperms.

The vascular bundles are composed of phloem, fascicular cambium and xylem. The xylem exclusively consists of tracheids with bordered pits and xylem rays. No vessels and wood fibres occur. Phloem consists of sieve tubes and phloem parenchyma; companion cells are absent. The stele is ectophloic dissected siphonostele. Cambium is present in between xylem and phloem.

The secondary wood contains special tracheidal rays *i.e.* the medullary rays. Secondary wood also contains tracheids; the medullary rays in the secondary bast or phloem consist of starch-containing cells and albuminous matter containing cells. Resin ducts are also present in the secondary wood. Cork cambium appears successively in the cortex and in the outer part of the phloem (Fig. 3.12).

Root—The root in transverse section shows an outermost piliferous layer (epiblema), a multilayered cortex composed of parenchyma and a diarch to tetrarch vascular cylinder. There is a single-layered endodermis which is followed by a pericycle; pericycle is several-layers thick sometimes. Protoxylem is exarch, it is slightly forked in the form of 'Y'. Resin canals, opposite to each protoxylem group often occur. *Pinus* root is mycorrhizal because of the presence of a fungus on the surface of the root forming ectotrophic mycorrhiza. Root hairs airse in young root but disappear ultimately.

Leaf—The leaf is needle-shaped *i.e.* acicular, the anatomical structure (Fig. 3.13) is peculiar. The anatomy of leaf shows xerophytic structure. In transverse section the leaf is somewhat semi-circular in out-line i.e. the leaf is *centric* type. The outer walls of leaf-epidermis are heavily cuticularised.

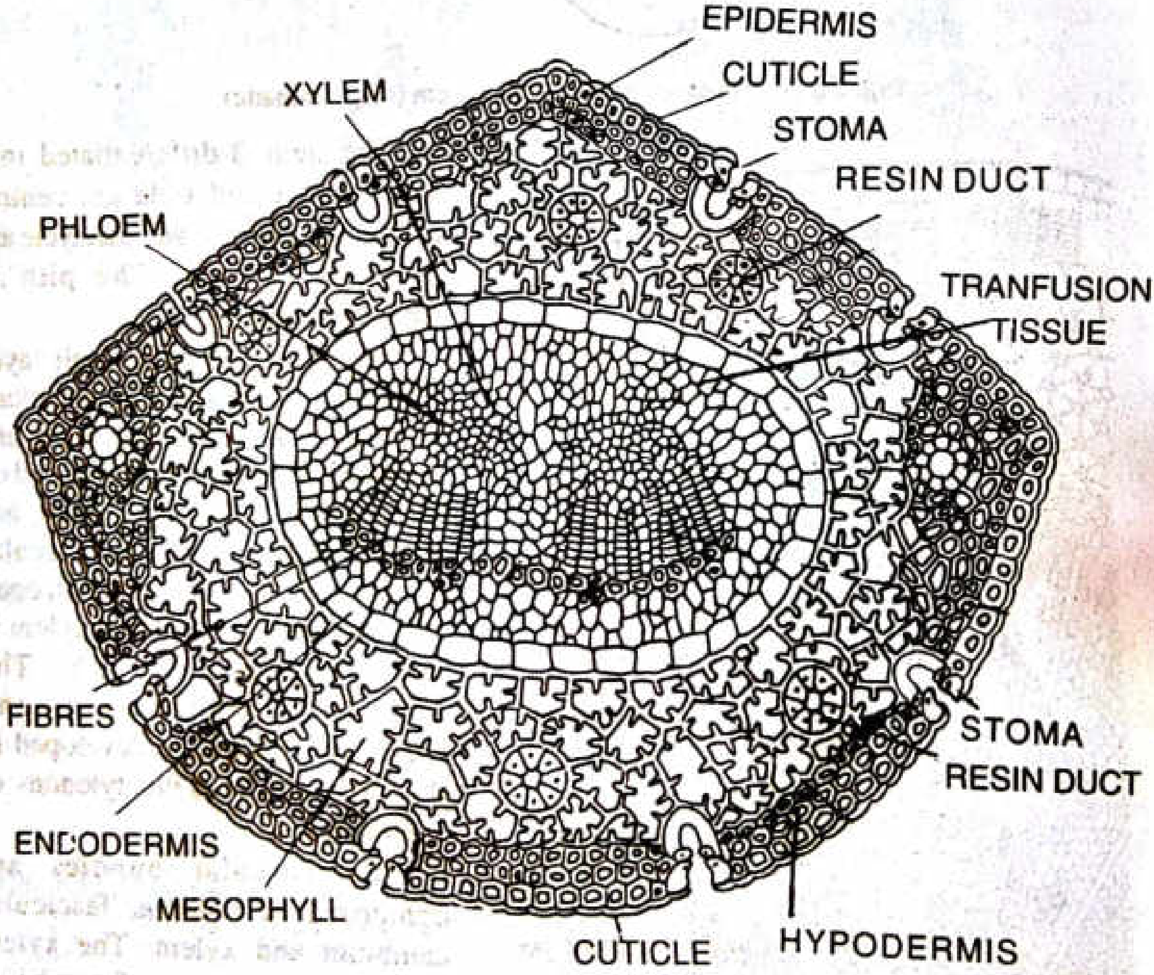


Fig. 3.13— *Pinus* sp. Transverse section of a needle (foliage leaf).

