Botany UG 2^{nd} Semester (Hons)

Paper- C4T, Unit- 6- Gymnosperms

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Gymnosperms

The term gymnosperm was coined by **Theophrastus.** Gymnosperms include the group of flowering plants with naked seeds. Unlike angiosperms, the seeds of gymnosperms are not enclosed in a ovary. The unique feature of angiosperms i.e, the double fertilization is completely absent in gymnosperms.

Gymnosperms form one of the major forest types of our planet having the greatest economical importance as source of timber, lumber and woodpulp.

Major characteristic features of Gymnosperms

1. Plants are woody and evergreen, either trees, shrubs or lianes without having any herbaceous member.

2. Plants have a tap root system, generally persists for a long time.

3. Xylem is made up of tracheids, parenchyma and rays. Vessels are only present in the members Gnetales which have evolved from pitted tracheids, as shown by intermediate stage between pits and perforations.

4. Phloem consists of sieve cells only where sieve area commonly occur on the radial wall. The companion cells are absent.

5. Secondary growth is present in all members, where mature metaxylem shows bordered pits (in *Stangeria* and *Zamia,* metaxylem shows scalariform thickening.

6. The anther has an exothecium which produces numerous anemophilous pollen grains. Pollen exine is alveolar or granular.

7. Prothallial cell is present in male gametophyte, male gametes rarely motile.

8. Ovules (seed) consists of a single integument (unitegmic) which is exposed (naked)

9. The development of female gametophyte shows a prolonged free nuclear phase and there is a long interval between pollination and fertilization.

10. Endosperm is haploid (n) and produced before fertilization.

11. There is a free nuclear stage in the development of proembryo.

Classification (up to family)

Stewart and Rothwell (1993)

Division: Gymnospermophyta

Class 1: Pteridospermopsida

Order 1: Cycadofilicales (Families: Calamopityaceae, Lyginopteridaceae, Medullosaceae, Callistophytaceae.)

Order 2: Glossopteridales (Family: Glossopteridaceae)

Order 3: Caytoniales (Families: Caytoniaceae, Peltaspermaceae, Corystospermaceae.

Class 2: Cycadopsida

Order 1: Cycadales (Family: Cycadaceae)

Order 2: Cycadeoidales (= Bennettitales) (Family: Williamsoniaceae, Cycadeoidaceae)

Class 3: Ginkgopsida

Order 1: Ginkgoales (Family: Ginkgoaceae)

Class 4: Other gymnosperms (gymnosperms of uncertain affinities)

- Order 1: Czekanowskiales (Family: Czekanowskiaceae)
- Order 2: Pentoxylales (Family: Pentoxylaceae)

Class 5: Coniferopsida

- Order 1: Cordaitales (Family: Cordaitaceae)
- Order 2: Voltziales (Family: Voltziaceae)
- Order 3: Coniferales (Family: Pinaceae, Taxodiaceae, Cupressaceae, Podocarpaceae, Araucariaceae, Cephalotaxaceae)
- Order 4: Taxales (Family: Taxaceae)

Class 6: Gnetopsida (=Chlamydospermopsida)

- Order 1: Ephedrales (Family: Ephedraceae)
- Order 2: Welwitschiales (Family: Welwitschiace)
- Order 3: Gnetales (Family: Gnetaceae)

Economic importance of Gymnosperms

1. **Gymnosperms used as timber-** The coniferous wood is very light or hard, strong or soft, coarse or straight grained and durable with distinct annual rings.

Pinus, Cedrus, Abies, Agathis, Araucaria, Cupressus etc. yield good quality of timber used in making building materials, furnitures, boxes, paper pulp, ply wood, railway sleeper, match boxes, matchsticks etc.

2. Gymnosperms as sources of resins- Resins are coniferous plant exudates which are soluble in organic solvents. Commercially resins are of two types- superior grade resin used in varnishes, plasters, enamels, paper sizing, medicines etc and inferior grade resin used in manufacturing of printing ink, laundry soap, oil and grease, adhesive, insulators, insecticides etc.

The different types of resins are-

a. Oleoresin or rosin- Several species of *Pinus* produce oleoresins known as **pine gum, pine pitch** or **turpentine.** Oleoresin is made up of **rosin** and **essential oils.** I ancient times, oleoresin eas used as smear in Egyptian mummies. Burgundy pitch is the purified resin obtained from *Picea abies.* The oleoresin and rosins are used in strong adhesives and in varnishes, lithographic work, histology and veterinary medicines.

b. Copals- Hard resins with little amount of essential oils. Among the *Agathis species* producing copals, "**Kauri copal"** is the most important and value copal found from *Agathis australis.* Other important copals are "**Manila copal"** or **"East India copal"** are obtained from *Agathis alba.* The copals are used in linoleum, plastics, oil cloth, enamel, printing ink, lacquers etc.

c. Sandarac- pale yellow or orange coloured hard resin containing one percent volatile oil. **"African sandarac"** obtained from *Tetraclinis articulate* and **"Australian sandarac"** obtained from several species of *Callitris.* Sandaracs are used in metal varnish, paper varnish, leather varnish and in cementing glass, porceline and preservation of fine paintings.

d. Canada balsam- transparent resin that does not granulate or crystallize on drying. Main source- *Abies balsamea.* Other sources- *Tsuga canadensis* and *Pseudotsuga taxifolia.* This is widely used as mounting medium for microscopic studies for its high refractive index nearing that of glass.

3. Gymnosperms as sources of essential oils and fatty oils. Almost all conifers yield essential oils along with resins.

"Spruce oil"- obtained from *Picea alba* used in room sprays, bath salts and deodorant.
"Siberian fir needle oil" – obtained from *Abies sibirica* used in deodorant, toilet,and shaving soaps, room sprays etc.
"Cedar oil"- obtained from *Cedrus deodara* and *Juniperus virginiana* and used in perfumery, oil immersion lens in microscopic studies.
The oil obtained from several other conifers such as *Dacrydium franklinii, Cedrus atlantica*, *Thuja occidentalis* is used against many disease like bronchitis, tuberculosis, gonorrhea etc.

4. Gymnosperms as source of papers- conifers yield timber that is used in making paper pulp in newsprint industry. Super quality writing and printing paper are manufactured from wood of *Picea, Abies, Larix* and *Tsuga,* whereas kraft papers are produced from *Pinus,* and *Cryptomeria.*

5. Gymnosperms used as drugs- the green branches of *Ephedra* are **important sources of alkaloids, ephedrine** which are used in treatment of **bronchial asthma**. The leaves of ***Ginkgo biloba*** are used in **treating cerebral insufficiency and vertigo**. **Taxol is an anticancer drug** obtained from *Taxus brevifolia* which has been used in the treatment of **ovarian cancer, breast cancer, colon cancer. Taxine** is a toxic substance obtained from *Taxus* which is an active heart poison.

6. Gymnosperms as sources of tannins- The bark of *Tsuga canadensis, Picea alba, Sequoia sempervirens, Latrix decidua, Araucaria* etc yield tannins which are used in medicine, leather and petroleum industry and also for dyeing purposes.

7. Gymnosperms used as ornamental plants- Plants such as pine, cedar, fir, spruce, juniper or hemlock are widely planted as ornamentals plants in gardens, parks and around tombs and religious buildings for their appearance, symmetrical growth and evergreen habit.

8. Gymnosperms used as food- the stem starch called "sago" is obtained from the species of *Cycas, Zamia,* and *Macrozamia.* The seeds of *Cycas* spp. are rich source of starch.

Cycas

Cycas has columnar aerial trunk and a crown of pinnately compound leaves. Stem are unbranched and develop from bulbils at the leaf base. The stem is covered by alternate bands of large and small rhomboidal leaf bases. The leaf bases are persistent. Large one give rise to foliage leaves and small ones belong to scale leaves (cataphylls) or to sporophylls in female plants.

Morphology-

Cycas has a **columnar aerial trunk** with a **crown of pinnately compound leaves**, normally unbranched (sometimes older leaves do exhibit branching).

The **branch** develops as **a small bulbil** which is actually an **adventitious bud**. These **bulbils arise from the lower fleshy region of the leaf bases**. Bulbils also serves as means for vegetative reproduction.

A thick armour of alternating bands of large and small rhomboidal leaf bases covers the aerial stem in a spiral manner. The **large leaf belong to the foliage leaves** and the **smaller ones to the scale leaves (in male plants)** and **sporophylls (in female plants**). The **armour is persistent** but in aged trees **the old leaf bases tend to abscise** thereby exposing the corky stem surface.

***Cycas* produces two types of leaves ie it exhibits dimorphism**. There are **large green foliage leaves and smaller scale leaves or cataphylls**. **Scale leaves are much smaller** with **reduced lamina** and well developed base. **The foliage leaves are unipinnately compound, thick and leathery, sessile or ovate-lanceolate, spine-tipped leaflet (pinnae) alternately or oppositely placed.**

The **leaves possess a long rachis and a short petiole**. There is a **single midrib running the entire length of the pinna.** Numerous hair are also present which is considered as a primitive character.

Primary root system is a tap root which **dies early** and is replaced by large fleshy persistent adventitious roots. Some of the lateral branches, growing near the ground surface, **frequently get infected with bacteria, fungi and blue green algae** which enter through **lenticels**. Roots grow horizontally in the soil called **apogeotropic roots**. **Roots get swollen at the tip followed by repeated dichotomy to form the so called coralloid roots**. Large number of lenticels are seen on coralloid as well as normal roots.

Reproductive structures-

Cycas is a **dioecious plant**. In the vegetative state the male plants are indistinguishable from the female plants. The appearance of the respective reproductive structures distinguishes the two sexes.

Male cone- the male cone usually occurs singly in the centre of the crown, emerging out of the scale leaves. The surface of the cone is covered all over by brown scales in young plants. An old male cone is very large, oval or conical in shape. It emits a very characteristic odour which can be smelt from a distance. It has a central cone axis that bears numerous almost perpendicular attached microsporophylls arranged in spiral manner. The microsporophylls at the apex and the base of the cone are sterile. A mature microsporophyll is a hard, horizontally flattened woody structure consisting of a wedge-shaped portion and a sterile extension tapering into an upward apex.