The stomata are sunken. The vascular bundles are 2 to 3 in number, they lie somewhat obliquely, the xylem facing towards the adaxial (upper) side and the phloem towards the abaxial (lower) side. The xylem is endarch and consists of crushed protoxylem and metaxylem composed of variously thickened tracheids. The entire xylem parenchyma is more abundant. Some phloem parenchyma cells are rich in dense cytoplasm and such cells are known as *albuminous cells.*

The most conspicuous feature is the presence of transfusion tissue surrounding the vascular bundles. Here the pericycle-cells are collectively called transfusion tissue. The transfusioin tissue consists of two kinds of cells e.g., (1) thin-walled, non-living lignified tracheids (tracheidal cells) whose function is translocation of food from mesophyll to the phloem and (2) living, non-lignified parenchymatous cells with cellulose cell walls (albuminous cells) whose function is conduction of water and dissolved mineral salts from xylem to the mesophyll tissue. The parenchyma cells contain tannin, resin-like substances and starch. Towards the xylem the transfusion tracheids are elongated further away from the vascular bundle. They are short and parencyma-like. The transfusion cells lying very close to phloem are similar to albuminous cells. According to Huber (1930) the transfusion tracheids and transfusion parenchyma form continuous systems and these two systems interpenetrate each other. The transfusion cells are auxillary conducting system helping the vascular bundle in coming close to mesophyll for physiological purpose. The

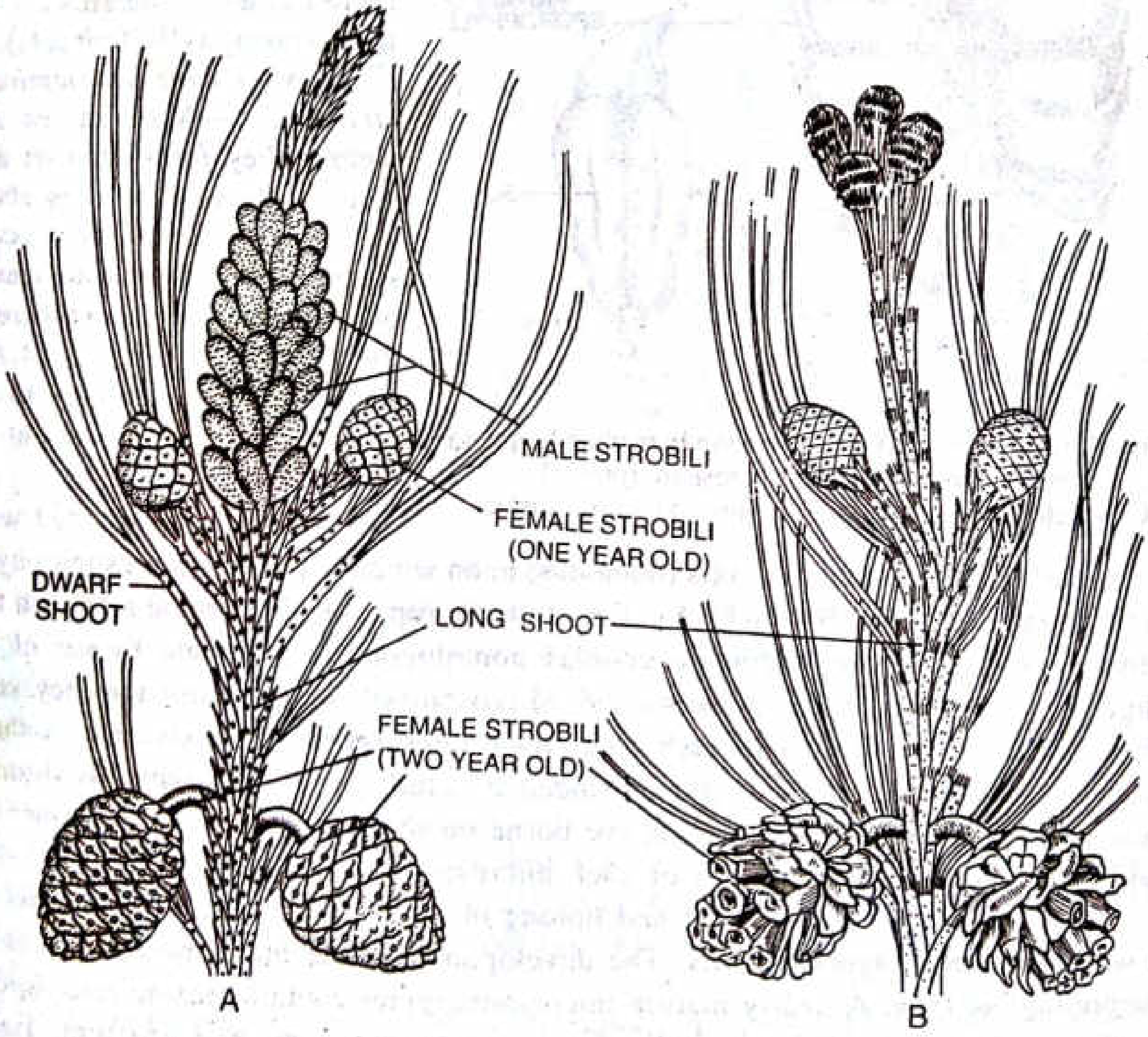


Fig. 3.14—*Pinus* sp. A-B –Long shoots bearing male and female strobili. A–At early spring. B–At early monsoon.

mesophyll tissue is not usually differentiated into palisade and spongy cells. The cells of mesophyll have ridges on the walls projecting inside the cell-cavities known as *arm palisade.*

The leaf shows xerophytic structure as the epidermis is heavily cuticularised with stomata having sunken guard cells which are overtopped by subsidiary cells. Below the epidermis lies the sclerenchymatous hypodermis having fibre-like thick-walled lignified cells.