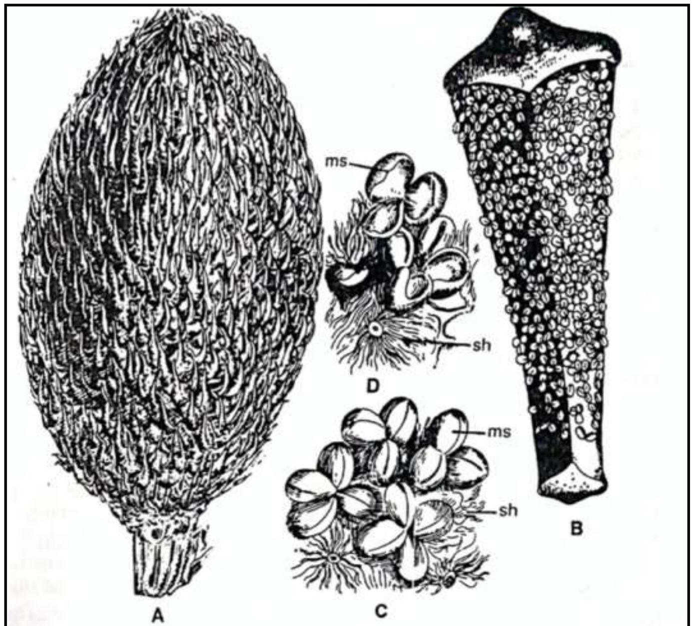


Fig. 6.2: *Cycas circinalis* (**ms**, microsporangium; **sh**, soral hair). **A.** Male cone with spirally arranged microsporophylls. **B.** Abaxial view of microsporophyll showing arrangement of microsporangia in sori. **C, D.** Undehisced and dehisced sporangia which are arranged in groups of three or four as sori and are surrounded by soral hairs. The lines of dehiscence radiate outwards from the centre of the sorus. (**A**, after Maheshwari, 1960; **B-D**, redrawn from Wieland, 1906).

Numerous sporangia are borne on the entire lower or abaxial surface. Microsporangia occur in group of 3,4 or 5 (sori). The sori are surrounded by single-celled soral hairs. Each sporangium has a short massive stalk.

The male cones are normally terminal in position. The further growth of the plant takes place with the help of a lateral bud arising from the base of the peduncle, pushing the cone to one side. The new shoot apex soon takes over forming a crown of leaves and scales, ultimately bearing another male cone. The male plant is called sympodium.

Female strobilus-

Cycas is the only genus which does not produce compact female cones. The female plant bears successive zones of appendages in the older vegetative leaves, cataphylls, megasporophylls, vegetative leaves and so on. The pinnate nature of the megasporophylls appear like modified and reduced foliage leaves, covered with brown hairy ramentum and spiral arrangement. Each megasporophyll bears two rows of opposite or sub-opposite, 2-12 orthotropous and shortly stalked ovules.

Cycas produces the largest ovules in the plant kingdom. The mature seeds are elliptical or egg shaped, slightly flattened laterally and bilobate.

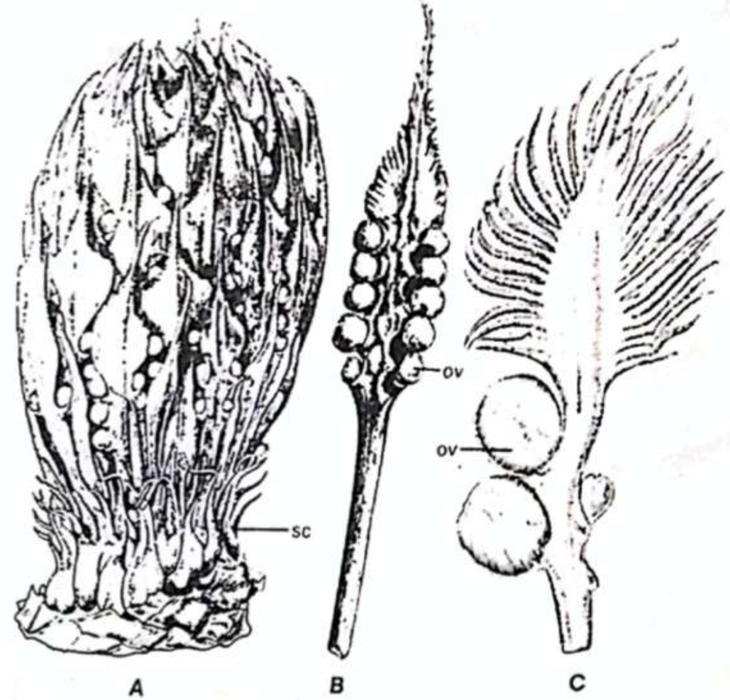


Fig. 6.3: A,B, *Cycas circinalis;* C, *C. revoluta* (ov, ovule; sc, scale leaves). A. Crown of megasporophylls; note sterile scales at the base. B. Megasporophyll showing five pairs of ovules. The upper part of megasporophyll is sterile and dissected. C. Megasporophyll is pinnatifid and leaf-like bearing ovules in two rows below the pinnae. (A,B, after Maheshwari, 1960; C, redrawn from Gifford & Foster, 1989).

Anatomy of root-

The primary root of *Cycas* is short-lived and is soon replaced by adventitious roots arising from the stem. It is **diarch at the tip** but becomes **tetrarch or even more higher up** at the point of attachment.

The xylem consists of varying number of **exarch protoxylem** elements with spiral and scalariform thickening. There is a parenchymatous pith at the center or may be covered with metaxylem elements. The cambium develops a bit away from the primary xylem so that after secondary growth the primary and secondary xylems are separated from each other.

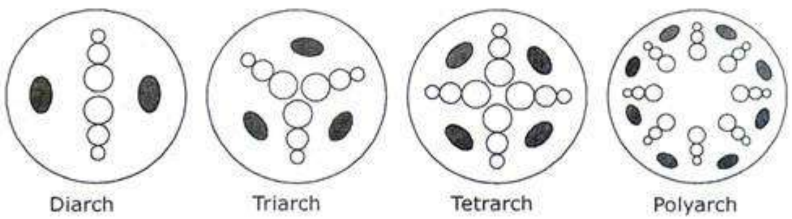


Figure 14.4

Diagram illustrating the different arrangements of the number of protoxylem groups in roots in cross-sectional view.

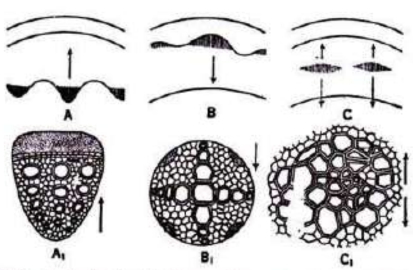


FIG. 570. Diagrams showing order of development of primray vascular tissue in transverse views. A & A_1. Centrifugal with endarch xylem. B & B_1. Centripetal with exarch xylem. C & C_1. Both centrifugal and centripetal with mesarch xylem.

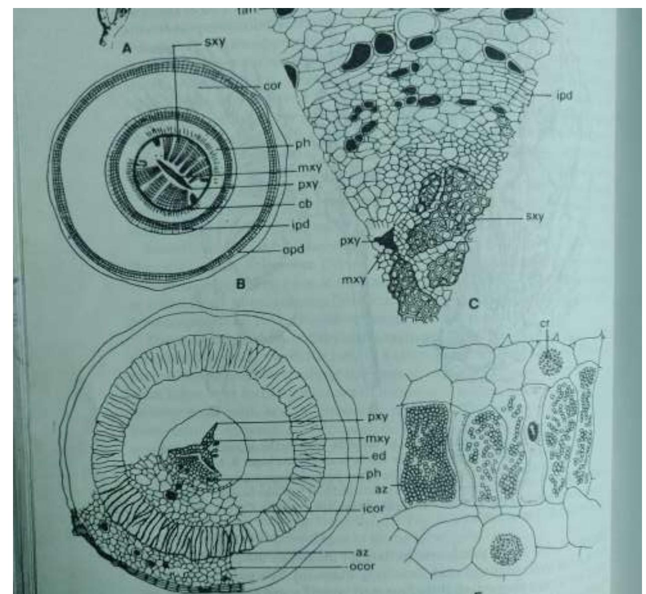


Fig. 6.4: A. *Cycas circinalis*; B-E, *Cycas revoluta* (az, algal zone; cb, cambium; cor, cortex; cr, crystal; ed, endodermis; icor, inner cortex; ipd, inner periderm; mxy, metaxylem; ocor, outer cortex; opd, outer periderm; ph, phloem; pxy, protoxylem; sxy, secondary xylem; tan, tanniniferous cells). A. Portion of coralloid root. B. TS of a diarch normal root. C. Portion enlarged; note the two periderms. D. TS of a triarch coralloid root. Algal zone is prominent in the cortex. E. Part of algal zone enlarged. (A, after Maheshwari, 1960; B-D, after Pant, 1973; E, after Wettstein, 1935).

Transection of the coralloid root of *Cycas,* shows a well defined zone in the cortex of thin-walled parenchyma with abundant intercellular spaces occupied by blue-green algae or cyanobacteria such as *Anabaena, Nostoc* etc. the cyanobacteia fix nitrogen and promote growth of host plants. In the coralloid root the tissues from outside inward are : a few layers of cork cells frequently interrupted by lenticels,a wide outer cortex consisting of an outer layer of parenchymatous cells, the algal zone, and the inner cortex of 6-12 layers of loosely arranged cells. The primary xylem is diarch to tetrarch. There is little or no secondary growth.