3. **Reproductive structures—**

Vegetative reproduction with the aid of vegetative reproductive structures has not been reported.

The *Pinus* plant represents the sporophytic generation. The plant is monoecious i.e. male and female sporophylls are borne on the same plant but in separate cones i.e. strobili. Flowers are unisexual, they are represented by sporophylls i.e. male flowers by microsporophylls (stamens) and female flowers by megasporophylls (carpels).

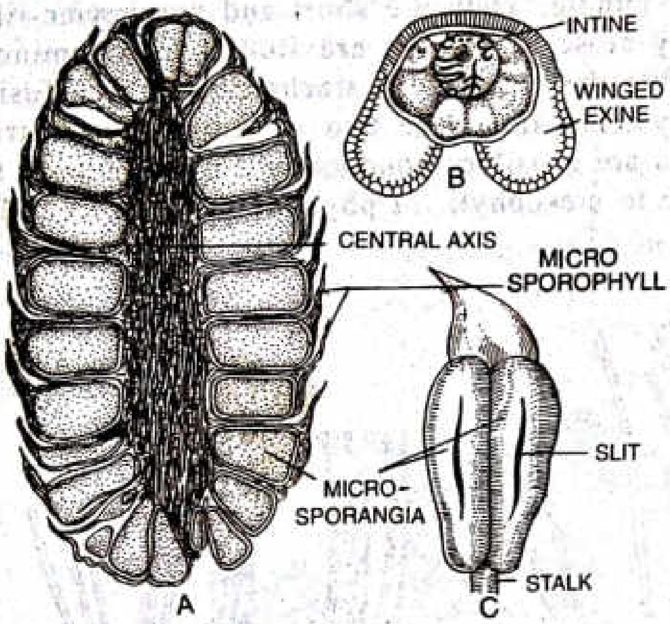


Fig. 3.15 –*Pinus* sp. A–A male cone in median longitudinal section. B–Single microspore (pollen). C–Single microsporophyll i.e. stamen (ventral surface).

(a) ***Male cone i.e. Staminate strobilus*** :—Male cones are simple; they form compact and oval structures, measuring about 2 to 3 cm in length. They occur singly in the axils of scale leaves of long shoots replacing thereby dwarf shoots (Fig. 3.14,A). Male cones thus appear to be morphologically equivalent to dwarf shoots.

Each cone is provided with a short and elongated central axis (thalamus) upon which numerous microsporophylls are arranged spirally (Fig. 3.15,A). The microsporophylls are borne directly on the central axis; therefore, the male cone is homologous to the male flower of an angiosperm and not to an inflorescence. Microsporophylls are scaly and they vary from 60 to 135 in number in each cone. Each microsporophyll consists of a short stalk (i.e. filament) and a leaf-like expanded structure, the apex of which is slightly bent upwards. Two microsporangia are borne on the lower i.e. abaxial surface of such leaf-like expanded portion of each microsporophyll (Fig. 3.15,C).

A microsporangium is sessile and oblong in shape (Fig. 3.15,C); it consists of a wall of several layers of cells. The development of the microsporangium is of eusporangiate type. A nearly mature microsporangium contains inside microspore mother cells surrounded externally by a sporangium wall and tapetum. Each microspore mother cell by reduction division forms four haploid uninucleate microspores *i.e.* pollen grains. Each mature microsporangium, therefore, contains numerous *microspores*. The pollen grains are *winged* (Fig. 3.15B) and yellow in colour. When mature, each microsporangium dehisces by a longitudinal slit along the long axis. As a result large number of pollen grains get released forming a cloud which is often called 'shower of sulphur'.

(*b*) ***Female cone i.e. Ovulate strobilus*** :— Female cones form true cone-like structures and they are compound in nature. They arise in clusters of 1 to 4 in the axils of scale leaves of the long shoots (Fig. 3.15, A-B) taking the position of