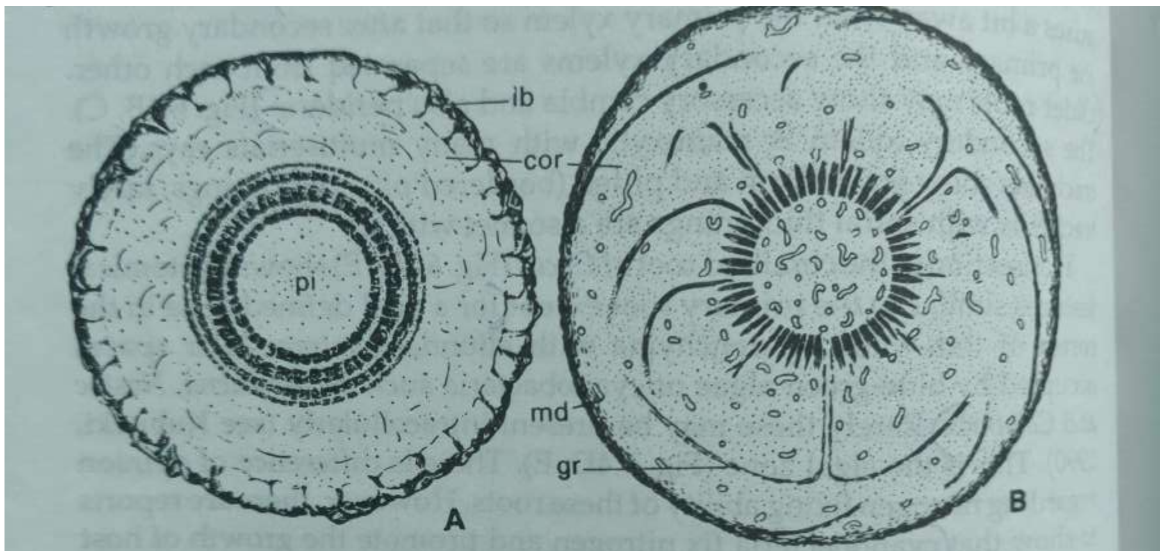
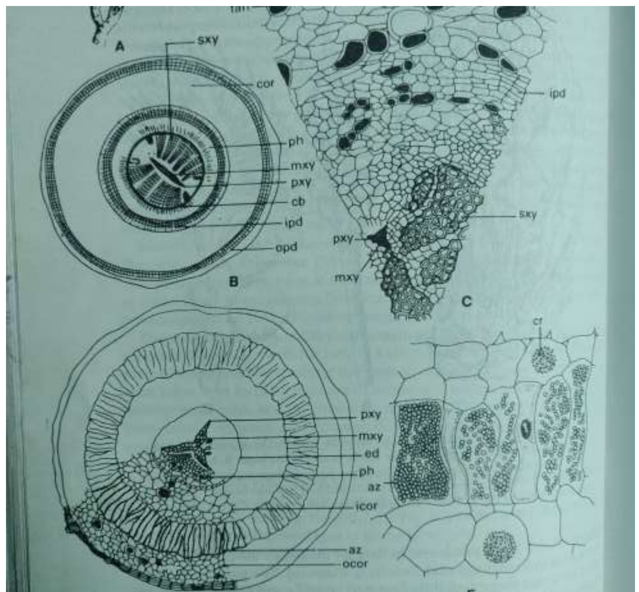


Fig. 6.5: A, *Cycas circinalis;* **B,** *Zamia floridana* (**cor,** cortex; **lb,** leaf base; **gr,** girdling leaf trace; **md,** mucilage duct; **pi,** pith). **A.** TS stem showing polyxylic condition, armour of leaf bases and a large cortex and pith. **B.** Same, *Zamia* showing prominent girdling leaf traces and manoxylic wood. Both cortex and pith are full of mucilage ducts. (A, after Maheshwari, 1960; B, after Chamberlain, 1935).

Non-coralloid aerial roots have been reported in *Cycas circinalis.* These roots are positively geotropic, adventitious and grow out from the lower sides of young and old bulbils or leaf bases while still attached to the plant. The roots are di- to polyarchy, a wide cortex and a mixed parenchymatous pith with scattered xylem elements. The older roots exhibit fair amount of secondary growth. The characteristic algal zone of coralloid roots is absent in these roots.



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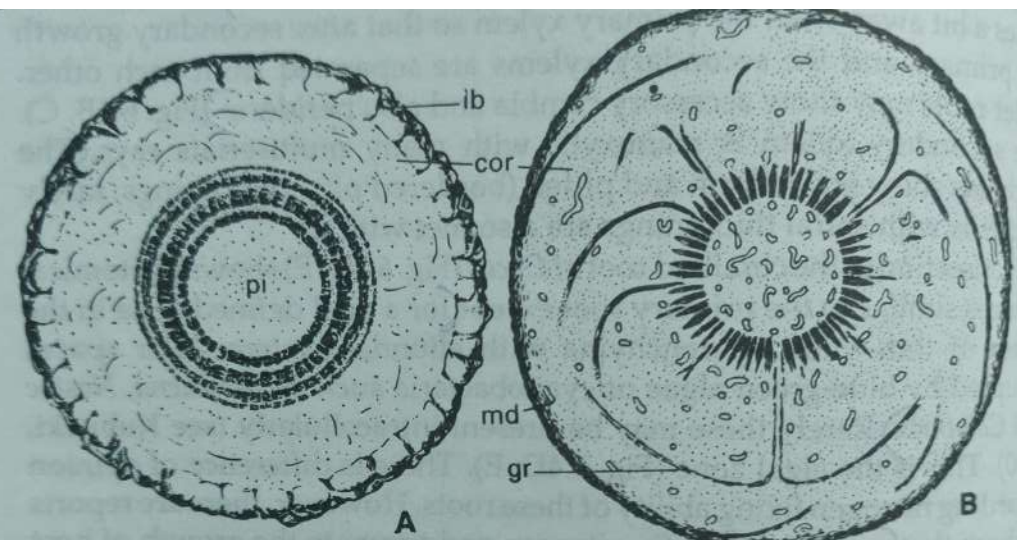
Stem

The stem of *Cycas* has an irregular outline because of numerous persistent leaf bases. It contains surprisingly small amount of wood (monoxylic). The stem show large central parenchymatous pith surrounded by a ring of numerous small vascular bundles which are followed by a wide parenchymatous cortex; broad medullary rays connect pith with the cortex.
The parenchymatous cells are full of starch which is commercially used as ‘sago’.
The vascular bundles are radially elongated, collateral and open. The protoxylem elements are endarch, metaxylem elements consistd of tracheids. The phloem comprises of sieve cells, phloem parenchyma and fibres.



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Secondry growth takes place very early in the life of the plant. The interfascicular cambium develops in the parenchymatous cells between the vascular bundles and joins the intrafacicular cambium. The cambium then cuts off radially seriated secondary xylem towards the pith and secondary phloem toward the outside.

The vascular rays are clear and are of three kinds;

1. Uniseriate which are 1-10 cells high
2. multiseriate rays which are 2-5 cells in width and much higher
3. Foliar multiseriate rays which are continuous from the pith to the phloem.

The phloem is very well developed in the stem and the petiole. Companion cells are absent; instead certain phloem parenchyma cells known as albuminous cells are found to be closely associated with the sieve cells.

An interesting feature of the stem of *Cycas* is that it is monoxylic in the beginning but becomes polyxylic later as a result of accessory rings of cambia that arise in the cortex. The leaf traces is small but becomes prominentin the corte. There are two types of traces found in *Cycas* both arising from the primary vascular bundle. These are girdling traces and radial/direct traces.

Pinus

Pinus wallichiana

Morphology

- Pinus is a beautiful tall tree (rarely shrub), with horizontal branches arranged in whorls, giving the tree a pyramidal appearance. The tree starts losing its symmetry with age and, in later stages, it may appear rounded, flat or even spreading. Pinus exhibits two types of root system viz., the long roots having potential for indefinite growth constituting the main root system, and the branches with restricted growth and relatively short life, called the short or dwarf root.
- The main stem is erect, woody and covered with rugged scaly bark which peels off. The branches are of two types viz., the long shoots and the dwarf shoots. The long shoots or branches of unlimited growth 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 such internode are formed in a year (multinodal pines).
- The long shoots, when they fall off, leave a scar on the stem. The dwarf shoots or branches of limited growth, also called short shoots, brachyblast or foliar spurs, are borne on long shoots and arise in the axil of scale leaves (Fig. 13.1 A-C). Each dwarf shoot bears two opposite scaly leaves, called prophylls followed by 5-13, spirally arranged scaly cataphylls in 2/5 phyllotaxy. The leaves on the dwarf shoots are of two types: 2-5, long, needle-like foliage leaves and the scale leaves of protective nature. The needle number is constant for a species and is used as a taxonomic character, e.g. *P. monophylla* has one, *P. sylvestris* has two and *P. roxburghii* has three needles (Fig. 13.1C), and *P. wallichiana* has five needles (Fig. 13.1D).