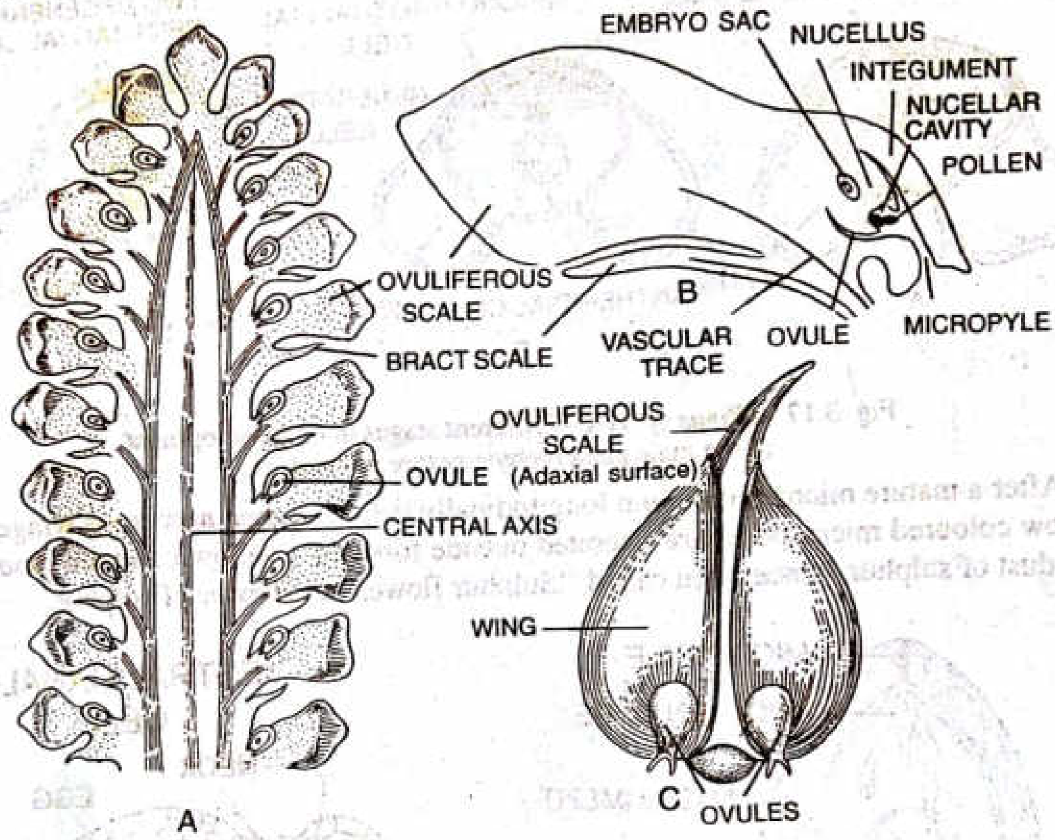


Fig. 3.16 —*Pinus* sp. A–Median longitudinal section of a female strobilus. B–Vertical longitudinal section of an ovule and its associated structures. C–An ovuliferous scale with its two ovules.

dwarf shoots. At first they are green in colour and gradually become brown-red.

The female cone is a hard, woody and dry structure; it consists of a central axis (Fig. 3.16, A) upon which numerous megasporophylls are spirally arranged.

The megasporophyll is shortly stalked and consists of a large ovuliferous scale and a bract scale attached on the lower side of the ovuliferous scale. Each ovuliferous scale bears two inverted or anatropous megasporangia (ovules) on the surface near the base (Fig. 3.16, C). Bract scale and ovuliferous scale are supplied with separate vascular traces.

An ovule (Fig. 3.16, A) consists of a massive nucellus surrounded by an integument. The integument is fused with the nucellus at the basal region and open at the top to form a micropyle. Nucellar beak and pollen chamber are not formed here. The integument consists of three layers e.g., an outer fleshy, a middle stony and an inner fleshy.

Only one megaspore mother cell is differentiated within the nucellar tissue (Fig. 3.18, A), which by meiosis gives rise to a linear-tetrad of four megaspores. Of these four megaspores, only the lowermost one is the functional megaspore while others degenerate (Fig. 3.20, B).

Structure of the Gametophytes

1. Male gametophyte —Microspore (pollen grain) is the first cell of the male gametophyte, which is provided with an outer exine and an inner intine. The exine becomes inflated into two wings (Fig. 3.17, A). Germination of the microspore starts inside the

microsporangium long before the shedding of microspores.

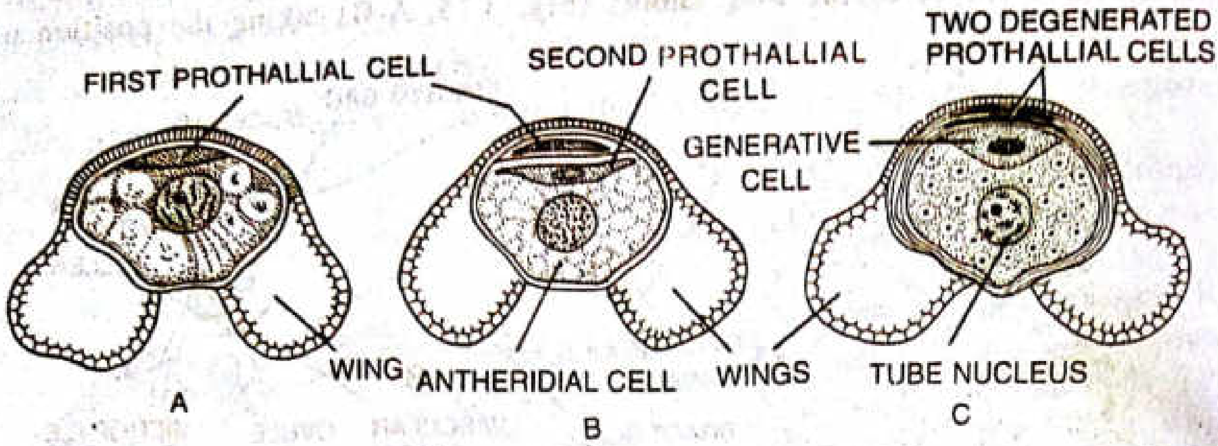


Fig. 3.17 —*Pinus* sp. A-C –Different stages in the development of the male gametophyte before pollination.

After a mature microsporangium longitudinally dehisces, then numerous winged and yellow coloured microspores are liberated outside forming a yellow coloured cloud just like dust of sulphur, hence often called "Sulphur flower" or shower of sulphur.

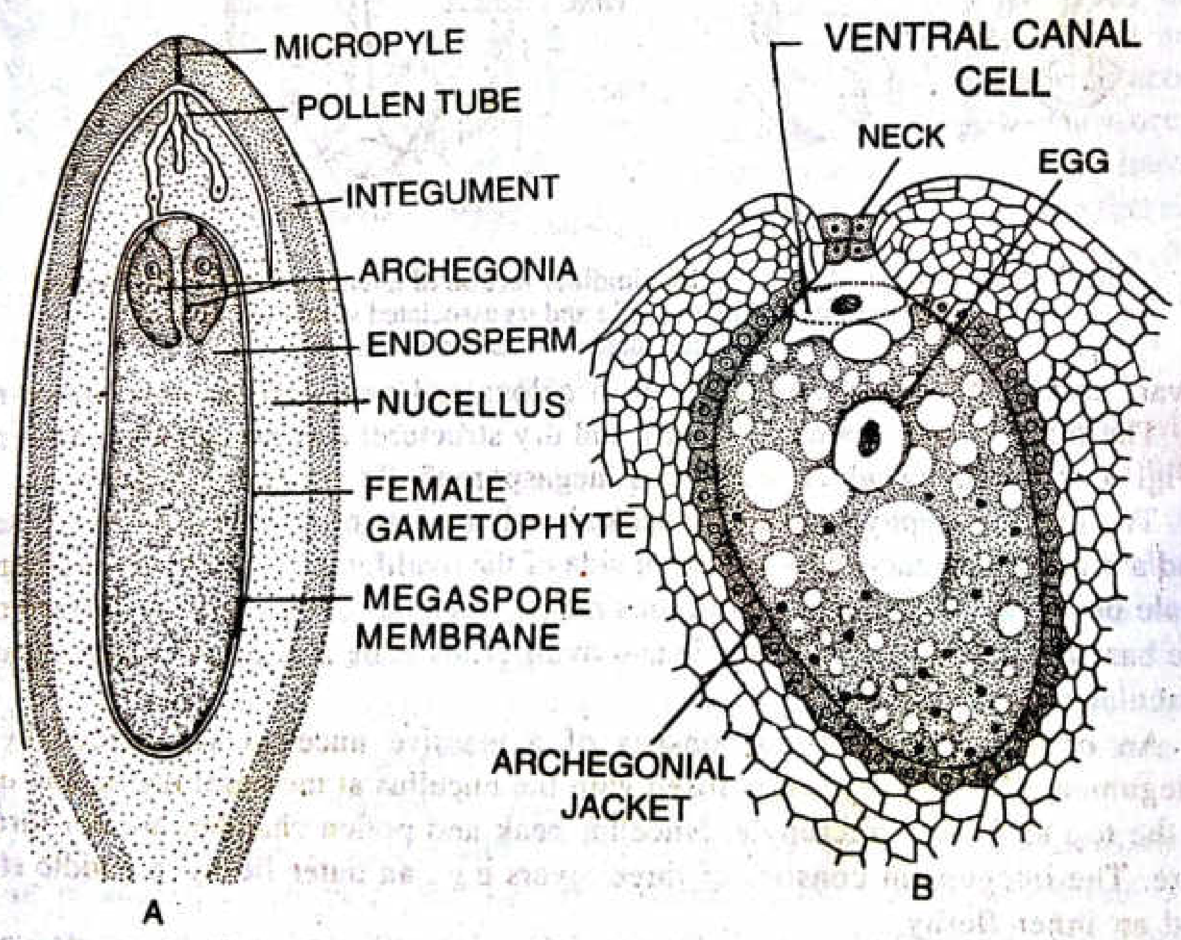


Fig. 3.18 —*Pinus* sp. A –Median longitudinal section of a mature ovule with the integument having three fused layers and a female gametophyte bearing archegonia ready for fertilization. B–Mature archegonium.

Microspore-nucleus cuts off two small prothallial cells one after another and a single larger antheridial cell (Fig. 3.17, B). Prothallial cells are not persistent, they degenerate very soon. Antheridial cell next cuts off against the second prothallial cell, a small generative cell and a larger tube cell (Fig. 3.17, C). At this 4-celled stage the microspores are shed from the microsporangium, further development of which takes place only when they reach the ovule (i.e. after pollination).

The tube cell elongates to form an unbranched pollen tube; within the pollen tube generative cell moves and later divides into a sterile stalk cell and a spermatogenous or body cell. The body cell further divides and forms two non-motile male gametes (Fig. 3.19, B). Of these two gametes, one may be slightly larger than the other.

2. **Female Gametophyte** —Female gametophyte i.e. embryo sac is monosporic i.e. of the four megaspores, only the lowermost is the functional megaspore which takes part in the development of the gametophyte. Development of the gametophyte takes place entirely within the megasporangium.

The functional megaspore enlarges in size, its nucleus divides and redivides repeatedly by free nuclear division forming numerous small nuclei (about 2,000) without walls (Fig. 3.20 C); these free nuclei are distributed in the cytoplasm of the megaspore i.e. embryo sac. A large central vacuole is formed pushing the protoplast towards the periphery. Then walls are formed between the nuclei; the formation of these walls starts from the periphery in a centripetal fashion. As a result a solid mass of gametophytic tissue, known as endosperm tissue is formed; this tissue is composed of one kind of cells.

Towards the micropylar end of the gametophyte 2 to 3 archegonia (Fig. 3.18, A) are formed from the superficial cells (archegonial initials) of the female gametophyte. At first