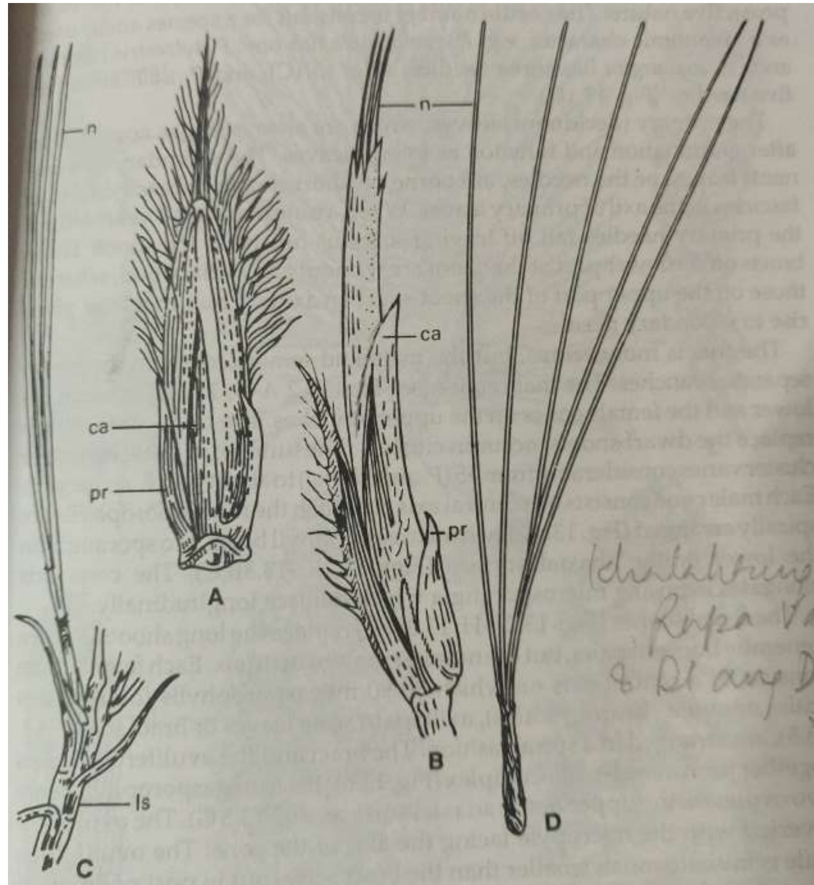

Fig. 13.1: A-C, *Pinus roxburghii*; D, *P. wallichiana* (ca, cataphyll; ls, long shoot; n, needle; pr, prophyll). A,B. Young dwarf shoots showing stages in the unfolding of needles. C. Part of long shoot bearing a dwarf shoot with three needles. D. Dwarf shoot bearing five needles (A-C, after Maheshwari & Konar, 1971; D, after Konar & Ramchandani, 1958).

- The primary (deciduous) leaves, which are always single, appear soon after germination and function as foliage leaves. The secondary (permament) leaves, or the needles, are borne on short shoots or brachyblasts in fascicles in the axil of primary leaves. When a pine plant is 2-3 years old, all the primary needles fall off leaving scarious bracts on the shoot. These bracts on the lower part of the shoot are without any axillary bud, whereas those on the upper part of the shoot sport an axillary bud that later gives rise to secondary needles.

- **Reproductive structures-**

- The tree is monoecious, but the male and female cones are borne on separate branches. The male cones (see Figs 13.2 A-D; 13.3A) rise in the lower and the female cones on the upper branches. The male cones, which replace the dwarf shoots, occur in clusters. The number of male cones per cluster varies considerably from 15(*P. wallichiana*) to about 140 (*P. roxburghii*). Each male cone consists of a central axis on which the microsporophylls are spirally arranged (Fig. 13.4). Each Microsporophyll Bears two sporangia on the lower or the abaxial surface (Figs 13.2E; 13.3B.C). The cone axis elongates exposing microsporangia which dehisce longitudinally.

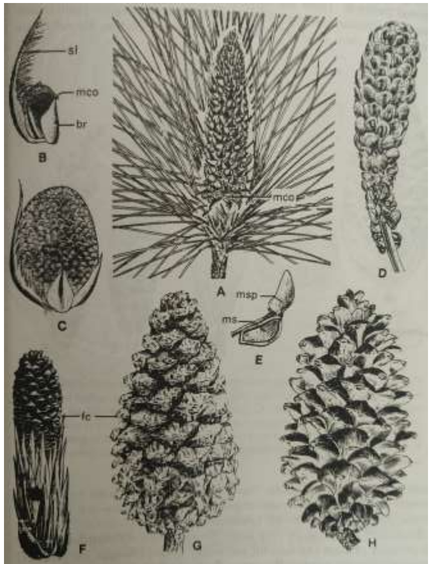

Fig. 13.2: *Pinus roxburghii* (br, bract; fc, female cone; mco, male cone; ms, microsporangium; msp, microsporophyll; sl, scale leaf). A. Cluster of male cones. B-D. Stages in the development of male cone. In D, sporangia have dehisced shedding pollen grains. E. Lateral view of a microsporophyll with dehisced sporangium. F-H. Stages in the development of female cone

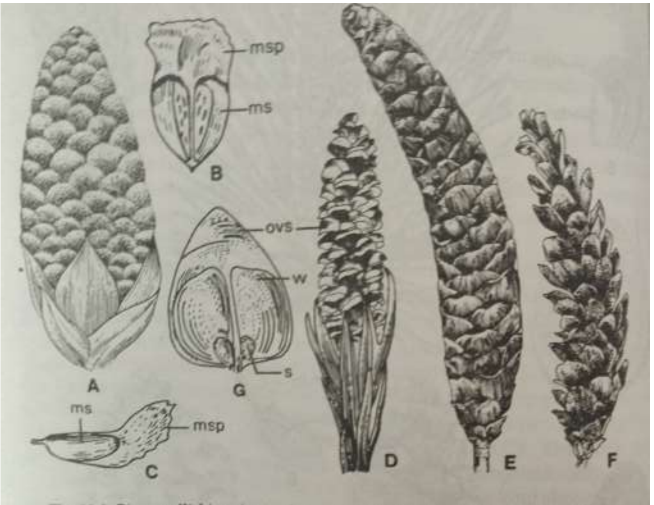

Fig. 13.3: *Pinus wallichiana* (ms, microsporangium; msp, microsporophyll; ovs, ovuliferous scale; s, seed; w, wing). A. Male cone. B. Microsporophyll bearing two sporangia on abaxial side. C. Same, in lateral view. D-F. Stages in the maturation of female cone (figures not to size). In D, female cone is ready for pollination. E-F, respectively depict stages before and after shedding of seeds. G. Ovuliferous scale with two winged seeds borne on adaxial side (after Konar & Ramchandani, 1958).

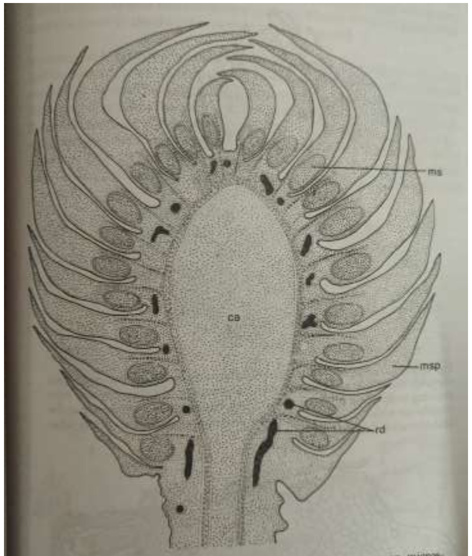

Fig. 13.4: *Pinus roxburghii* (ca, cone axis; ms, microsporangium; msp, microsporophyll; rd, resin duct). LS male cone; note the position of microsporophylls with respect to the cone axis. The microsporangia are abaxial.

- The female cones (Figs 13.2F-H; 13.3D-F) replace the long shoots and are generally borne in pairs, but the number may go up to six. Each female cone consists of a central axis on which 80-90 megasporophylls (ovuliferous scales or ovule - bearing scales), axillary to scale leaves or bract scale (Fig 13.5), are arranged in a spiral fashion. The bract and the ovuliferous scales together form a seed-scale-complex (Fig. 13.6). Each megasporophyll bears two ovules on the upper or the adaxial surface (Fig. 13.3G). The ovules are inverted with the micropyle facing the axis of the cone.
- The exposed part of the ovuliferous scale (also called cone scale in a mature cone) is known as 'apophysis'. The tip of the apophysis becomes the 'umbo' in the mature cone. The umbo of all diploxylon pines is dorsal, whereas it is terminal or dorsal in haploxylon pines. Sporophylls at the apex and the base of a cone are generally sterile

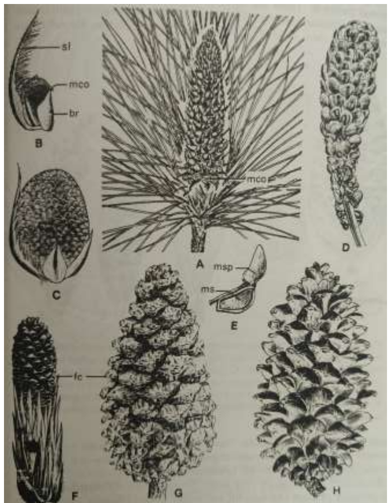

Fig. 13.2: *Pinus roxburghii* (**br**, bract; **fc**, female cone; **mco**, male cone; **ms**, microsporangium; **msp**, microsporophyll; **sl**, scale leaf). **A**. Cluster of male cones. **B-D**. Stages in the development of male cone. In **D**, sporangia have dehisced shedding pollen grains. **E**. Lateral view of a microsporophyll with dehisced sporangium. **F-H**. Stages in the development of female cone

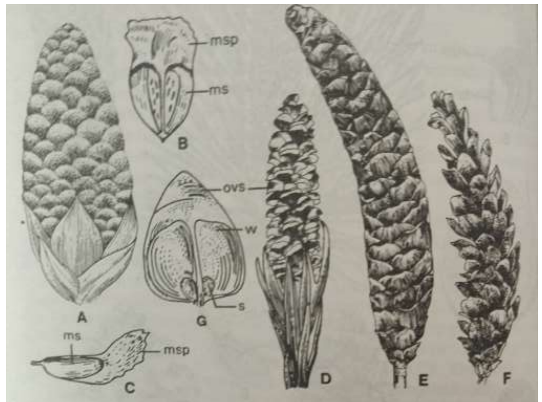

Fig. 13.3: *Pinus wallichiana* (**ms**, microsporangium; **msp**, microsporophyll; **ovs**, ovuliferous scale; **s**, seed; **w**, wing). **A**. Male cone. **B**. Microsporophyll bearing two sporangia on abaxial side. **C**. Same, in lateral view. **D-F**. Stages in the maturation of female cone (figures not to size). In **D**, female cone is ready for pollination. **E-F**, respectively depict stages before and after shedding of seeds. **G**. Ovuliferous scale with two winged seeds borne on adaxial side (after Konar & Ramchandani, 1958).