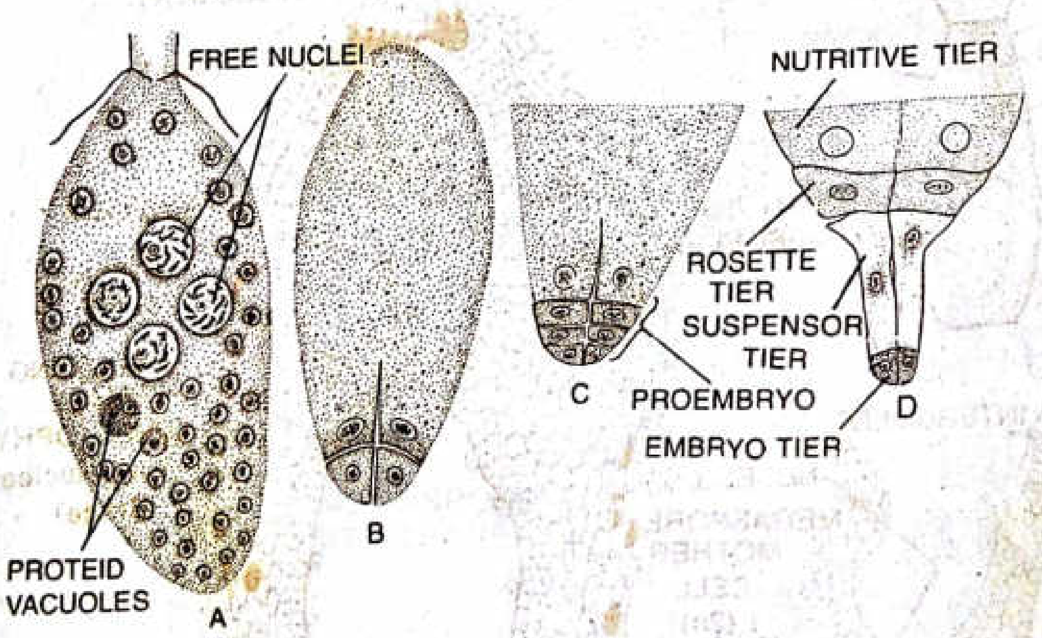


Fig. 3.21 —*Pinus* sp. A-D –Different stages in the development of proembryo.

the archegonial initial divides transversely to form an upper primary neck initial and a lower large central cell.

Each mature archegonium (Fig. 3.18, B) consists of a neck of eight cells (developed from the neck initial), one ventral canal cell and a large egg (developed from the lower central cell). Neck canal cell is absent.

Pollination —Pollen grains, after liberation from microsporangia, are carried by means of wind (anemophilous) at the 4-celled stage. The yellow coloured pollen grains are carried in a mass and they resemble dust of sulphur.

At the time of pollination, the scales of the female cone remain open for the reception of pollen grains, and pollens are caught in the mucilage drop oozing out of the micropyle.

This pollination drop contains excess glucose and fructose. As the mucilage drop dries up, pollen grains are gradually drawn down the micropyle and are finally taken at the nucellus

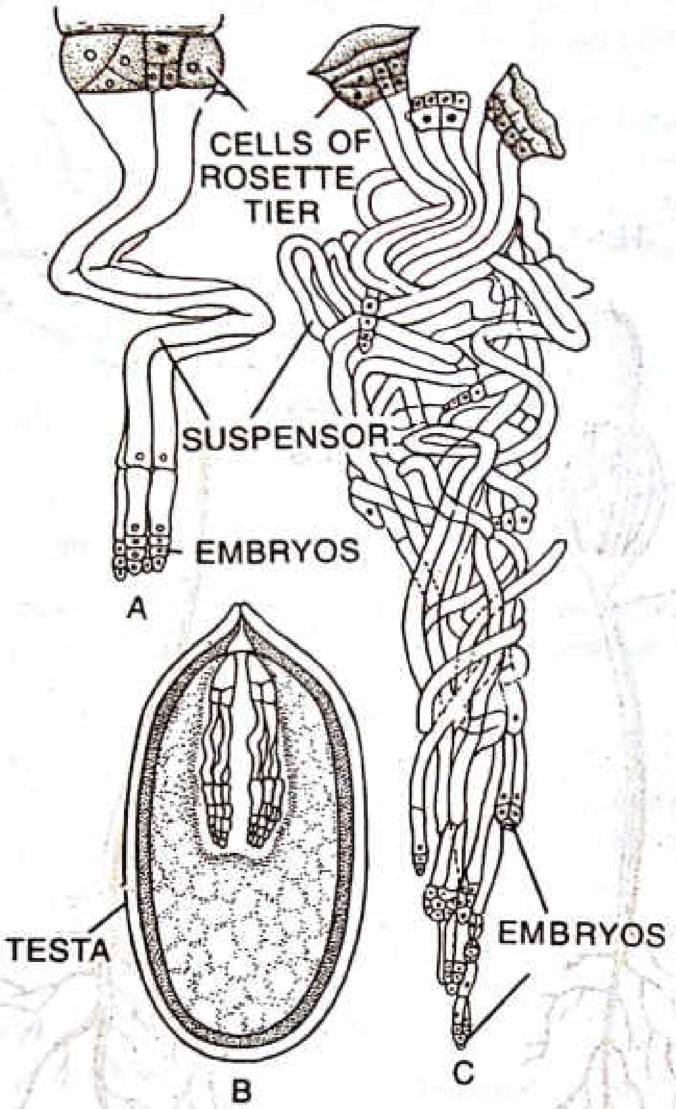


Fig. 3.22 –Different stages in the development of proper embryos. A–Formation of 4 embryos, each of their respective suspensor. B–Several embryos are pushed down within the endosperm tissue of the seed. C–About 12 embryos with their respective suspensors developing from three zygotes of three archegonia.

tip.

Fertilization : Fertilization takes place after an year of pollination. Pollen tube makes its way down until it reaches the neck of the archegonium, the neck is penetrated and the tip of the pollen tube bursts. The contents of the pollen tube are then discharged and of the two male cells, only one unites with the egg i.e. oosphere, as a result a diploid zygote i.e. oospore is formed.

Endosperm is cellular and is formed before fertilization from the megaspore nucleus due to repeated divisions. Endosperm tissue is therefore haploid (n).

Embryo and the Seed : First division of the zygote is not accompanied by a transverse or vertical wall; instead, free nuclear divisions of the zygote-nucleus take place.