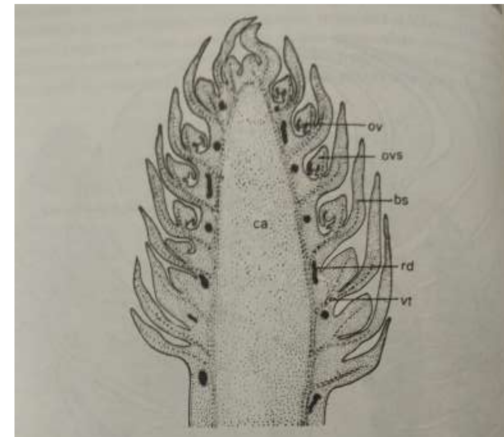

Fig. 13.5: *Pinus roxburghii* (**bs**, bract scale; **ca**, cone axis; **ov**, ovule, **ovs**, ovuliferous scale; **rd**, resin duct; **vt**, vascular trace). Longisection of a young female cone showing seed-scale complexes. At this stage, the bract scale is longer than the ovuliferous scale. The latter bears ovules on its upper or adaxial surface (after Maheshwari & Konar, 1971).

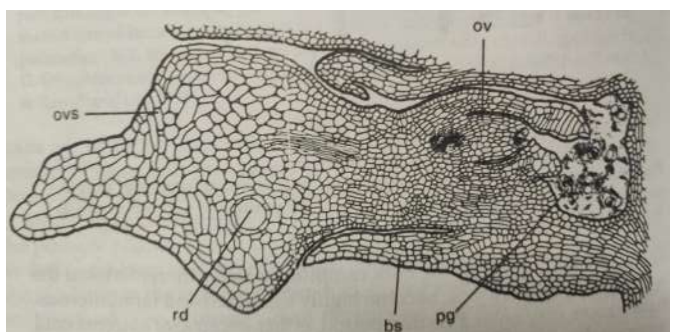

Fig. 13.6: *Pinus banksiana* (**bs**, bract scale; **ov**, ovule; **ovs**, ovuliferous scale; **pg**, pollen grain; **rd**, resin duct). Longisection of bract, ovuliferous scales and ovule to show their relative positions. The ovule is in post-pollination stage (after Chamberlain, 1935).

Root

- The long root is diarch or tetrarch in Pinus (Pl. 13.3 A, B).
- The structure from outside inward is: epidermis followed by starch filled cortex having an outer zone of small and an inner zone of larger parenchyma cells. The endodermis-is single-layered with Casparian strips and is followed by 6 or 7-layered pericycle. There are eight to sixteen protoxylem elements with scalariform or scalariform-pitted thickenings. Each protoxylem point is associated with a resin duct (Pl. 13.3A, B). The metaxylem elements are made up of pitted tracheids. The phloem alternates with xylem and consists of sieve cells and parenchyma The pith cells are rich in starch.

- Secondary growth starts very early. The cambium differentiates below the primary phloem and cuts off secondary xylem towards the pith and secondary phloem towards the cortex. The primary xylem persists for a much longer period as compared to the primary phloem which gets crushed very soon. The secondary xylem is composed of tracheids with bordered pits. The cork cells, cut off by the cork cambium which differentiates in the outer region of the pericycle, become highly suberized and tanniferous.
- The pine roots may enter a resting period, either because of extreme cold or summer drought. In such a case, the periderm extends towards the top of the root and may completely enclose it, forming a "winter root cap" of suberized cells. With the resumption of growth, the living cells break through this protective layer re-establishing the active growing point.

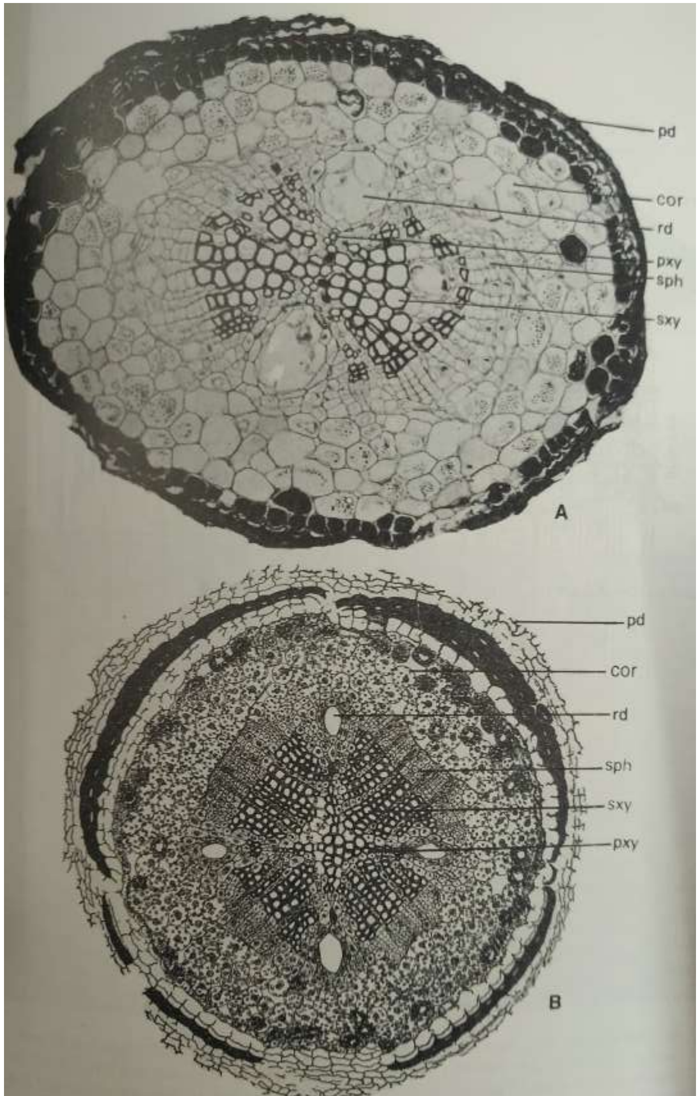

Plate 13.3: A, *Pinus roxburghii*; **B,** *P. edulis* (**cor,** cortex; **pd,** periderm; **pxy,** protoxylem; **rd,** resin duct; **sph,** secondary phloem; **sxy,** secondary xylem). **A,B.** TS diarch and tetrarch roots, respectively after secondary growth. A resin duct is associated with each protoxylem point. (**A,** after Konar, 1963a; **B,** after Chamberlain, 1935).

Mycorrhiza-

- Mycorrhiza occurs in several conifers. In Pinus it is not only well developed, but is also extensively studied. It exhibits well developed ectotrophic mycorrhizal association with over 50 different species of fungi belonging to families Boletaceae and Agaricaceae of the Basidiomycetes.
- The dwarf roots divide dichotomously and become modified into mycorrhizal system after fungal infection, when the entire rootlet is enclosed by mycelium (Fig. 13.7A-D). The fungal hyphae penetrate the intercellular spaces in the cortical cells of the root forming the so-called Hartig's net. (Fig. 13.7B,E).
- Occasionally intracellular hyphae are also met with. As the resistance of the host cell develops, most of the intracellular hyphae digested and the fungus remains primarily in the intercellular spaces.
- The pine-fungal relationship is symbiotic; the pine tree is benefitted by the increase in absorbing area of the mycorrhizal roots for soil nutrients The surface area of the infected roots is more than the ordinary roots. Many factors, such as prolonged life of infected roots, greater degree of branching, addition of sheath as an external layer and radial expansion of epidermal and cortical cells (Harley, 1959) are responsible for it.

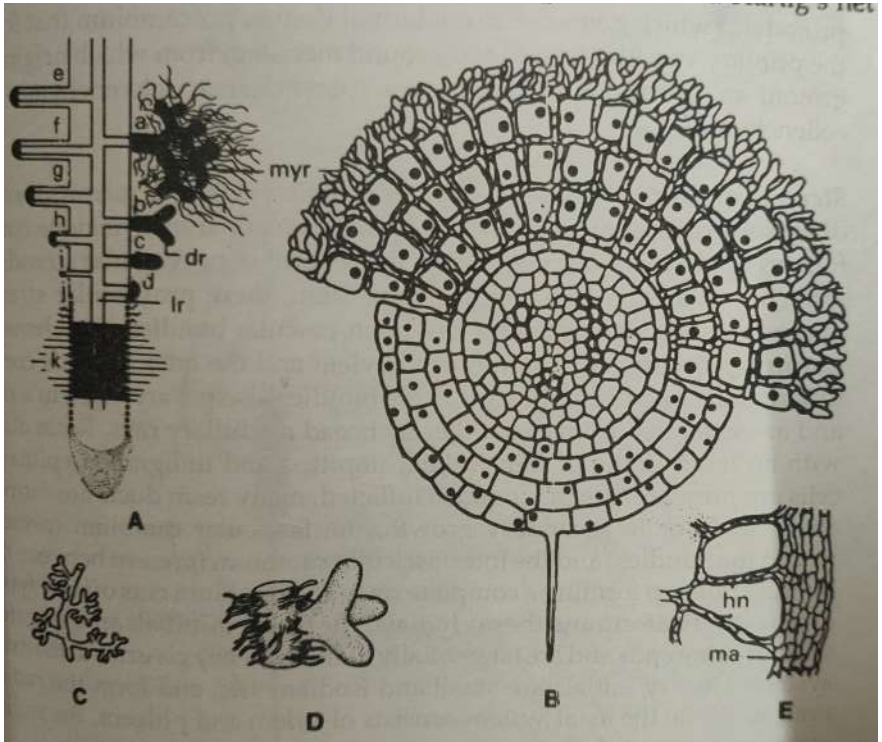

Fig. 13.7: *Pinus* (**dr**, dwarf root; **hn**, Hartig's net; **lr**, long root; **ma**, mantle; **myr**, mycorrhizal root). **A.** Diagrammatic representation of a young pine root. Root hair zone **k** (in black) is near the tip. Note that the absorbing surface (in black) on the infected side (**a-d**) is greater than on normal side (**e-j**). **B.** TS root whose one half is normal and the other half (upper portion in the figure) is mycorrhizal. Cortical cells are hypertrophied and enveloped by fungal filaments forming an ectotrophic mycorrhiza in the infected part. **C.** Short lateral roots in infected condition branch dichotomously. **D.** Mycorrhiza in an enlarged view. **E.** Ectotrophic mycorrhiza with the characteristic Hartig's net and mantle. (A, C, D, after Hatch, 1937; B, E, after Hatch & Doak, 1933).

Shoot apex: The pine tree grows as a result of the activity of an apical meristem. The initials and their immediate derivatives are called promeristems which differentiate into basic systems. The latter includes protoderm which gives rise to epidermal tissues, procambium that forms the primary vascular tissue, and ground meristem from which originates ground or the fundamental tissues (parenchyma, sclerenchyma and collenchyma).

Stem

- TS of a very young stem of Pinus exhibits ridges and furrows formed due to adpressing of surrounding leaves. Broad parenchymatous cortex follows epidermis. Vascular tissue, in the form of provascular strands, is arranged in a ring.
- The elements towards pith differentiate into protoxylem and the ones towards cortex differentiate into protophloem. These bundles also get arranged in a ring and are separated from each other by broad medullary rays.
- Resin ducts with an inner lining of thin-walled, unpitted and unlignified epithelial cells are present.
- Prior to secondary growth, the fascicular cambium (present within the bundles) and the interfascicular cambium (present between the bundles) join up forming a complete ring. The cambium cuts off two types of cells-the fusiform and the ray initials.
- The cambium produces a continuous cylinder of secondary xylem towards inside and secondary phloem towards outside (Pl. 13.5B). At places, the cambium cuts off parenchyma cells which give rise to secondary medullary rays. The secondary xylem consists of tracheids with bordered pits on radial walls (Pl. 13.5C) and, rarely, on tangential walls.
- The sieve plates consist of numerous narrow channels (0.1-0.5um in diam.) lined with callose. In a good preparation, these sieve areas look like nuclei and the entire sieve cell as a multinucleate cell.
- The vascular rays are initiated by the cambium and, once formed, they continue to increase in radial length indefinitely. The cells are always elongated in the direction of the long axis of the ray. The rays are of two types: (i) uniseriate rays, and (ii) multiseriate or fusiform rays (Pl. 13.6A,B).
- In the wood, one can easily demarcate between the outer lighter zone, the sapwood, and the inner darker region, the heartwood. The wood consists of ray parenchyma cells and tracheids that serve as the conducting tissue. With age, the ray parenchyma cells begin to die and tracheids stop the function of conduction and mainly provide support.

  The sapwood gets gradually converted into heartwood which becomes resinous and rich in phenolic compounds.
- The wood of Pinus is much simpler in structure as compared to the wood of dicotyledons. A characteristic feature is the absence of vessels.
- The age of a pine tree is commonly determined by counting the number of annual rings.

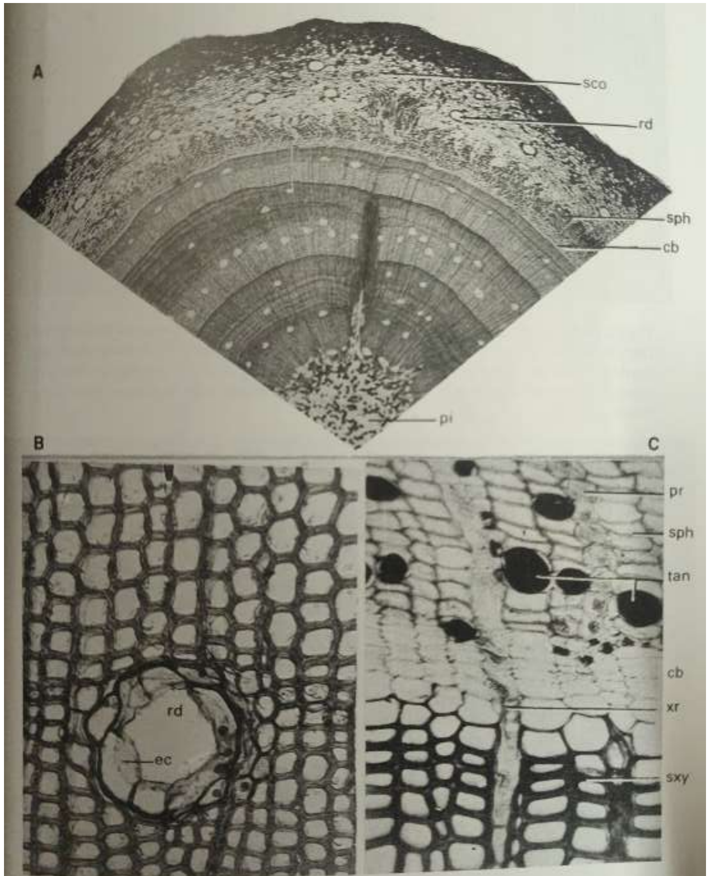

Plate 13.5: *Pinus roxburghii* (**cb**, cambium; **ec**, epithelial cell; **pi**, pith; **pr**, phloem ray; **rd**, resin duct; **sco**, secondary cortex; **sph**, secondary phloem; **sxy**, secondary xylem; **tan**, tanniniferous cell; **xr**, xylem ray). **A.** Sector of old stem in TS showing prominent growth rings, resin ducts, and a branch trace. **B.** Part from **A** enlarged to show cambial zone, secondary phloem and secondary xylem. **C.** Secondary xylem with a resin duct enlarged to show epithelial cells lining the resin canal (after Konar, 1963a).

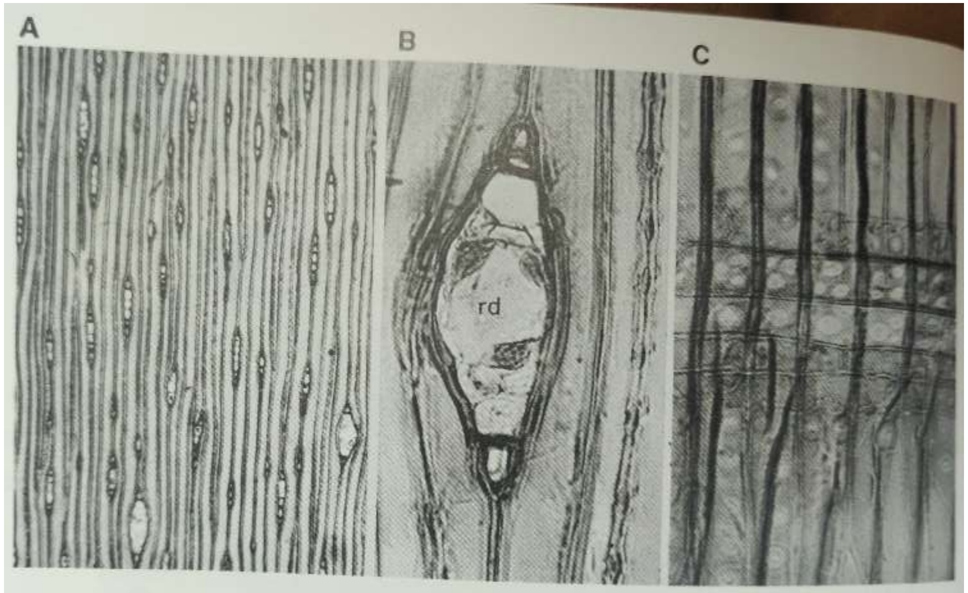

Plate 13.6: *Pinus roxburghii* (**rd**, resin duct). **A.** TLS wood to show uni- and multiseriate rays. **B.** Multiseriate or fusiform ray with resin duct enlarged. C. RLS wood showing bordered pits on radial walls of tracheids. Xylem ray is distinguishable into ray parenchyma with simple pits and marginal ray tracheids with bordered pits (after Konar, 1963a).

Leaf

- In *P.monophylla*, the solitary needle is round (Fig. 13.9 A); the 2-needle pine (*P. merkusii*) is semicircular, and in three needle pines as in *P. roxburghii*, it is triangular (Fig. 13.9B).
- In a cross-section of *P. durangensis* six needle pine the needles appear as very narrow segments of a circle.
- The dermal layer (epi- and hypodermis) is followed by mesophyll cells are devoid of Casparian strips. The pericycle is parenchymatous interspersed with transfusion tracheids. The transfusion tissue is composed of parenchymatous cells, albuminous cells and tracheids cells with bordered pits on their tangential and transverse walls.
- A sclerenchymatous sheath is present around the vascular bundle.
- There may be one or two vascular bundles. When there is only one vascular bundle (as in *P. wallichiana*) it is medianly placed. In those species where there are two vascular bundles (as in *P. roxburghii*) they are placed at an angle to each other (Figs 13.9B; 13.10).
- The vascular bundles consist of protoxylem elements (scalariform pitted tracheids) and metaxylem elements (helically thickened tracheids with bordered pits).
- The tracheids elements are in radial rows alternating with rows of parenchymatous cells and albuminous cells.
- A cambium is present in the vascular bundle. It cuts off secondary phloem and little or no secondary xylem.
- The stomata are sunken. The walls of the subsidiary cells and the guard cells are partly lignified. The stomata may be located on all surfaces of the needle as in diploxylon pines or they may be absent on the outer surface of the needle as in some of the haploxylon pines.
- Edges of pine needles may be smooth or serrated.