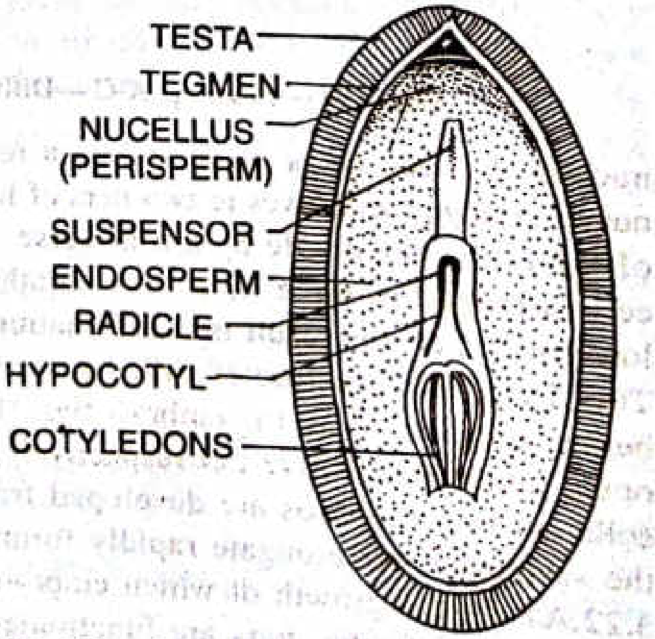


Fig. 3.23 —*Pinus* sp. Longitudinal section of a seed.

The zygote-nucleus passes towards the lower end, then divides twice. The resultant four free nuclei (Fig. 3.21, A) now move to the bottom. Then another

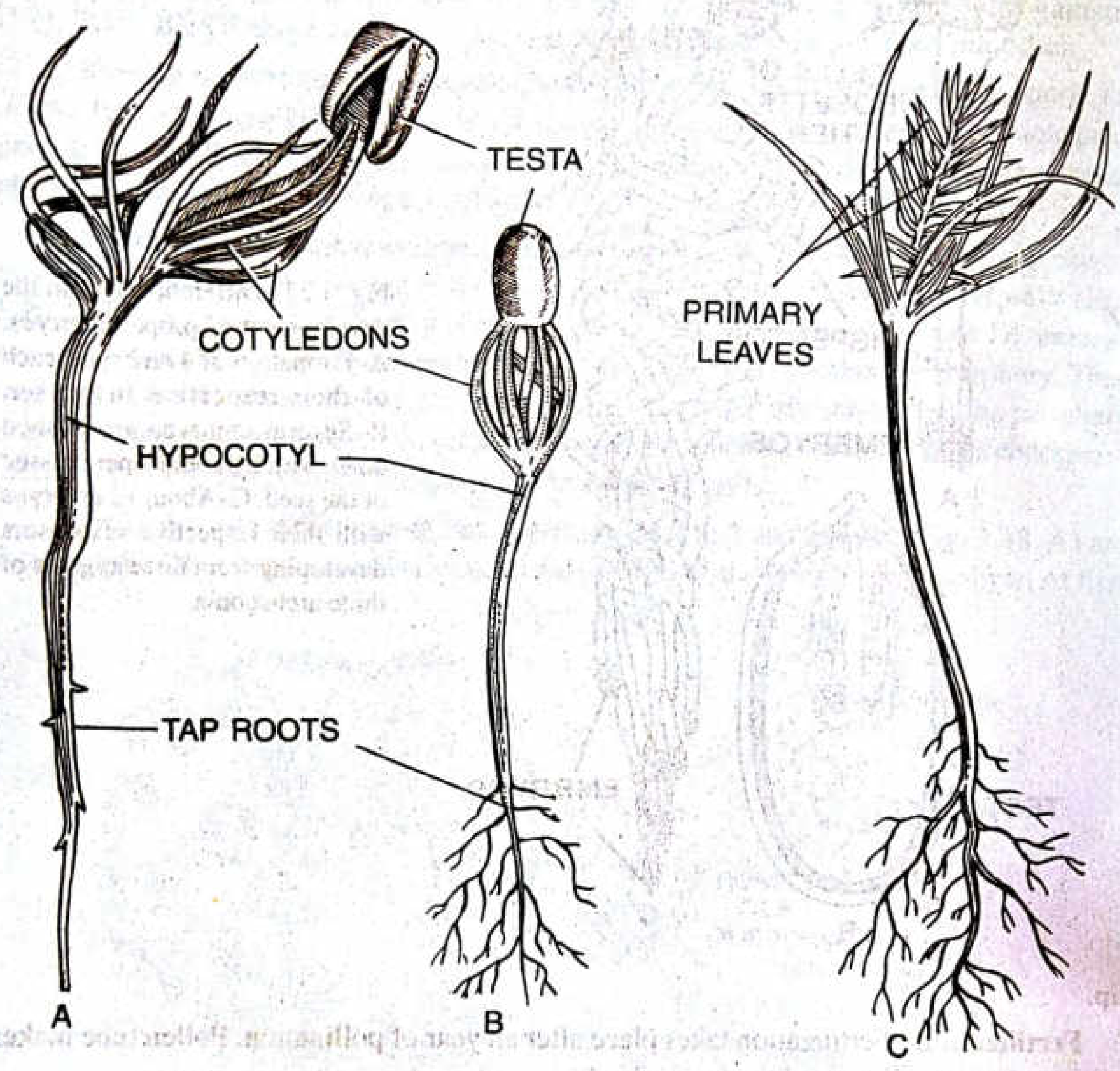


Fig. 3.24 —*Pinus* sp. A-C —Different stages in germination of seed.