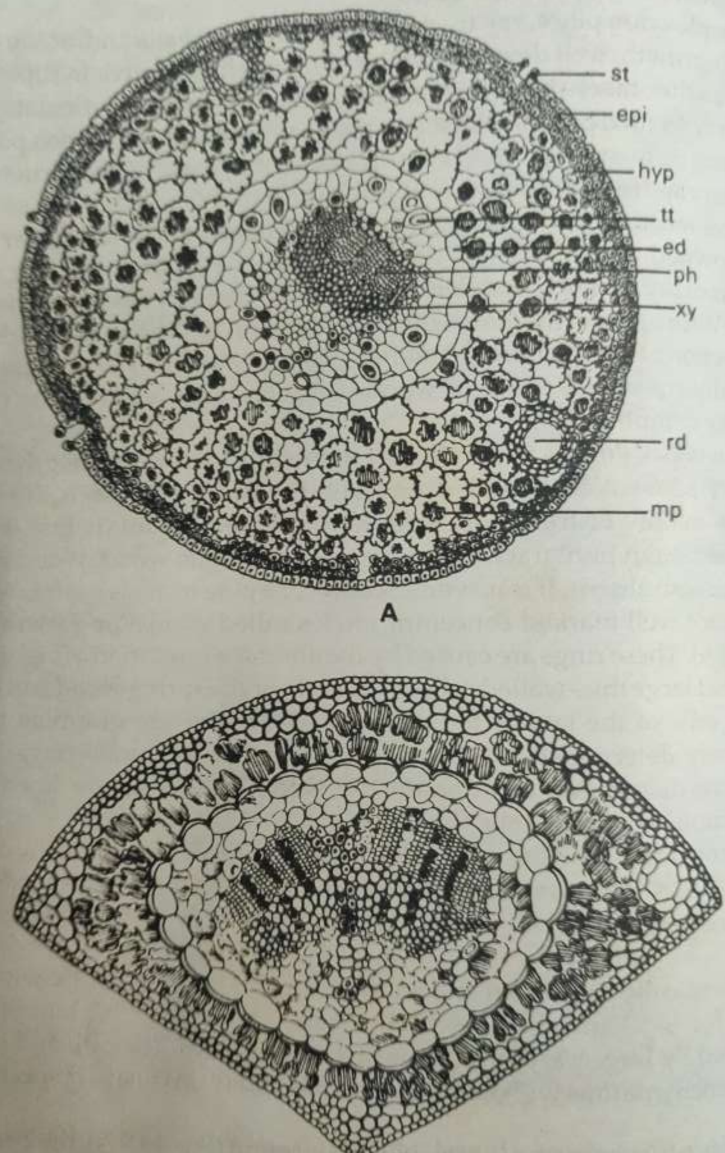

Fig 13.9: A, *Pinus monophylla*, **B**, *P. roxburghii* (**ed**, endodermis; **epi**, epidermis; **hyp**, hypodermis; **mp**, mesophyll; **ph**, phloem; **rd**, resin duct; **st**, stomata; **tt**, transfusion tissue; **xy**, xylem). **A,B.** TS needle. (**A**, redrawn from Gifford & Foster, 1989; **B**, after Konar, 1963a).

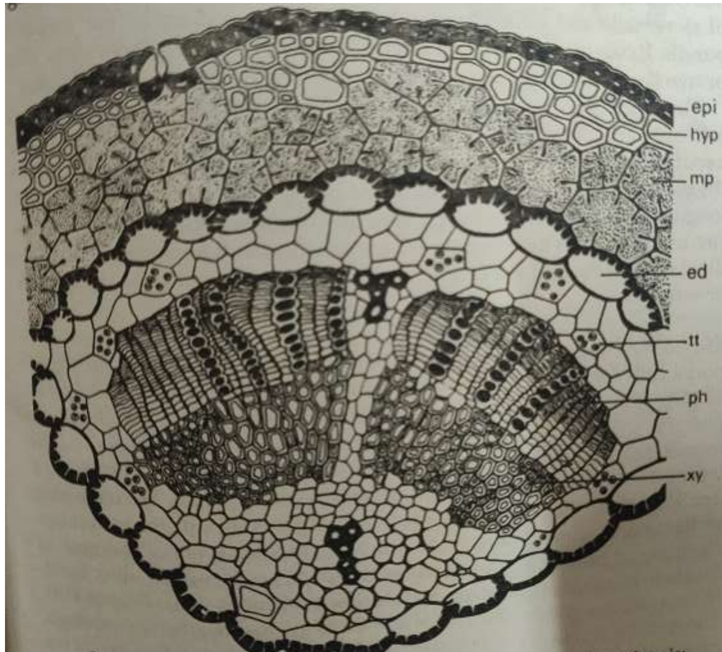

Fig. 13.10: *Pinus roxburghii* (**ed**, endodermis; **epi**, epidermis; **hyp**, hypodermis; **mp**, mesophyll; **ph**, phloem; **tt**, transfusion tissue; **xy**, xylem). Part of a needle in TS enlarged to show lignified epidermis, hypodermis, mesophyll with cells showing infolding of walls, endodermis with thickened outer walls, transfusion tissue and two vascular bundles placed at an angle.

Gnetum

Gnetum gnemon

Morphology

- ***Gnetum* resembles more an angiosperm than a gymnosperm.**
- Most of the species are climbers with twining stem.
- *G. gnemon* is a tall, stout tree, whereas *G. ula* is a woody climber.
- It exhibits two types of branches viz. branches of limited growth and branches of unlimited growth.

Inflorescence-

- *Gnetum* is dioecious and the inflorescence occurs in a solitary or fascicled panicle. The inflorescence is axillary on a short shoot.
- The strobilus consists of an axis with two sterile, connate, opposite bracts at the base and a series of circular bracts (cupules or collars) which are superposed one above the other (Fig. 15.1A, B).
- A young strobilus appears compact because the axis is much reduced with very short inter nodes and the collars appear to be continuous. With the elongation of the axis, the collars get separated (Figs 15.1D; 15.2B).

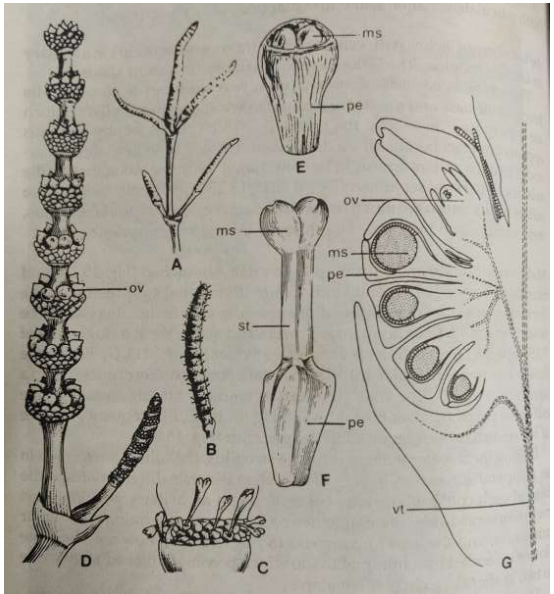

Fig.15.1: **A-C**, *Gnetum ula;* **D-G**, *G. gnemon* (**ms**, microsporangium; **ov**, ovule; **pe**, perianth; **st**, stalk; **vt**, vascular trace). **A.** Branch bearing a panicle of male cones. **B.** Male cone at dehiscense. **C.** Portion from **B** enlarged; male flowers are dehiscing. **D.** Male cone enlarged. At each collar, just above male flowers, there is a ring of imperfect female flowers or abortive ovules. **E-F.** Elongation of stalk and emergence of anthers from perianth. **G.** LS part of male cone to show the position of sporangia and ovule and vasculature to collar, male flowers and ovule. (**A-C**, after Vasil, 1959; **D-G**, after Sanwal, 1962).

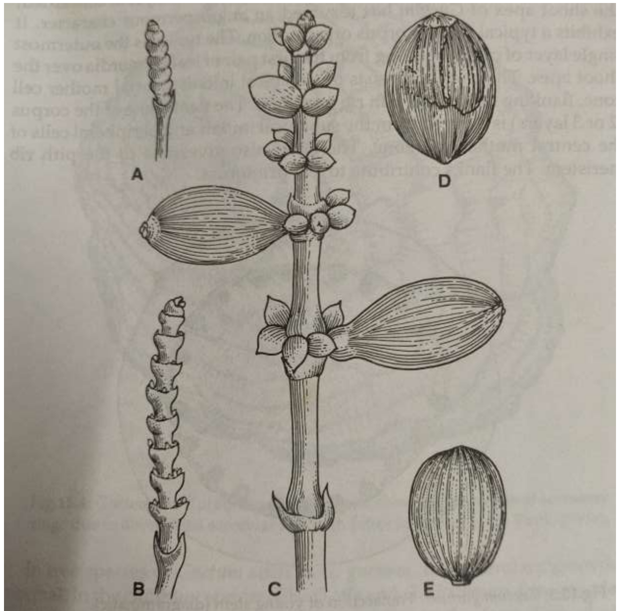

Fig.15.2: *Gnetum gnemon*. **A-C.** Stages in the development of female cone. In C only two ovules have developed into seeds, whereas the rest have aborted. **D, E.** Mature seeds. The outer fleshy layer has dried in E (after Maheshwari & Vasil, 1961a).

Male strobilus

- The male strobilus is invariably branched (Fig. 15.1A) and branching may be of several kinds due to differential suppressing or the dormancy of some cones in an inflorescence.
- In each collar, there are three to six rings of 12-15 or more male flowers and above them a single ring of 7-15 imperfect female flowers or abortive ovules (Fig. 15.1D, G). Each male flower has two unilocular anthers on a stalk (antherophore) enclosed in a sheath of perianth. The stalk elongates at maturity and the anthers come out of the perianth cover through a slit (Fig 15.1C, E, F). Frequent presence of sclereids has been reported in the perianth.