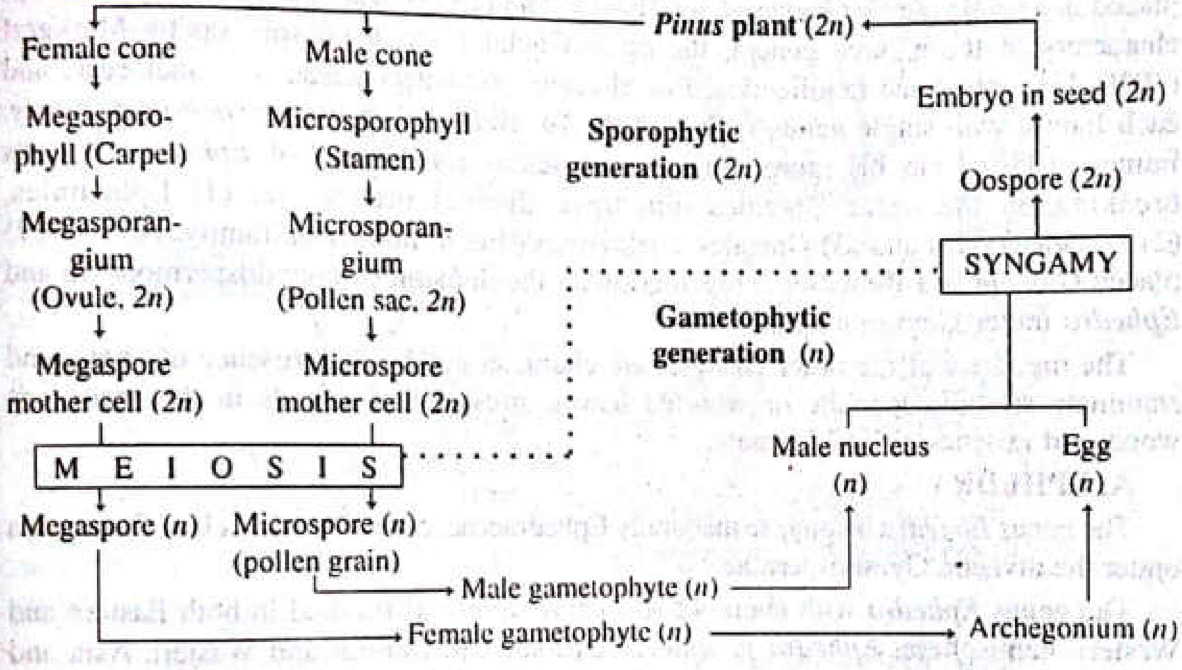
nuclear division takes place and as a result eight nuclei are formed. These eight nuclei arrange themselves in two tiers of four cells each (Fig. 3.21B). Again four cells of the lower tier divide by a transverse wall, the result is the formation of twelve cells arranged in three tiers. Next another division takes place in the cells of the lowermost tier, the result is the formation of sixteen cells in four tiers (Fig. 21, C). This 16-celled structure is called *proembryo* and the four tiers, beginning from below, are known as (a) embryo tier, (b) suspensor tier, (c) rosette tier and (d) open, upper or nutritive tier respectively (Fig. 3.21, D). As each tier contains four cells, so four embryos are developed from four cells of the embryo tier. Cells of the suspensor tier elongate rapidly forming spirally twisted long suspensors (Fig. 3.22,A), by the growth of which embryos are pushed down within the endosperm tissue. Cells of other tiers are functionless. In *Pinus* polyembryony occurs as four potential embryos are developed although only one of them matures ultimately.

The embryo matures and forms the seed. The seed coat is formed from the integument of the megasporangium. The testa is formed from the middle stony layer of the integument and forms the outermost covering of the seed. The outer fleshy layer of the integument is dried up. The innermost layer of the integument is sometimes present as a thin membrane.

The mature seed (Fig. 3.23) also contains perisperm and kernel. Perisperm is a thin, membranous and reddish-brown structure; it is a nutritive tissue and forms a remnant of the nucellar tissue and hence possesses diploid chromosome number. Kernel is also a kind of nutritive tissue which surrounds the embryo; this tissue is composed of cells with haploid chromosome number.

The embryo consists of a radicle, the hypocotyl, 3 to many cotyledons and a plumule. After a period of rest the seed germinates by epigeal means (Fig. 3.24) to form a new sporophytic plant.

Life cycle of *Pinus* (in word diagram)



Economic Importance of *Pinus* –Most of the species of *Pinus* have economic value. The seeds of *P. gerardiana* are edible and commercially known as 'chilgoza' *P. roxburghii* and *P. wallichiana* are timber yielding plants; the timber is used for making furnitures, poles, match boxes, building materials etc. Some species e.g. *P. roxburghii* and *P. insularis* are important sources of resin and turpentine.

Morphology of the Ovuliferous scale of *Pinus* —Various morphological interpretations have been offered by different authors regarding the morphological nature of the ovuliferous scale of *Pinus*. Some of the interpretations given by different authors are discussed as follows :—

1. Robert Brown (1827)—Ovuliferous scale is an exposed carpel developing in the axil of the bract and which bears two naked ovules.

2. Schleiden (1829) —Interpreted the ovuliferous scale as an axial placenta which arises in the axil of the leaf bearing two ovules. The bract scale is the true carpel.

3. A. Brown (1842)—The ovuliferous scale represents the first two leaves of an axillary shoot which are fused by their posterior margins.

4. Baillon (1863)—The ovuliferous scale is regarded as an axillary shoot bearing two bicarpellary ovaries.

5. Eichler (1868)—Bract is a carpel and the ovuliferous scale is a ligular outgrowth from the upper surface.