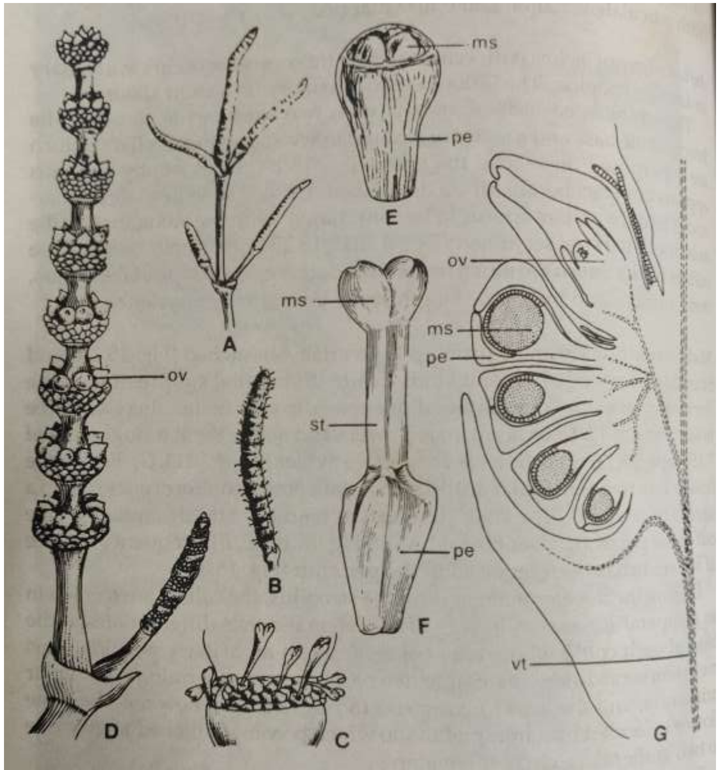

Fig.15.1: **A-C**, *Gnetum ula*; **D-G**, *G. gnemon* (**ms**, microsporangium; **ov**, ovule; **pe**, perianth; **st**, stalk; **vt**, vascular trace). **A.** Branch bearing a panicle of male cones. **B.** Male cone at dehiscense. **C.** Portion from B enlarged; male flowers are dehiscing. **D.** Male cone enlarged. At each collar, just above male flowers, there is a ring of imperfect female flowers or abortive ovules. **E-F.** Elongation of stalk and emergence of anthers from perianth. **G.** LS part of male cone to show the position of sporangia and ovule and vasculature to collar, male flowers and ovule. (A-C, after Vasil, 1959; D-G, after Sanwal, 1962).

Female strobilus

- The female strobilus looks similar to the male strobilus in the young stages so much so that it is difficult to even distinguish (Fig. 15.2A). However, as the strobili grow the distinction becomes clear.
- In a female strobilus, a ring of four to ten female flowers (ovules) is present above each collar (Fig. 15.2B). There is a total absence of any male flowers.
- all the ovules look alike, but later only a few grow to maturity (Fig. 15.2C-E). The upper few collars usually lack ovules and are thus sterile

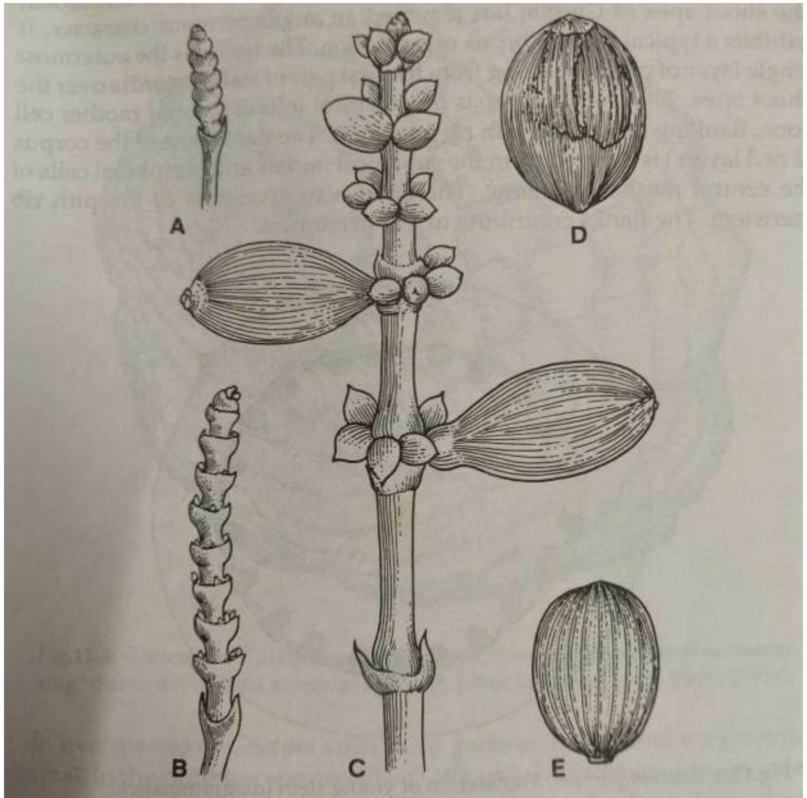

Fig.15.2: *Gnetum gnemon*. A-C. Stages in the development of female cone. In C only two ovules have developed into seeds, whereas the rest have aborted. D, E. Mature seeds. The outer fleshy layer has dried in E (after Maheshwari & Vasil, 1961a).

Root-

- The outermost layer or epidermis is followed by many layered parenchymatous, starch filled cortex. Thick-walled fibre cells are common in the cortex. The endodermis encloses a multilayered pericycle. The primary xylem is diarch.
- The phloem is composed of uniform cells. The xylem ray consists of thin-walled, starch containing parenchymatous cells. The xylem elements produced after secondary growth are larger than those of the stem. In older roots some xylem elements contain starch.

Stem apex-

- The shoot apex of *Gnetum* has assumed an angiospermous character.
- It exhibits a typical tunica-corpus organisation. The tunica is the outermost single layer of cells. The corpus consists of subapical initials, central mother cell zone, flanking layers and pith rib meristem.

Stem-

- A young stem of *G. ula* and *G. gnemon* shows a single layered epidermis of rectangular cells with a thick coating of cuticle and sunken stomata.
- The cortex consists of 12-16 layers of parenchymatous cells; some cells in the inner zone become fibrous with narrow lumen.
- In older stems, a ring of parenchymatous cells becomes sclerenchymatous in the inner cortex, and it is referred to as the ring of spicular cells.
- Endodermis and peri cycle are not distinct.
- There are 20-24 collateral and endarch vascular bundles, arranged in a ring (Fig. 15.3).
- The xylem consists of tracheids and few vessels. The phloem is composed of sieve cells and phloem paren chyma. Medullary rays between vascular bundles are broad and high. The pith is parenchymatous. Laticiferous elements are seen in pith as well as in cortex.
- In tree species of *Gnetum* such as *G. gnemon*, the secondary growth is normal.
- In the climbing species, like G. ula and G. africanum, the secondary growth is normal to begin with but,later, due to the formation of new cambium, several rings of xylem and phloem, separated into wedge shaped bundles because of medullary rays, are produced.
- The secondary phloem is composed of sieve cells and parenchyma.
- The vascular rays are quite massive.

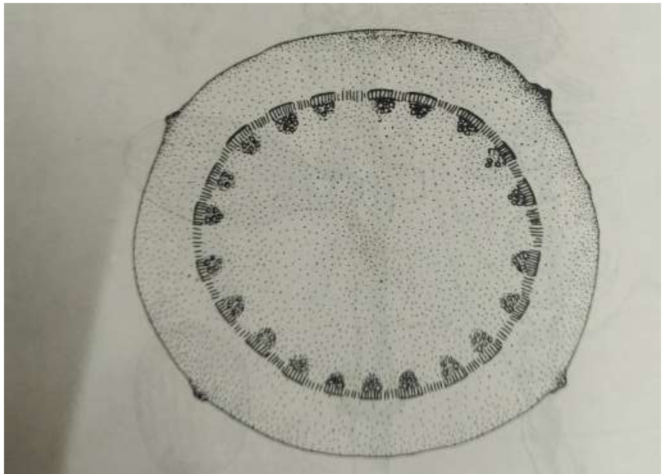

Fig.15.3: *Gnetum gnemon*. Transection of young stem (diagrammatic).

Leaf-

- The epidermis has undulating walls with a thick cuticle.
- The mesophyll is distinguishable into palisade and spongy parenchyma.
- The palisade consists of a single layer of compact cells which show the presence of branched sclereids near the lower epidermis.
- Fibres and latex tubes are abundant, especially in the midrib region.
- Stomata occur only on the lower surface and are irregularly oriented. According to Maheshwari & Vasil (1961b), their development is haplocheilic, i.e. the stomatal initial only forms the guard cells.
- The epidermal cells around them are irregularly arranged and do not function as subsidiary cells (Fig. 15.8 A-C).
- Xylem consists of vessels, tracheids and parenchyma. The phloem is arranged in regular rows just beneath the xylem. Thick-walled pitted cells form a patch outside the phloem. During later stages, mesophyll cells situated near the protoxylem also become thick-walled and pitted.

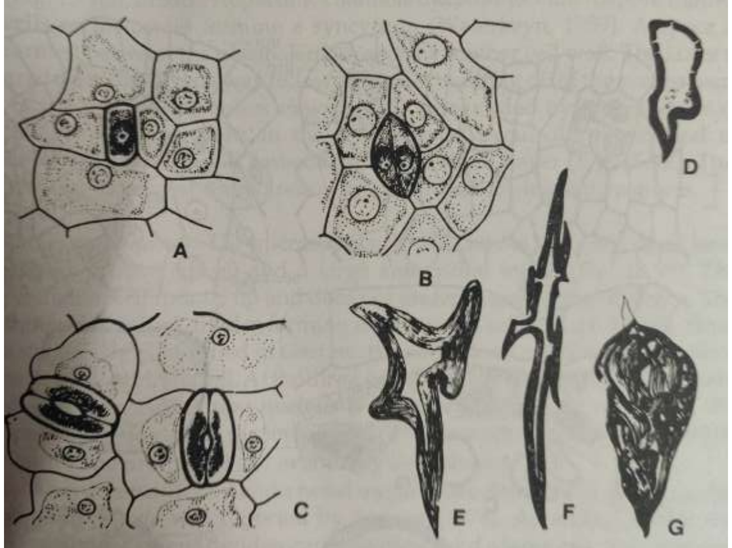

Fig.15.8: *Gnetum ula*. A-C. Epidermal peels from lower epidermis of leaf showing stomatal initial (A), division of stomatal initial to form guard cells (B) and mature stomata (C). D,E,G. Sclereids from outer envelope of an ovule. F. Same, from perianth of male flower (after Maheshwari & Vasil, 1961 a).

Reference -

Gymnosperms- S P Bhatnagar and Alok Moitra